IOP Conf. Series: Materials Science and Engineering **370** (2018) 012013 doi:10.1088/1757-899X/370/1/012013

Validation of Harris Detector and Eigen Features Detector

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Abstract. Harris detector is one of the most common features detection for applications such as object recognition, stereo matching and target tracking. In this paper, a similar Harris detector algorithm is written using MATLAB and the performance is compared with MATLAB built in Harris detector for validation. This is to ensure that rewritten version of Harris detector can be used for Unmanned Aerial Vehicle (UAV) application research purpose yet can be further improvised. Another corner detector close to Harris detector, which is Eigen features detector is rewritten and compared as well using same procedures with same purpose. The simulation results have shown that rewritten version for both Harris and Eigen features detectors have the same performance with MATLAB built in detectors with not more than 0.4% coordination deviation, less than 4% & 5% response deviation respectively, and maximum 3% computational cost error.

1. Introduction

Features detection is a process to detect significant curves, edges or corners from an image. These features have necessary information for motion tracking and pattern recognition through feature extraction and matching with features from other frame [1, 2]. Hence, features detection is very useful and crucial in the development of UAV application as it can make UAV to be more robust and intelligent.

Nonetheless, precision and speed are the main requirements for implementation of features detection in real applications. The computational cost of detection needs to be low and features must be detected consistently in each frame to maintain tracking or recognition in various viewpoints and orientations [3].

Among features detector, the Harris detector is one of the most widely used method due to its simplicity, reliability and invariance of lighting, transformation and rotation [4]. Generally, this detector considers corner points as features by determining whether there is large intensity change in all directions for each pixel. Shi and Tomasi [5] proposed Eigen features detector and it has the same concept as Harris detector in some ways. The advantage of this method is that it is more stable, but the computational cost is higher than Harris detector.

In this paper, the algorithm of Harris detector and Eigen features detector are made using MATLAB, and both algorithms' performance will be compared with its MATLAB version built-in function detectors for validation. This is crucial so that both written algorithms can be used, analyzed and further improvised for UAV application research if they are validated. The performance comparison is analyzed in the respect of features' coordinates, response value and overall computational cost.

2. Methodology

In this section, the introduction of Harris detector and Eigen features detector is elucidated. In addition, the principle of both detectors is briefly explained.

2.1. *Harris detector*

Harris detector is proposed by Harris and Stephens [6], which is basically to determine the corner points of an image [7] and to have improved performance than the Moravec's corner detector [8]. There are three aspects in terms of improvement. Firstly, Morevec's corner detector only consider eight discrete directions in obtaining corner points while Harris detector minimize the dependency on the direction [9]. Next, Harris detector is utilizing the Gaussian function which avoids interference that occurs in Moravec's corner detector. Lastly, Harris detector decreases the probability of false detection to edge by having various direction grey measurement [9].

In general for the Harris detector, the gradient of image in x and y direction, I_x and I_y will be estimated for each pixel. Then, the correlation matrix of each pixel is formed [10, 11] as shown in equation (1).

$$M = \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} \tag{1}$$

The elements in the matrix are smoothed with Gaussian function in order to increase the robustness of the detection. The response of each pixel can be calculated using equation (2) [12],

$$H = \lambda_1 \lambda_2 - k * (\lambda_1 + \lambda_2)^2 \tag{2}$$

whereby λ_1 and λ_2 are the eigenvalues of M and k is the sensitivity factor which is usually within [0.04, 0.06]. The pixel is considered as corner, only when both eigenvalues λ_1 and λ_2 are large as shown in figure 1 [13].

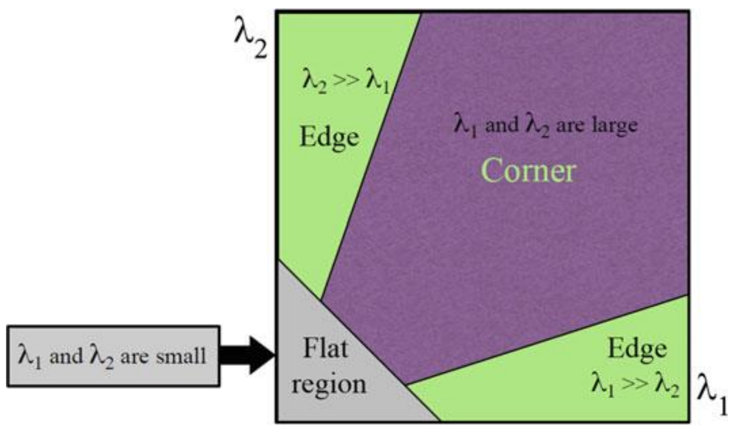

Figure 1. Classification of image point based on eigenvalues of the autocorrelation matrix.

Still, the computation cost of calculating eigenvalues is high, thus, an approximation using equation (3) having the determinant and the trace of M is developed to replace equation (2).

$$H = \det(M) - k * trace(M)^2 \tag{3}$$

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If the response is negative, this means the pixel is an edge, while if the response is small in value; the pixel is in flat region. Only when the response is positive and large in value, the pixel might be considered as corner point [14]. This is confirmed by comparing the value of response with threshold value as shown in equation (4) and those with higher value than threshold are corner points.

$$Corner = true, only\ if\ H > threshold \quad (4)$$

2.2. *Eigen features detector*
This method has the same steps as Harris detector in the beginning by forming correlation matrix with intensity gradient for each pixel. The components of the matrix will be smoothed using Gaussian function as well. Nevertheless, the response of each pixel is estimated using equation (5) as shown below [5]. Only when eigenvalues are greater than threshold value, the pixel will be considered as corner point, which is illustrated in light yellow region in Figure 2.

$$R = \min(\lambda_1, \lambda_2) \quad (5)$$

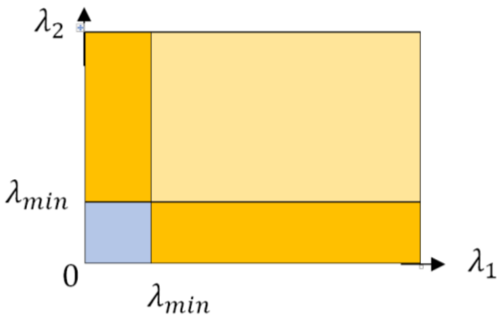

Figure 2. Classification of image point based on eigenvalues of the autocorrelation matrix.

3. Results ad Discussions
In this section, a simulation comparison test is done on MATLAB built in detectors and rewritten version detectors using 6 various images. In terms of Harris detectors, the sensitivity factor, k is set as 0.04 in both versions of the detector. The threshold of both Harris and Eigen features detectors is set as 1% of maximum response value in the image. Figures 3-6 display two out of the 6 case studies images used to assess both Harris and Eigen features detectors.

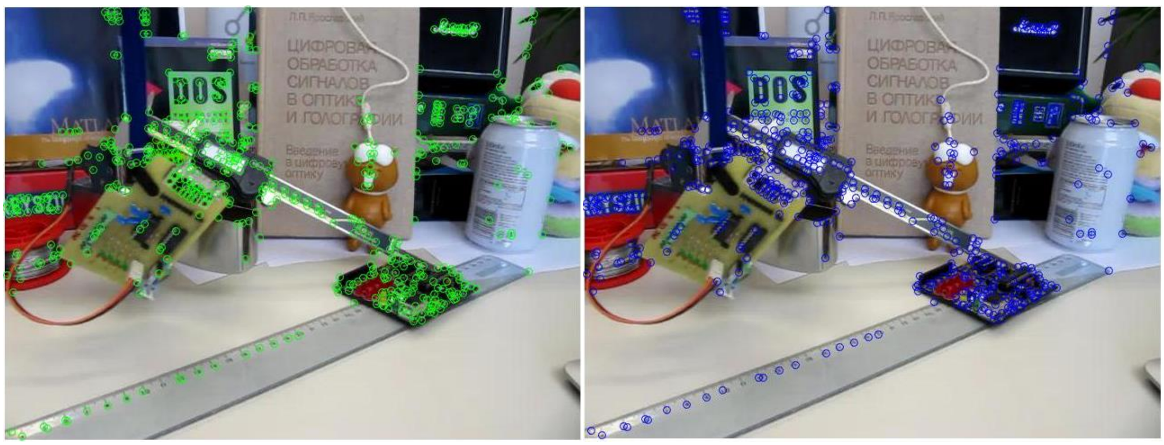

Figure 3. MATLAB built in (left) and the rewritten version of Harris detector

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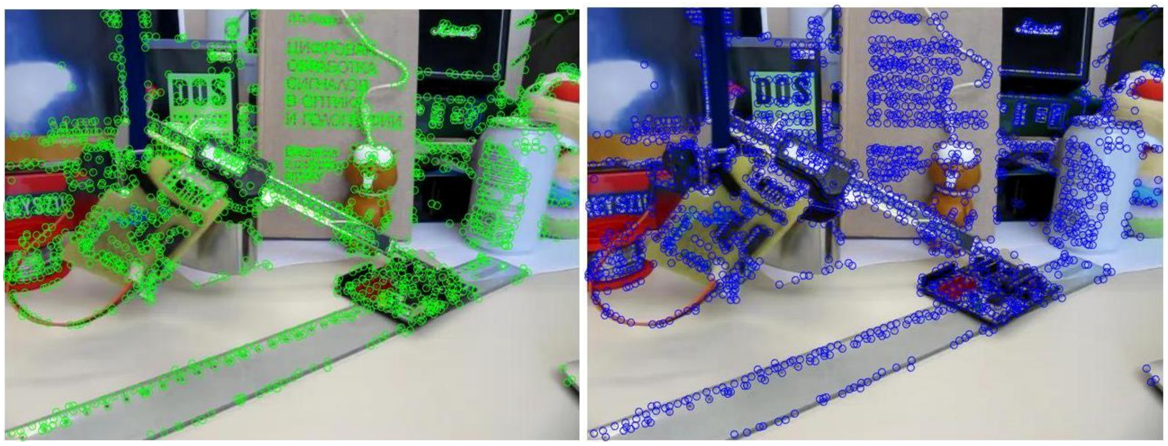

Figure 4. MATLAB built in (left) and the rewritten version of Eigen features detector

Figure 5. MATLAB built in (left) and the rewritten version of Harris detector

Figure 6. MATLAB built in (left) and the rewritten version of Eigen features detector

The comparison includes the difference of x and y coordinates, the response value, and the computational cost for each corner points between the MATLAB built in detectors and the rewritten version detectors. The comparison results are shown in table 1 and 2. Based on table 1 and 2, the error difference comparison between x and y coordinates in both Harris and Eigen features detector is less than 0.4% for all case studies. In addition, both rewritten detectors are able to find the same feature points as in MATLAB built in detectors.

Table 1. Comparison of x and y coordinates, response and computational cost of Harris detector

Image	1	2	3	4	5	6
X coordinate error (%)	0.30	0.10	0.32	0.24	0.19	0.16
Y coordinate error (%)	0.24	0.08	0.39	0.15	0.18	0.10
Response error (%)	4.3	5.1	3.7	4.3	4.6	5.1
Computational cost error (%)	0.7	1.5	1.6	1.5	0.2	1.6

Table 2. Comparison of x and y coordinates, response and computational cost of Eigen detector

Image	1	2	3	4	5	6
X coordinate error (%)	0.28	0.13	0.28	0.25	0.33	0.19
Y coordinate error (%)	0.22	0.07	0.32	0.22	0.20	0.23
Response error (%)	3.7	3.1	3.6	3.7	4.1	3.8
Computational cost error (%)	1.8	1.1	2.5	1.6	2.3	2.9

Furthermore, the maximum difference of response value is around 5% in Harris detector comparison, while in Eigen features detector comparison is around 4%. Although these two values are at least 10 times higher than coordinates error, it is still small in value and acceptable. Besides, it can be observed that small deviation in coordinates can lead to large deviation in corner point response value. Also, the difference of computational cost is less than 3% in both Harris and Eigen features detectors case studies, which is satisfactory.

4. Conclusion

In conclusion, the difference in detectors of MATLAB built in and the rewritten version in terms of coordinates are less than 0.4%. In terms of response value are around 5% for Harris detector and 4% for Eigen features detector. While in terms of computational costs are less than 3% in both detectors. Thus after analysing the corner points' coordinates, response value, and computation cost, the rewritten version of detectors is validated and can be considered to have similar performance as MATLAB's built in detectors. Both rewritten detectors can be used in research, either as comparison with other detectors, or for modification and improvement in detectors.

Acknowledgement

This publication was supported by Universiti Sains Malaysia Grant No. 304/PAERO/6315002.

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