Segmentation of Exudates Based on High Pass Filtering in Retinal Fundus Images

Hanung Adi Nugroho[1*], KZ Widhia Oktoeberza[1**], Teguh Bharata Adji[1], Muhammad Bayu Sasongko[2]
[1]Department of Electrical Engineering and Information Technology, Faculty of Engineering
[2]Department of Ophthalmology, Faculty of Medicine
Universitas Gadjah Mada
Yogyakarta, Indonesia
[*]adinugroho@ugm.ac.id, [**]widhia.oktoeberzakz.mti13@mail.ugm.ac.id

***Abstract*— The World Diabetes Foundation has predicted that more than 439 million people in 2030 will suffer from diabetes. Long-term diabetics can lead to the damage of retinal blood vessels, known as diabetic retinopathy, the leading cause of blindness in developing countries. One of the clinical features of diabetic retinopathy is exudate. Exudates have similar characteristic with optic disc. Therefore, in this research work, removal of optic disc is conducted to reduce false positive of exudates detection. The optic disc detection is done by finding the small area of the optic disc which is enlarged to obtain its total area. Green channel that contains useful information for exudates detection is filtered based on high pass filter. Afterwards, segmentation of exudates is conducted by using thresholding and morphological operations. Final result of exudates is validated with ground truth images by measuring accuracy, sensitivity and specificity. The results show that proposed approach for exudates detection achieves accuracy, sensitivity and specificity of 99.99%, 90.15% and 99.99%, respectively. This result indicates that the proposed method successfully detects exudates and is useful to assist the ophthalmologists in analysing retinal fundus image especially for exudates detection to diagnose diabetic retinopathy.**

Keywords—exudates; high pass filtering; optic disc; retinal images; diabetic retinopathy

I. INTRODUCTION

One of the major health problems in developing and developed countries is diabetes. The World Diabetes Foundation predicted that more than 439 million people will be threatened from diabetes in 2030 [1]. It is related to an aging population and obesity caused by unhealthy life style. The long-term indications of diabetes will lead to change and damage of retinal blood vessels which is called diabetic retinopathy (DR) [2]. Diabetic retinopathy is one of the chronic eye diseases which may the major cause of blindness in working population among adults aged 20-74. Therefore, early detection and diagnosis are needed to overcome the progression of this disease [3].

Diabetic retinopathy is mainly classified as non-proliferative diabetic retinopathy (NPDR) and proliferative diabetic retinopathy (PDR). NPDR as background retinopathy is divided into three subclasses, i.e. mild NPDR, moderate NPDR and severe NPDR [4]. These stages are identified based on appearance of clinical features, such as microaneurysms, haemorrhages, cotton wool spots, exudates, neovascularisation and macular edema, as depicted in Figure 1. Exudates are the major sign of diabetic retinopathy and affected permanent blindness especially if its presence near from macula. Exudates are yellowish, vary in size and location [5]; which is the accumulation of lipid and protein from damaged retinal blood vessels [3]. Exudates have similar characteristics to optic disc (OD) as another bright area in retina; specified in colour, luminance, texture and contrast [2]. In some patients, exudates can represent the only visible clinical feature of diabetic retinopathy [6]. The blindness can be prevented by detecting exudates in early stages [2] but it is difficult if only relying on visual examination [7].

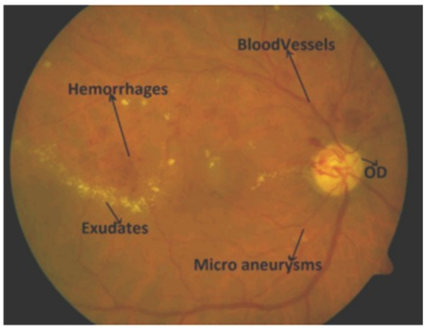


Fig. 1. Clinical features of diabetic retinopathy [8].

Several researchers have developed various processing techniques of exudates detection using retinal fundus images for assisting ophthalmologists to diagnosis diabetic retinopathy. Yazid *et al.* [9] obtained candidate area of exudates using fuzzy c-means (FCM) on green channel image. Inverse surface thresholding was applied to segment exudates area. Similar thing is done by [2] that used contrast limited adaptive histogram equalisation (CLAHE) to process green channel for exudates detection followed by segmentation clustering-based. Ranamuka and Meegama [10] also used CLAHE to contrast enhancement and Gaussian filtering to remove noises. Pre-processed image was processed using morphology operation and thresholding to obtain exudates area.

Sanchez *et al*. [11] used modification of RGB to segment hard exudates by applying Frei-Chen operator. Edge of segmented image was enhanced using Kirsch's method to remove other yellow lesion. García *et al*. [12] focused on the detection of hard exudates through lesions appeared on the retinal fundus image. In their works, the candidate areas of exudates were obtained from normalised image segmented by combining the global and adaptive thresholding methods. Kavitha and Duraiswamy [13] detected automatically for hard and soft exudates by using CIELab colour space. Region props were employed to detect and localise optic disc area; for decreasing false positive exudates detection based on colour histogram thresholding. Red channel is processed by [14] using combination of thresholding and morphological operation to localise and segment optic disc.

Sae-Tang *et al*. [15] conducted work using non-uniform illumination retinal fundus image to detect exudates. Greyscale image was pre-processed using low pas filtering. Optic disc was removed by setting the region of interested to obtain clear exudates area. Eadgahi and Pourreza [16] segmented of hard exudates based on morphological operation; combining process of top hat, bottom hat and reconstruction operation. Bottom hat was used to remove blood vessels from retinal images while top hat operation was applied to obtain hard exudates area. Optic disc area was eliminated using Sobel operator. Osareh *et al*. used morphological operation to localise optic disc using L band from HSL and Lab colour space [17].

This research consists of two works, i.e. removal of optic disc from retinal fundus image using L band and detection of exudates as a clinical feature of diabetic retinopathy using green channel. Filtering and contrast enhancement are conducted in pre-processing, while segmentation is done by thresholding-based and morphological operation. Finally, segmented exudates are validated to ground truth images. The rest of this paper is organised as follows. Section 2 describes the proposed approach. Section 3 presents results and discussion followed by conclusion in Section 4.

II. Approach

The approach in this research work is described as follows. Firstly, original image in RGB format is extracted to green channel and is converted to obtain L band from HSL colour space. In pre-processing step, CLAHE, contrast stretching and median filtering are applied to L band, while high pass filtering-based is conducted to green channel. Pre-processed L band image is segmented by enlarging radius to obtain optic disc area. Otsu thresholding is used to segment filtered image of green channel. Removal of optic disc is conducted by multiplying inverse of segmented optic disc with segmented candidates of exudates, followed by morphological operation. Segmented exudates are validated to ground truth image to obtain evaluation result. Flowchart of the approach is depicted in Figure 2.

A. Pre-processing

Pre-processing aims to enhance and improve the quality of retinal fundus image to facilitate detection clinical features for diagnosis diabetic retinopathy disease.

CLAHE does not operate on the entire of image, but merely on small region of image called 'tile'. Enhancement calculation is modified based on contrast-limit level according to user-specified maximum, by placing limit l, $0 \leq l \leq 1$ [18].

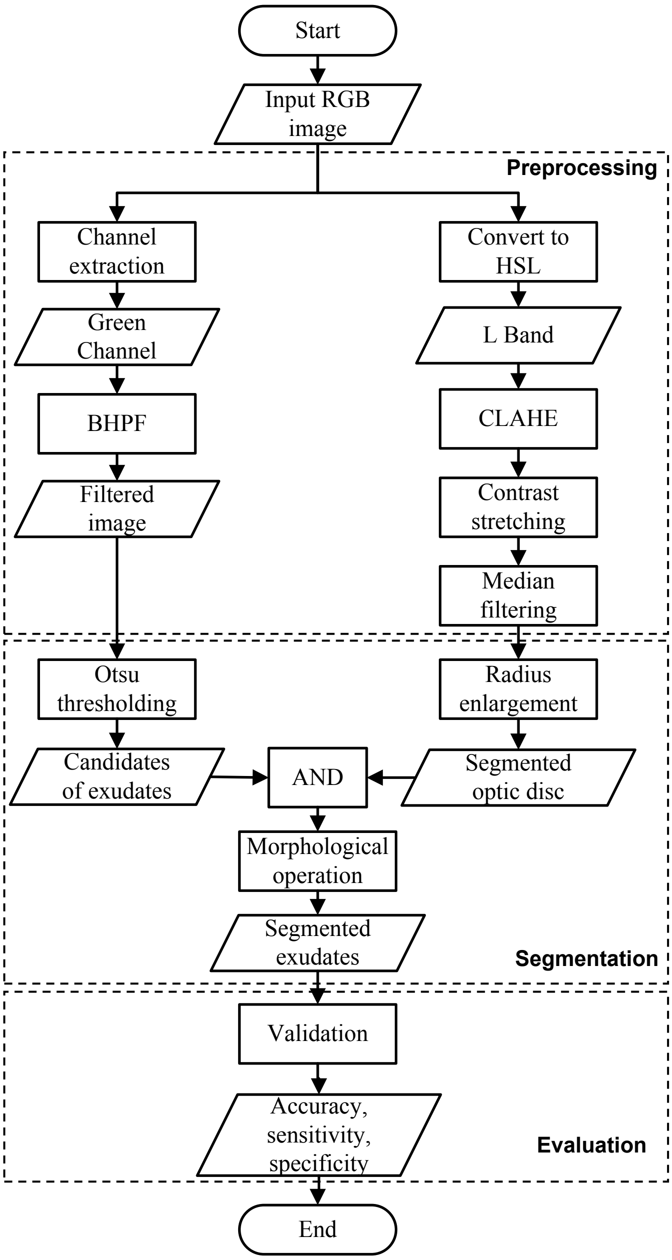


Fig. 2. Flowchart of the approach.

Contrast stretching is a technique to enhance contrast image especially for low contrast that calculated by (1). This technique works well on image that has Gaussian distribution.

$$o(i,j) = \left(\frac{u(i,j) - c}{d - c}\right)(L - 1) \tag{1}$$

Here, $o(i,j)$ and $u(i,j)$ are pixels after transformed and pixels before transformed in (i,j) coordinate, respectively; c is maximum pixel value; d is minimum pixel value of input image and L is maximum value of greyscale [19].

Median filter has a good performance to reduce noise. Median filtering is very popular in image processing to remove noise. Median filtering replaces pixel value in the centre coordinate of sliding windows with median value of pixels in the window. Median filtering is expressed mathematically in (2).

$$f(x,y) = median_{(s,t)\in S_{xy}}\{g(s,t)\} \tag{2}$$

Butterworth high pass filtering (BHPF) is one of the high pass filters that suppress low frequency until specific frequency and to pass other frequencies. High pass filtering has relation to low pass filtering, as expressed in (3).

$$H_{lt}(v,u) = 1 - H_{lr}(v,u) \tag{3}$$

Here, $H_{lt}(v,u)$ is transfer function of high pass filtering while $H_{lr}(v,u)$ is transfer function of low pass filtering.

B. Segmentation

Image segmentation is a process of pixel classification to extract objects or segment regions that have similarity of attributes from the background [20, 21].

Enlargement of radius is measured in terms of diameter of pre-processed image. Diameter is calculated by using (4).

$$diameter = \sqrt{(U(p,1) - U(q,1))^2 + (U(p,2) - U(q,2)^2} \tag{4}$$

Here, U is contour of binary image; p and q respectively are pixel 1 and pixel 2 as the longest distance.

Otsu method calculated threshold value T based on input image, automatically. Firstly, Otsu calculated intensity value i of histogram with mathematical formulation in (5). N as number of pixel images while n_i as number of pixels with i intensity. Weighted of object and background is declared in (6) and (7).

$$p(i) = \frac{n_i}{N}, p(i) \geq 0, \sum_{1}^{256} p(i) = 1 \tag{5}$$

$$w_1(t) = \sum_{i=1}^{t} p(i) \tag{6}$$

$$w_2(t) = \sum_{i=t+1}^{L} p(i) = 1 - w_1(t) \tag{7}$$

Here, L is as number of grey level. Mean of object and background is then calculated by using (8)-(9).

$$m_1(t) = \sum_{i=1}^{t} i.p(i)/w_1(t) \tag{8}$$

$$m_2(t) = \sum_{i=1}^{t} i.p(i)/w_2(t) \tag{9}$$

Variance is calculated by using (10)-(11), while total of variance is expressed in (12) as follows.

$$\sigma_1^2(t) = \sum_{i=1}^{t} (1 - m_1)^2.\frac{p(i)}{w_1(t)} \tag{10}$$

$$\sigma_2^2(t) = \sum_{i=t+1}^{t} (1 - m_2)^2.\frac{p(i)}{w_2(t)} \tag{11}$$

$$\sigma^2(t) = \sigma_w^2(t) + \sigma_B^2(t) \tag{12}$$

Here, σ_w^2 is called as within-class variance (WVC) that is expressed in (13), while σ_B^2 called between-class variance (BVC) that is expressed in (14). WVC is the amount of individually class variance that has been weighted with probability of each class. Average total is calculated using (15). Threshold value can be obtained from minimisation of WVC or maximisation of BVC, but BVC has less computation time [20].

$$\sigma_w^2(t) = w_1(t).\sigma_1(t)^2 + w_2(t).\sigma_2(t)^2 \tag{13}$$

$$\sigma_B^2(t) = w_1.[m_1(t) - m_T]^2 + w_2.[m_2(t) - m_T]^2 \tag{14}$$

$$m_T = \sum_{i=1}^{N} i.p(i) \tag{15}$$

Morphological is a set of discrete coordinates that related to pixel object of image that involves logical operation, such as "or" and "and". Opening operation aims to refine object contour and repair object contour with eliminated pixel area that smaller than structure element [19]. Opening operation is expressed in (16).

$$AoB = (A \Theta B) \oplus B \tag{16}$$

C. Evaluation

Evaluation aims to analyse results and to know how well performance of the proposed techniques. In this research work, evaluation of segmented exudates is conducted by measuring accuracy, sensitivity and specificity as expressed in (17)-(19).

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{17}$$

$$Sensitivity = \frac{TP}{TP + FN} \tag{18}$$

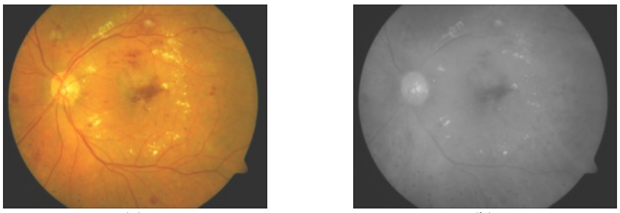
$$Specificity = \frac{TN}{TN + FP} \tag{19}$$

III. Results and Discussion

In this work, 28 retinal colour fundus images with PNG (RGB) format from DIARETDB1 database [22] that contain exudates are used.

A. Removal of optic disc

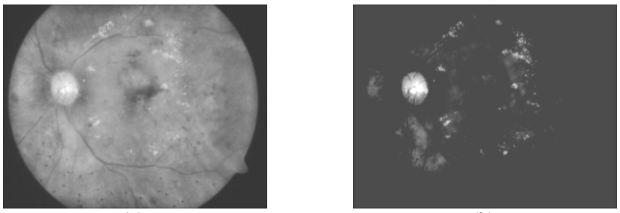
Conversion of colour space is conducted by converting RGB image as original image to HSL colour space. It is employed to facilitate process in further. L band is selected caused by other band do not contain enough information to detect optic disc. In H and S band, information tends to be lost. Selecting L band is also supported by the appearance of blood vessels in this component less strong and blur; thus, it could facilitate to eliminate an optic disc area from other objects and background. Results of conversion process are illustrated in Figure 3.



(a) (b)

Fig. 3. The result RGB to HSL (a) RGB image (b) L band.

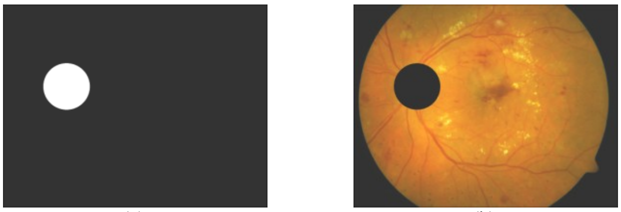
Contrast limited adaptive histogram equalisation (CLAHE) is proposed to enhance contrast retinal image, followed by contrast stretching process. It is presented in Figure 4. Then, enhanced image is filtered by using median filtering, in which to decrease varied intensity and make optic disc area more clearly.



(a) (b)

Fig. 4. The result of contrast enhancement: (a) CLAHE (b) Contrast stretching.

Filtered image by median filtering is converted to binary scale image. It aims to get small area that represents optic disc area. The radius of detected area binary image is used to create a circle. Then is conducted enlargement of radius to cover optic disc area in retinal fundus image. Multiplication operation is conducted to remove optic disc area from retinal image to facilitate and decrease false positive for exudates detection. Removal of optic disc from retinal image is depicted in Figure 5.



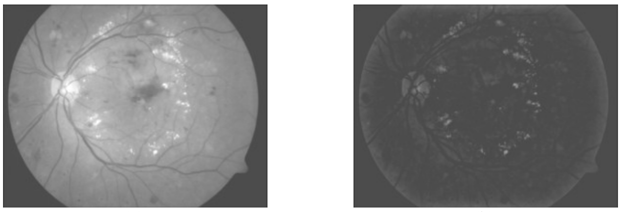
(a) (b)

Fig. 5. (a) Radius enlargement (b) Removal of optic disc.

B. Detection of exudates

The pre-processing step for exudates detection consists of channel extraction and filtering. Channel extraction is conducted to facilitate further steps. Original image in RGB format is extracted to obtain three channels, namely red channel, green channel and blue channel. Green channel is selected to be processed because it contains useful information for exudates detection, as presented in Figure 6 (a). Whilst, red channel is so bright that affects exudates area and background to be similar and is difficult to separate. Blue channel is so dark that affects some information of exudates to be lost.

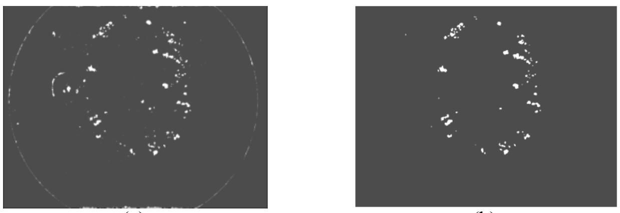
Green channel that is obtained from extraction process is filtered based on high pass filtering, that is Butterworth high pass filtering (BHPF). Because of exudates is bright lesion in retina be considered term to use high pass filtering. BHPF is operated by suppressing low frequency and passing high frequency. The result of high pass filtering-based is depicted in Figure 6 (b).



(a) (b)

Fig. 6. (a) Extracted green channel (b) Filtered green channel.

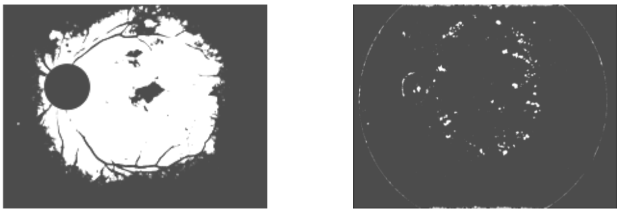
Filtered image as result of filtering process obtained the candidate region of interest (RoI) of exudates. These were considered as the candidates of exudate areas. Afterwards, Otsu thresholding is applied to obtain candidate areas of exudates. As the result, segmented image with binary mask is presented in Figure 7 (a). This process aims to separate candidate exudates to other object and background. Removal of optic disc and masking is a way of fine segmentation to obtain the real exudates. Then, unwanted detected areas are eliminated from image by conducting morphological operation as shown in Figure 7 (b).



(a) (b)

Fig. 7. (a) Threshold image (b) Morphology image.

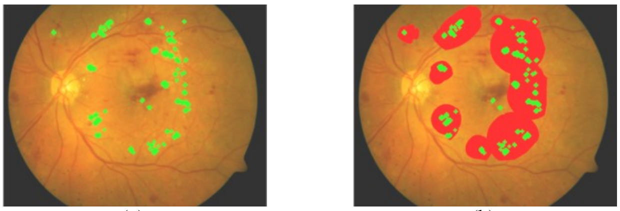
Meanwhile, if the images are not followed by filtering process based on high pass filtering, it can affect to the result of thresholding process as depicted in Figure 8.



(a) (b)

Fig. 8. Threshold image (a) Without filtering (b) By filtering.

Finally, exudates area that has been detected is validated with ground truth image that has labelled by expert. Figure 9 shows the result of validation process, in which green area is segmented exudates by proposed method while red area is segmented region of interest (RoI) of exudates by expert in ground truth image.



(a) (b)

Fig. 9. (a) Segmented exudates (b) Validated exudates.

Validation between segmented exudates and ground truth image is conducted by calculating evaluation measurement consists of accuracy, sensitivity and specificity. The results show that accuracy, sensitivity and specificity for exudates detection by considering detected exudates in RoI of ground truth image are 99.99 %, 90.15 % and 99.99 %, respectively.

IV. Conclusion

Due to similar characteristics between optic disc and exudates, removal of optic disc on retinal image can reduce false positive on exudates detection. Detection of exudates in green channel is processed using high pass filtering-based that suppressed low frequency and pass high frequency. Afterwards, thresholding-based followed by morphological operation is applied to filtered image for obtaining better result of exudates area. Detected exudates are validated to ground truth image by measuring accuracy, sensitivity and specificity that achieves 99.99 %, 90.15 % and 99.99 %, respectively. This result indicates that the proposed method successfully detects exudates and is useful to assist the ophthalmologists in analysing retinal fundus image especially for exudates detection to diagnose diabetic retinopathy. The proposed method is recommended to be implemented as part of the development of computer aided diagnosis diabetic retinopathy system. In future work, it is suggested to propose other technique to differentiate hard and soft exudates in the segmented exudates.

References

[1] V. M. Mane and D. V. Jadhav, "Review: Progress Towards Automated Early Stage Detection of Diabetic Retinopathy: Image Analysis Systems and Potential," *Journal of Medical and Biological Engineering,* vol. 34, 2014.

[2] H. A. Nugroho, K. W. Oktoeberza, T. B. Adji, and F. Najamuddin, *Detection of Exudates on Color Fundus Images using Texture Based Feature Extraction* vol. 6, 2015.

[3] O. Faust, R. Acharya U, E. Y. K. Ng, K.-H. Ng, and J. Suri, "Algorithms for the Automated Detection of Diabetic Retinopathy Using Digital Fundus Images: A Review," *Journal of Medical Systems,* vol. 36, pp. 145-157, 1 February 2012.

[4] M. R. K. Mookiah, U. R. Acharya, C. K. Chua, C. M. Lim, E. Y. K. Ng, and A. Laude, "Computer-aided diagnosis of diabetic retinopathy: A review," *Computers in Biology and Medicine,* vol. 43, pp. 2136-2155, 2013.

[5] W. Luangruangrong, P. Kulkasem, S. Rasmequan, A. Rodtook, and K. Chinnasarn, "Automatic exudates detection in retinal images using efficient integrated approaches," in *Asia-Pacific Signal and Information Processing Association, 2014 Annual Summit and Conference (APSIPA)*, 2014, pp. 1-5.

[6] M. García, C. I. Sánchez, M. I. López, D. Abásolo, and R. Hornero, "Neural network based detection of hard exudates in retinal images," *Computer Methods and Programs in Biomedicine,* vol. 93, pp. 9-19, 2009.

[7] D. Kayal and S. Banerjee, "An Approach to Detect Hard Exudates Using Normalized Cut Image Segmentation Technique in Digital Retinal Fundus Image," in *Advances in Computer Science, Engineering & Applications*. vol. 166, D. C. Wyld, J. Zizka, and D. Nagamalai, Eds., ed: Springer Berlin Heidelberg, 2012, pp. 123-128.

[8] S. Gupta and A. Karandikar, "A Survey on Methods of Automatic Detection of Diabetic Retinopathy," *International Journal of Research in IT, Management and Engineering,* vol. 5, January 2015.

[9] H. Yazid, H. Arof, and H. Mohd Isa, "Exudates segmentation using inverse surface adaptive thresholding," *Measurement,* vol. 45, pp. 1599-1608, 2012.

[10] N. G. Ranamuka and R. G. N. Meegama, "Detection of hard exudates from diabetic retinopathy images using fuzzy logic," *Image Processing, IET,* vol. 7, pp. 121-130, 2013.

[11] C. I. Sánchez, R. Hornero, M. I. López, M. Aboy, J. Poza, and D. Abásolo, "A novel automatic image processing algorithm for detection of hard exudates based on retinal image analysis," *Medical Engineering & Physics,* vol. 30, pp. 350-357, 2008.

[12] M. García, C. I. Sánchez, J. Poza, M. I. López, and R. Hornero, "Detection of hard exudates in retinal images using a radial basis function classifier," *Annals of biomedical engineering,* vol. 37, pp. 1448-1463, 2009.

[13] S. Kavitha and K. Duraiswamy, "Automatic detection of hard and soft exudates in fundus images using color histogram thresholding," *European Journal of Scientific Research,* vol. 48, pp. 493-504, 2011.

[14] K. W. Oktoeberza, H. A. Nugroho, and T. B. Adji, "Optic Disc Segmentation Based on Red Channel Retinal Fundus Images," in *Intelligence in the Era of Big Data*, ed: Springer, 2015, pp. 348-359.

[15] W. Sae-Tang, W. Chiracharit, and W. Kumwilaisak, "Exudates detection in fundus image using non-uniform illumination background subtraction," in *TENCON 2010-2010 IEEE Region 10 Conference*, 2010, pp. 204-209.

[16] M. G. F. Eadgahi and H. Pourreza, "Localization of hard exudates in retinal fundus image by mathematical morphology operations," in *Computer and Knowledge Engineering (ICCKE), 2012 2nd International eConference on*, 2012, pp. 185-189.

[17] A. Osareh, M. Mirmehdi, B. Thomas, and R. Markham, "Comparison of colour spaces for optic disc localisation in retinal images," in *Pattern Recognition, 2002. Proceedings. 16th International Conference on*, 2002, pp. 743-746.

[18] C. Solomon and T. Breckon, *Fundamentals of Digital Image Processing: A practical approach with examples in Matlab*: John Wiley & Sons, 2011.

[19] D. Putra, "Pengolahan Citra Digital," *ANDI OFFSET: Yogyakarta,* 2010.

[20] A. Kadir and A. Susanto, *Pengolahan Citra Teori dan Aplikasi*, 1 ed. Yogyakarta: ANDI, 2012.

[21] F. Y. Shih, *Image processing and pattern recognition: fundamentals and techniques*: John Wiley & Sons, 2010.

[22] T. Kauppi, V. Kalesnykiene, J.-K. Kamarainen, L. Lensu, I. Sorri, A. Raninen, R. Voutilainen, J. Pietilä, H. Kälviäinen, and H. Uusitalo, "DIARETDB1 - Standard Diabetic Retinopathy Database Calibration level 1," ed, 2007.