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A New Approach for Detection of Retinal Haemorrhages in Colour Fundus Images

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***Abstract*—We propose a new approach for retinal haemorrhages detection in a retinal image. Our approach is divided into three steps. Pre-processing step which consists of green and V band extraction, histogram matching, contrast enhancement and morphological opening operation is needed to improve the image quality. In the most important step, retinal haemorrhage which is a benchmark of diabetic retinopathy is extracted from colour retinal images using a two-dimensional matched filter. Finally, a post-processing step is performed to reduce the false positive of detected haemorrhages. Our approach is validated on 89 public retinal images from DIARETDB1 database. Three validation parameters, namely sensitivity, specificity and accuracy are calculated by comparing our result to its corresponding hand labelled haemorrhages image. The obtained average sensitivity, specificity and accuracy are 0.91, 0.98 and 0.98, respectively. This achievement is much better than that of other published methods.**

***Index Terms*—Colour Retinal Image; Diabetic Retinopathy; Haemorrhages; Two-dimensional Matched Filter.**

I. INTRODUCTION

Diabetic retinopathy (DR), one of the diabetes complications is the most leading causes of blindness [1]. Mostly, DR is recognized at its later stage, so that development of an automated tool for early screening of DR is required [2]. Many benchmarks are used in DR detection including a retinal vessel, retinal pathology, and foveal avascular zone [3, 4]. Nevertheless, to construct such tool can be a challenging task, particularly in dark lesion detection such as microaneurysms and retinal haemorrhages.

Microaneurysms and retinal haemorrhages are the first observable benchmarks of diabetic retinopathy. In colour fundus image, microaneurysms and retinal haemorrhages appear as dark reddish spots and flames. The example of microaneurysms and retinal haemorrhages is depicted in Figure 1. The appearance of dark lesion particularly retinal haemorrhages determines the grade of diabetic retinopathy. In addition, retinal haemorrhages occurring in the macula can cause serious visual impairment.

Various algorithms for detection of retinal haemorrhages have been published. Shivaram *et al.* [5] employed arithmetical and mathematical morphology for detecting the retinal haemorrhages and suppress the retinal vessels. The result was compared to the ground truth obtained by an ophthalmologist. The achieved sensitivity, specificity and accuracy were 0.89, 0.99 and 0.98, respectively.

Zhang and Fan [6] used multi-scale morphological processing to detect retinal haemorrhages. Overdetection objects such as retinal vessels were reduced using scale-based pathology validation. The method was evaluated on 30 colour fundus images and it yielded a sensitivity and predictive values of 0.84 and 0.89 respectively. Recursive region growing was applied by Sinthanayothin *et al.* [7] to segment retinal haemorrhages. The contrast of retinal haemorrhages was enhanced using moat operator.

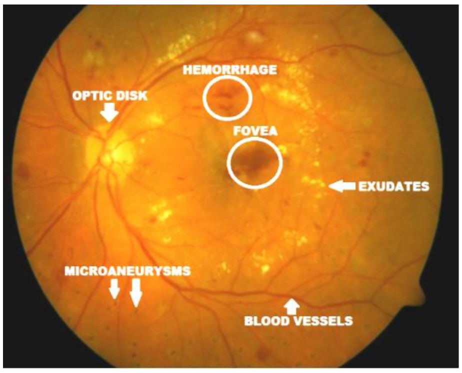


Figure 1: The example of dark lesion in Colour fundus image including microaneurysms and retinal haemorrhage

Tang *et al.* [8] presented a splats technique, a collection of pixels with similar colour and spatial location, for retinal haemorrhages segmentation. The watershed algorithm was used for splats segmentation. Having removed retinal vasculatures using automated vessels segmentation method, the *k*-NN classifier was applied in training and testing stage to distinguish the retinal haemorrhage and background. Training stage involved 20 fundus images from DRIVE database while 1200 images from MESSIDOR database were used in the testing stage.

Several algorithms for detection of retinal haemorrhages have been presented above. Unfortunately, most of them either involved complex method or yielded unsatisfactory results. In this paper, a novel approach for the detection of retinal haemorrhages is proposed and validated. It introduces a histogram matching of green and value (V) bands to enhance the fundus image quality. It also employs a multi-scale matched filter and double length filter for haemorrhages detection and noise reduction, respectively.

II. METHODOLOGY

Our approach for detection of retinal haemorrhages in colour fundus images is divided into three steps. Those are pre-processing retinal haemorrhages candidate detection and post-processing. Pre-processing consists of green and V band extraction, histogram matching, morphological opening operation and contrast enhancement. The main step or retinal haemorrhage detection step is conducted using a matched filter. Finally, post-processing step consists of retinal vessel elimination and length filtering is applied to reduce the false positive of detected retinal haemorrhages. Detailed step conducted in this paper is depicted in Figure 2.

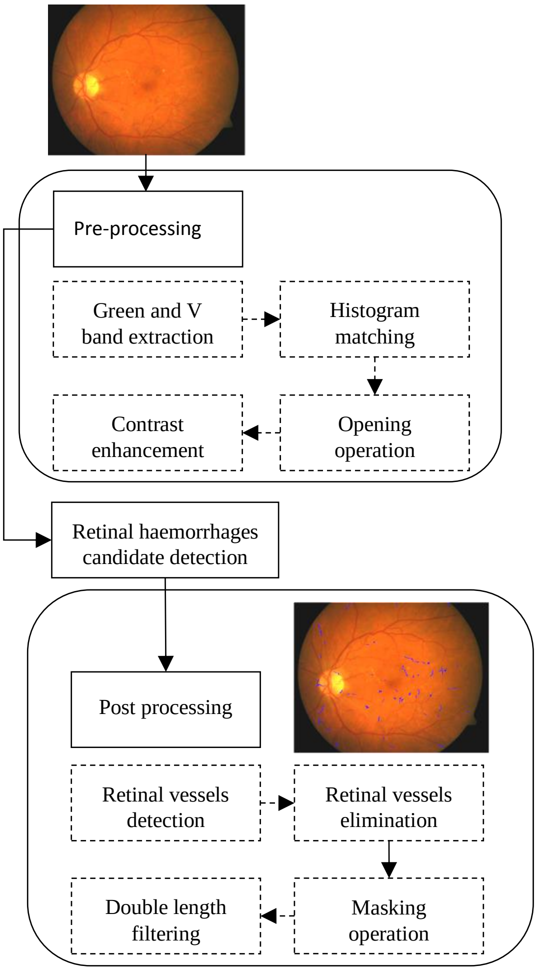


Figure 2: The block diagram for detection of retinal haemorrhage in colour fundus images

A. Pre-processing

Pre-processing step aims to enhance the colour fundus image quality. Colour image is known for having three bands including red (R), green (G) and blue (B). Colour image can also be represented using a hue (H), saturation (S) and value (V) system. The relations of RGB and HSV colour image representations are expressed in Equation (1) until Equation (3) [9].

The green and V bands are then used in histogram matching [10], followed by morphological opening operation and contrast enhancement.

B. Retinal Haemorrhages Candidate Detection

The retinal haemorrhages candidate detection step plays a key role in this paper. Therefore, applying a robust method in this step is beneficial to obtain a great result. The matched filter has been extremely used both in the one and two-dimensional signal detection. In colour fundus image processing, the two-dimensional matched filter has been used to detect retinal vessels. In this paper, the two-dimensional matched filter is used to match the retinal haemorrhages intensity profile which is similar to that of retinal vessels'. Two-dimensional matched filter equations are given in Equation (4) until Equation (6).

$$MAX = \max(R,G,B),\ MIN = \min(R,G,B)$$

$$H = \begin{cases} 0, if\ R = G = B \\ 60^\circ \times \left(0 + \dfrac{G-B}{MAX - MIN}\right), if\ MAX = R \\ 60^\circ \times \left(2 + \dfrac{B-R}{MAX - MIN}\right), if\ MAX = G \\ 60^\circ \times \left(4 + \dfrac{R-G}{MAX - MIN}\right), if\ MAX = B \end{cases} \tag{1}$$

$$S = \begin{cases} 0, if\ R = G = B \\ \dfrac{MAX - MIN}{MIN}, otherwise \end{cases} \tag{2}$$

$$V = MAX \tag{3}$$

$$K(x,y) = -\exp\left(\frac{u^2}{2\sigma^2}\right) \tag{4}$$

$$\overline{p_i} = [u \quad v] = [x \quad y]\begin{bmatrix} \cos\theta_i & -\sin\theta_i \\ \sin\theta_i & \cos\theta_i \end{bmatrix}, \forall \overline{p_i} \in N \tag{5}$$

$$N = \{(u,v) \mid |u| \le T, |v| \le L/2\} \tag{6}$$

L, T, σ and θ represent the length, width, standard deviation and orientation of matched filter window, respectively. Twelve matched filter windows for $\theta = 0 - 175°$ are convolved to the enhanced fundus image. The retinal haemorrhages candidate is defined as the maximum response of all matched filter responses.

C. Post Processing

The objective of post-processing step is to reduce over-detection objects which cause false positive invalidation process. This step consists of retinal vessels elimination and length filtering. Retinal vessels are detected using a matched filter and morphological reconstruction. Detail explanation of retinal vessels detection using morphological reconstruction can be found in [11]. Retinal vessels are then eliminated by subtracting the vessel image from the haemorrhage candidate image. Finally, double length filters are used to remove the remaining noise. The length filters apply up and bottom threshold to ensure that only haemorrhage appearing in the final result. The up threshold is designated to remove any object larger than haemorrhages while the bottom threshold is aimed to eliminate any object having a smaller area than the average area of haemorrhages.

D. Validation of Our Approach

To validate our approach, 89 retinal images from public database DIARETDB1 are used. The hand labelled detection of retinal haemorrhage is included. DIARETDB1 contains 89 colour fundus images in BMP format. On each colour fundus image, all steps mentioned above are applied. Thereafter, four classification parameters including true positive (TP), false positive (FP), true negative (TN) and false negative (FN) are calculated. A detail description of those parameters is presented in Table 1. Having obtained those parameters' values, three validation parameters such as sensitivity (SN), specificity (SP) and accuracy (ACC) are determined. Table

2 represents the equations to determine those parameters' values.

Table 1
Classification Parameters

	Ground truth image	
	Haemorrhages Present	Haemorrhages Absent
Haemorrhages detected	True positive (TP)	False positive (FP)
Haemorrhages not detected	False negative (FN)	True negative (TN)

Table 2
Validation Parameters

Parameter	Definition
Sensitivity (SN)	TP/(TP + FN)
Specificity (SP)	TN/(TN + FP)
Accuracy (ACC)	(TP + TN)/(TP + FN + TN + FP)

III. RESULT AND DISCUSSION

A. Pre-processing

Pre-processing step is started by extracting the green and V bands of each colour fundus image. Extracting the red, green and blue bands from colour fundus image is done by taking the matrix represented the green band. Further, the H, S and V band can be obtained using Equation (1) and Equation (3). The examples of colour fundus image in RGB and HSV formats are depicted in Figure 3. As shown in Figure 3 (b), green bands have the best contrast among other bands. Whereas, V band (Figure 3 (f)) represents the largest component colour among of R, G and B intensities. In other words, green band estimates the dark lesion while V band corresponds to the background so that joining them together is beneficial to obtain high contrast fundus image.

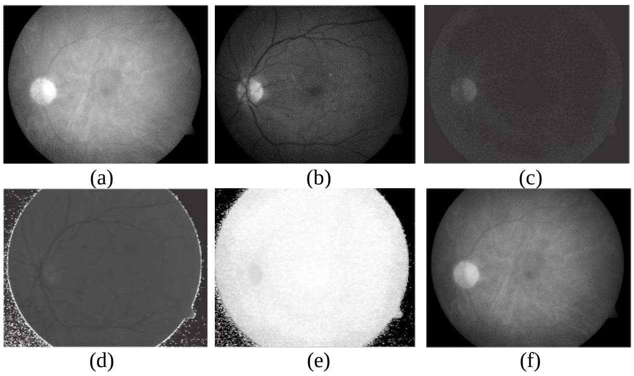


Figure 3: The examples of colour fundus image in RGB (a-c) and HSV (d-f) formats

The green and V bands become the inputs of the histogram matching. In Figure 4 (a), the histogram matching joins the retinal vessel and dark lesion profiles from the green band together with the background of the V band to construct the desired image. Further, the opening operation is applied to remove small artefact as depicted in Figure 4 (b). Afterwards, opening operation is employed to obtain an image in Figure 4 (c). As shown in Figure 4 (c), the dark lesion is clearly distinguished with the background, making the haemorrhages candidate detection step can be done successfully.

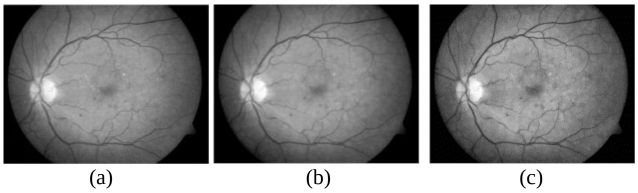


Figure 4: The results of pre-processing step

B. Retinal Haemorrhage Candidate Detection

This step is the most important step in retinal haemorrhage detection method. In this step, a two-dimensional matched filter is used. Twelve matched filter windows for $\theta = 0 - 175°$calculated using Equation (6) are convolved to the enhanced fundus image. L, T and σ are set equal to 16, 12 and 3; so that the filter has a large enough window to match the retinal haemorrhages profile. Then the retinal haemorrhages candidate is obtained by taking the maximum response of twelve matched filter responses. The results of this step can be seen in Figure 5. As shown in Figure 5 (b) till Figure 5 (e), the matched filter successfully detects the retinal haemorrhages at θ = 0, 45, 90 and 135^o. Further, the maximum response of all possible θ values forms the retinal haemorrhages candidates. The result is then converted into binary image using threshold equals to 0.3 as depicted in Figure 5 (f).

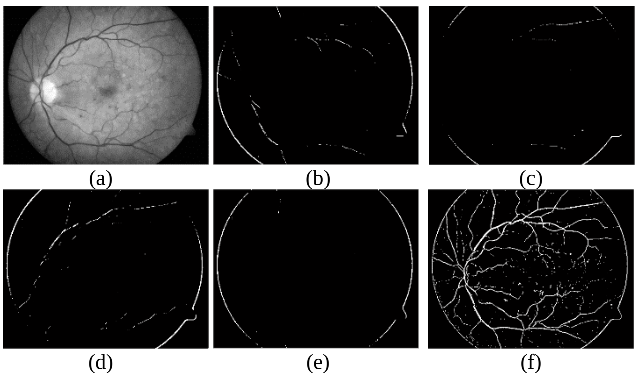


Figure 5: The results of retinal haemorrhages detection step

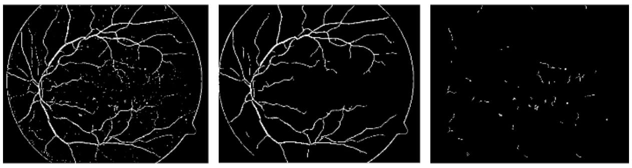
C. Post Processing

As mentioned above that matched filter successfully detects retinal haemorrhages candidate. Nevertheless, there are many undesired objects appear in Figure 5 (f). To overcome this problem, retinal vessels elimination and length filtering are applied. Retinal vessels are firstly segmented using a matched filter and morphological reconstruction.

Having converted the vessels image into a binary image, retinal vessels are then eliminated, followed by applying, up-down length filters. Up and down thresholds are set equal to 600 and 30, respectively. The results of this step are shown in Figure 6. As shown in Figure 6 (b), the retinal vessel and the border disappear. Furthermore, the undesired objects are also removed as can be seen in Figure 6 (c), indicating that the subsequent steps are efficient for retinal haemorrhages detection.

D. Validation of Our Approach

Our approach is validated on 89 retinal images from public database DIARETDB1. The hand labelled detection of retinal haemorrhage is included. DIARETDB1 contains 89 colour fundus images in PNG format. On each colour fundus image, all steps mentioned above are applied. Four



(a) (b) (c)

Figure 6: The results of post-processing step

classification parameters (TP, FP, TN and FN) and three validation parameters (SN, SP and ACC) are determined. Our approach achieves the average sensitivity, specificity and accuracy of 0.91, 0.98 and 0.98, respectively.

To ensure the readers, the comparison of our result to that of other published methods is presented in Table 3. As shown in Table 3, we achieve the highest sensitivity, indicating that our approach is more reliable to be used in the automated tool for early screening of DR compared to other existing methods.

Table 3
Our Result Compared to Other Methods

Authors	Performance Measurement		
	SN	SP	ACC
Shivaram *et al*. [5]	0.89	0.99	Not Reported
Sinthanayothin *et al*. [7]	0.78	0.89	Not Reported
Marwan and Eswaran [12]	0.88	0.95	Not Reported
Proposed approach	**0.91**	**0.98**	**0.98**

IV. CONCLUSION

A novel approach for the detection of retinal haemorrhages in colour fundus images has been presented. It introduces histogram matching of green` and V bands to enhance the fundus image quality, employs multi-scale matched filter for haemorrhages detection and applies double length filter for noise reduction, respectively. Our satisfying result demonstrates that our approach is reliable to be implemented in the automated tool for early screening of DR.

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REFERENCES

[1] H. A. Nugroho, L. Listyalina, N. A. Setiawan, S. Wibirama, and D. A. Dharmawan, "Automated segmentation of optic disc area using mathematical morphology and active contour," in *International Conference on Computer, Control, Informatics and its Applications (IC3INA)*, 2015, pp. 18-22.

[2] A. F. M. Hani, H. Nugroho, H. A. Nugroho, L. I. Izhar, N. F. Ngah, T. M. George, *et al.*, "Toward a Fully Automated DR Grading System," in *5th European Conference of the International Federation for Medical and Biological Engineering*, 2012, pp. 663-666.

[3] A. F. M. Hani, L. I. Izhar, and H. A. Nugroho, "Analysis of foveal avascular zone in color fundus image for grading of diabetic retinopathy," *Int. J. of Recent Trends in Engineering and Technology,* vol. 2, 2009.

[4] M. J. Paranjpe and M. Kakatkar, "Review of Methods for Diabetic Retinopathy Detection and Severity Classification," *International Journal of Research in Engineering and Technology,* vol. 3, pp. 619-24, 2014.

[5] J. M. Shivaram and R. Patil, "Automated Detection and Quantification of Haemorrhages in Diabetic Retinopathy Images using Image Arithmetic and Mathematical Morphology Methods," *International Journal of Recent Trends in Engineering,* vol. 2, pp. 174-176, 2009.

[6] X. Zhang and G. Fan, "Retinal Spot Lesion Detection using Adaptive Multiscale Morphological Processing," in *International Symposium on Visual Computing*, 2006, pp. 490-501.

[7] C. Sinthanayothin, J. Boyce, T. Williamson, H. Cook, E. Mensah, S. Lal, *et al.*, "Automated Detection of Diabetic Retinopathy on Digital Fundus Images," *Diabetic Medicine,* vol. 19, pp. 105-112, 2002.

[8] L. Tang, M. Niemeijer, and M. D. Abràmoff, "Splat Feature Classification: Detection of The Presence of Large Retinal Hemorrhages," in *2011 IEEE International Symposium on Biomedical Imaging: From Nano to Macro*, 2011, pp. 681-684.

[9] M. Loesdau, S. Chabrier, and A. Gabillon, "Hue and Saturation in The RGB Color Space," in *International Conference on Image and Signal Processing*, 2014, pp. 203-212.

[10] D. Coltuc, P. Bolon, and J.-M. Chassery, "Exact Histogram Specification," *IEEE Transactions on Image Processing,* vol. 15, pp. 1143-1152, 2006.

[11] D. Welfer, J. Scharcanski, C. M. Kitamura, M. M. Dal Pizzol, L. W. Ludwig, and D. R. Marinho, "Segmentation of The Optic Disk in Color Eye Fundus Images using An Adaptive Morphological Approach," *Computers in Biology and Medicine,* vol. 40, pp. 124-137, 2010.

[12] M. D. Saleh and C. Eswaran, "An Automated Decision Support System for Non-proliferative Diabetic Retinopathy Disease Based on MAs and HAs Detection," *Computer Methods and Programs in Biomedicine,* vol. 108, pp. 186-196, 2012.