Enhanced Global and Local Curvature Properties for Corner Detection

Suraya Abu Bakar¹, Muhammad Suzuri Hitam², Wan Nural Jawahir Hj Wan Yussof³ and Junaida Sulaiman⁴

¹,⁴Faculty of Computing, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Kuantan, Pahang, Malaysia
²,³Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia

surayaab@ump.edu.my, suzuri@umt.edu.my, wannurwy@umt.edu.my, junaida@ump.edu.my

Abstract. Corner detection is basically a methods used to extract certain kind of features in images which could produce some information including the location or position of the corner points. Thus, in this paper an enhancement shape corner detection method is proposed to detect true corners of shape images. The overall performance of the proposed enhanced shape corner detector and six other existing shape detectors and descriptors including Harris, SUSAN, Harris-Laplace, CSS, SIFT and global and local curvature properties is presented. The experimental results of corner detection methods are tested using the benchmark binary image MPEG-7 Core Experiment Shape-1 Part B dataset. To measure the performance of corner detection evaluation, an appropriate number of true corners were determined.

1. Introduction

In the late 1970’s, the first corner detector was developed and since that many corner detectors have been proposed. Figure 1 shows the timeline of corner detectors since late 1970 until 1999 that been discussed by Yadav and Yadav [1].

Figure 1. Timeline of corner detectors [1]

Corner detectors have been used in many applications for example in the field of image retrieval [2-4], object recognition [5] and image matching [6]. In computer vision area, corner detection is widely
used in pre-processing process for various applications including tracking for event cameras in real-time [7], motion detection [8] and mobile robots [9-10].

For robust image corners detection, Mokhtarian et. al. [11] proposed Curvature Scale Space (CSS). He and Yung [12] proposed an improved multi-scale corners detector with dynamic region of support based on CSS technique. The results indicated that it offers an effective and robust solution to images that contains extensively varying size features. Then, in the 2008 the work continued, where they [13] proposed a corners detector based on curvature where it detects fine and coarse features.

An enhanced corner detector has higher ability to detect high amount of true corners compared to the typical technique. Nevertheless, there are still a number of the true corners do not seem to be detected. During the analysis, the original methods of global and local curvature properties were modified to ensure only true corners identified in a single object binary shape dataset.

2. Global and Local Curvature Properties
The corner detector based on Global and Local Curvature Properties was proposed by He and Yung [13] and this work is the improved version from their previous works [12]. They proposed a corners detector based on curvature where it detects fine and coarse features precisely with low computational cost and their work consists of improved version of the original Curvature Scale Space (CSS). The aim of He and Yung [13] suggested steps is to employ global and local curvature properties and balance their effect once corners are extracted. Their proposed steps are described in two subsections as follows.

2.1. Initial list candidates for corners
In listing corner candidates, $j$ th extracted corners are defined as in equation (1):

$$\mathbf{A}_j = \{ P^j_1, P^j_2, ..., P^j_N \}$$

where $P^j_i = (x^j_i, y^j_i)$ are pixels on the contour, $N$ is the amount of pixels on the contour and $x^j_i, y^j_i$ are the coordinates of the $i$ th pixel on the $j$ th contour.

2.2. Corner Evaluation
Region of Support (ROS) has been described by He and Yung [13] to employ global curvature characteristics of the neighbours which remove round corners but not the obtuse corners. Figure 2 shows the examples of round and obtuse corners. As can be observed in Figure 2(a) and 2(c), certain difference is not important though the curve around the corners is the biggest between its neighbours. However, the curvature of an obtuse corner as in Figure 2(b) may additionally have alike or maybe smaller than absolute maximum compared with round corner. From Figure 2(d), frequently the magnitude is expressive higher than its neighbours.
The ROS of a corner is outlined by the segment of the contour, that is finite by the corners of two nearest curvature minima. The ROS of every corner is then accustomed calculate an area of local threshold where \( u \) is the position of the corner candidate on the contour, \( L_1 + L_2 \) is the size of the ROS targeted at \( u \) and \( R \) is the coefficient as defined in equation (2):

\[
T(u) = R \times \bar{K} = R \times \frac{1}{L_1 + L_2 + 1} \sum_{i=u-L_2}^{u+L_2} |K(i)|
\]

where \( \bar{K} \) is the mean curvature of the ROS. A true corner is declared if the curvature of the corner candidate is larger than \( T(u) \) or otherwise it is eliminated from the list.

3. Enhanced Global and Local Curvature Properties

Ideally, the proposed enhanced shape corner detection is basically inspired from corner detection based on global and local curvature properties proposed by He and Yung [13]. An example process and images for enhanced corner detection can be found in our previous work [14]. To get clear or picture with the whole process, this sections presents the original steps of corner detection based on global and local curvature properties [13] and the proposed enhanced shape corner detection process as illustrated in Figure 3(a) and Figure 3(b), representatively. As can been seen in Figure 3(a), there are eight steps that have been suggested by them in detecting corners.
The 6th International Conference on Software Engineering & Computer Systems  IOP Publishing
IOP Conf. Series: Materials Science and Engineering 769 (2020) 012041  doi:10.1088/1757-899X/769/1/012041

*a*. Corner detection process based on global and local curvature properties by He and Yung [13].

*b*. The proposed enhanced global and local curvature properties shape corner detection process.

**Figure 3.** The process flow of corner detector method

It begins with the input image and followed by the detection of edges by utilizing Canny edge technique. Then, the contour was extracted as within the CSS process. After that, the curvature was computed at a fixed low scale for every contour to preserve the true corners. It is followed by the process of threshold computation according to the mean curvature within a region of support (ROS). In this step, round corners will be removed by comparing the curvature of corner candidates with the adaptive threshold. Next, the end points of open contour are taken into consideration to mark it as corners unless it is very close to another corner. Finally, the detected corners will be displayed. The proposed enhanced shape corner detection process is presented in Figure 3(b).

As illustrated in Figure 3(b), the proposed enhanced shape corner detection has less steps process then the original global and local curvature properties. Given an input image, it first extracts the edges
of the object shape using a Canny edge detector. After that, the same processes as in original global and local curvature properties in Figure 3(a) are applied until the threshold computation process. The process is complete until the corner detected results are displayed. Noticed that throughout the rules the used pairs of larger and equal to because the value acquired that later on will define as the corners.

4. Experimental Results

The experimental results of the proposed enhanced global and local curvature properties are presented and the numbers of true corner detected is compared with other existing methods. The experiments used the MPEG-7 dataset to assess the enhanced global and local curvature properties. The foremost common corner descriptors and detectors such as Harris, Harris Laplace, SUSAN, CSS, SIFT and Global and Local Curvature Properties has been assessed and compared to the enhanced global and local curvature properties concerning of true corners observation.

To show a clearer performance of different corner detection method, the overall number of recognized corners is calculated and the experimental results evaluation are summarized as shown in Table 1. The MPEG-7 Core Experiment Shape-1 Part B dataset were applied in this investigation. From Table 1, the number of corners points detected on MPEG-7 images under all of the six existing methods and the proposed enhanced methods are presented. As displayed in Table 1, Harris technique identified most noteworthy corners with the foremost corners identified under image category hammer, ray, bird and face images. Nevertheless, there are corners spotted on the straight line of the object. Furthermore, some identified corners are not suitable and not reliable for shape representation meanwhile some of them are either nearby to each other or overlooked the true corners of the shape. As a consequence, the entire shape of the object could not be fully represented.

A Harris Laplace and SUSAN methods almost detect the same number of corners except for ray, rat and bird images. Moreover, SIFT representing the second highest in detecting corners after Harris but as discussed in the previous sections, some of the corners detected are false corners or redundant. So that, most of the corners are not meaningful because of false corner does not give any significant information of the shape object. On the other hand, CSS produced the lowest total number of identified corners unsuitable for shape representation since missing significant shape points as can be observed under all types of image category in Table 1.

Table 1. Corners Detection Evaluation Results using MPEG-7 Core Experiment Shape-1 Part B dataset.

| Image with corner detected | Brick | Hammer | Rat  | Ray  | Bird | Face |
|----------------------------|-------|--------|------|------|------|------|
| Harris                     | 40    | 17     | 71   | 120  | 61   | 50   |
| Harris Laplace             | 21    | 14     | 28   | 33   | 18   | 31   |
| SUSAN                      | 21    | 15     | 58   | 82   | 43   | 34   |
| SIFT                       | 44    | 13     | 73   | 38   | 29   | 23   |
| CSS                        | 11    | 4      | 17   | 9    | 8    | 8    |
| Global and Local Curvature | 14    | 7      | 26   | 21   | 14   | 10   |
| Enhanced Global and Local Curvature | 15 | 8 | 28 | 22 | 15 | 12 |

Corner detector using global and local curvature properties detected appropriate corner compared with CSS but there are seems some corners points cannot be detected. It can be highlighted that the corners detected by the proposed enhanced methods are more appropriate compare with original methods.
5. Conclusion
To summarize, the proposed method detected good corner points where additional corner points could be found compared to the original approaches. Consequently, the detected corners are more accurate and every spotted corner points are significant in improving shape representation. Hence, it is appropriate to be applied in various applications such as computer vision and image matching. Detection appropriate corners of object shape is crucial so that all the features information of the significant points can be stored and used in retrieving the similar shape object.

Acknowledgements
This work was partly supported by Universiti Malaysia Pahang under grant number RDU190307.

References
[1] Yadav, A. and Yadav, P. 2009 Digital Image Processing. Published by USP/Laxmi Publications (P) Ltd., New Delhi.
[2] Kavitha, K., and Sudhamani, M. V. 2014 Object Based Image Retrieval from Database Using Combined Features. Paper presented at the Signal and Image Processing (ICSIP)
[3] Kuo-Lung, H., and Chieh-Hsien, L. 2012 A Novel Image Retrieval Technique Based on Salient Image Features. Innovations in Bio-Inspired Computing and Applications (IBICA)
[4] Bakar, S.A., Hitam, M.S. and Yussof, W.N.J.H.W 2019 A Comparative Analysis of the Zernike Moments for Single Object Retrieval Baghdad Science Journal vol. 16, pp.504-514
[5] Ben-Musa, A. S., Singh, S. K., and Agrawal, P. 2014 Object detection and recognition in cluttered scene using Harris Corner Detection. International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT)
[6] Xin, Z., Guojin, H., and Jiying, Y. 2009 A Rotation Invariance Image Matching Method Based on Harris Corner Detection International Congress on the Image and Signal Processing (CISP).
[7] Ignacio A. and Margarita C. 2018 Asynchronous Corner Detection and Tracking for Event Cameras in Real Time IEEE Robotics and Automation Letters Vol. 3, No. 4
[8] N. Algethami and S. Redfern, 2018 Combining accumulated frame differencing and corner detection for motion detection Proceedings of the Conference on Computer Graphics & Visual Computing (CGVC)
[9] Morgan Q., Kartik M., Shreyas S.S., Micheal W. and Yash M., 2019 The Open Vision Computer : An Integrated Sensing and Compute System for Mobile Robots IEEE International Conference on Robotics and Automation (ICRA)
[10] D, Pebrianti, YH, Hao, NAS, Suarin, L, Bayuaji, Z, Musa, M, Syafrullah and I, Riyanto 2018 Motion tracker based wheeled mobile robotoller system identification and controller design Intelligent Manufacturing & Mechatronics
[11] Mokhtarian, F., S. Abbasi and J. Kittler, 1997 A new approach to computation of curvature scale space image for shape similarity retrieval Proceedings of the 9th International Conference on Image Analysis and Processing.
[12] He, X. C., and Yung, N. H. C. 2004 Curvature scale space corner detector with adaptive threshold and dynamic region of support Proceedings of the 17th International Conference on the Pattern Recognition (ICPR).
[13] He., X. C., and Yung, N. H. C. 2008 Corner Detection based on Global and Local Curvature Properties. S P I E - International Society for Optical Engineering.
[14] Bakar, S.A., Hitam, M.S. and Yussof, W.N.J.H.W 2017 Improved Global and Local Curvature Properties for Shape Corner Detection Journal of Applied Sciences 458-566.