Segmentation of Optic Disc Using Dispersive Phase Stretch Transform

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***Abstract*—Indonesia is one of ten countries with the highest diabetic prevalence. It becomes a concern of the government because aside from personal health, this disease also has social and economic impacts since it causes a decrease in productivity. One complication of this disease to the patient is impaired vision is diabetic retinopathy (DR). In order to prevent further development of DR, early detection needs to be performed with routine check on patient's eyes. Clinical features on eye retina that can be used for detection of DR include microaneurysms, hard and soft exudates, haemorrhages, neovazcularisation and macular edema. Segmentation of optic disc (OD) is a very important step to detect these features. This study used red channel from original image based on dispersive phase stretch transform (PST) to detect OD. Final result of segmented optic disc is validated by measuring positive predictive value (PPV). The result shows that PPV for optic disc detection by comparing detected optic disc in ground truth image is 97.74%. This result indicates that the proposed approach successfully detect optic disc and is able to assist the ophthalmologists in analysing retinal fundus image to diagnose glaucoma and diabetic retinopathy.**

Keywords—diabetic retinopathy; segmentation; colour fundus image; optic disc; phase stretch transform

I. INTRODUCTION

In the 21st century, diabetic has caused health emergency throughout the world [1]. In 2015, with 10 million diabetic patients, it makes Indonesia becomes one of ten countries with the highest diabetic prevalence. Many countries have not realized the social and economic impacts of this disease. The budget spent may reach 5 to 20% of the whole allocation for health sectors. Hence, diabetic has become a significant problem in healthcare systems and hindered sustainable economic development, since it causes a decrease in productivity.

Diabetic may cause several complications, such as kidney failures, heart problems, as well as impaired vision, for instance diabetic retinopathy. Diabetic retinopathy (DR) is a vascular disorder within eye retina on patients with diabetic [2]. According to a paper published by the Fred Hollow Foundation, one of three diabetic patients experienced DR [3].

Ideally, every diabetic patient needs to be undergone eye checking routinely to perform early detection of indication of disorders on their eyes. Eye checking uses fundus camera to acquire eye retina images. Figure 1 shows the images of normal eye as well as retina with DR.

The severities of DR according to the International Classification of DR scale are classified into five levels, namely: no DR, mild non-proliferative DR, moderate non-proliferative DR, severe non-proliferative DR and proliferative DR [3].

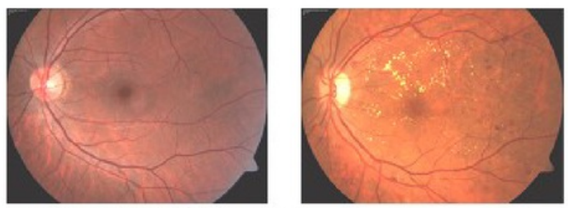


Fig. 1. Normal and DR retinal images [4]

There are some indications of abnormalities in the retina as the effects of DR, i.e. [4]

- *Microaneurysms (MA)*, an early sign of damage to the retina, appears as red spots with a size of less than 125 μm;
- *hard exudates*, proteins that go into the vessels of retina in the form of white or yellowish-white tiny specks, located in the outer layer of the retina;
- *soft exudates or cotton wool spots (CWS)*, in the form of white lesions;
- *haemorrhages (HEM)*, appear as irregular shaped-red spots in size of generally larger than 125 μm;
- *neovazcularisation (NV)*, an abnormal growth of new blood vessels on the inner surface of the retina; and
- *macular edema (ME)*, a swelling of the retina.

Segmentation of the optic disc is required to detect the signs of DR. Detection of central macula or fovea is used to determine the level of severity of the lesion, such as ME at locations that have geometrical links between OD location and blood vessel structures. Accurate identification of OD will improve the quality of exudates segmentation [5].

Some methods have been reported to detect optic disc for the diagnosis of glaucoma and diabetic retinopathy. Thresholding based is used by Godse *et al.* [6] to locate optic disc area, and to eliminate optic disc from retinal image is conducted by Ranamuka *et al.* [7]. Many authors have experimented active contour or snake based to segment OD. The modification of active contour, e.g. gradient vector flow (GVF) and active shape model (ASM) are used to locate OD in fundus images [4].

Asghari and Jalali stated that phase transformation has unique and important properties and indicated that the phase can be used to detect edges. The edge detection technique was obtained by convoluting the phase obtained from anamorphic transformation with a localization kernel. The result was then undergone thresholding and morphological operations [8]. Based on aforementioned literatures, the phase transformation based has not been applied in retinal imaging especially to segment OD or other pathologies.

II. APPROACH

In this work, dispersive phase stretch transform (PST), a recent edge detection algorithm developed by Asghari and Jalali, is used to detect the location of optic disc. Three steps, i.e. (1) pre-processing steps, consist of channel extraction, complement operation and contrast stretching (2) Segmentation, consist of filtering, PST, thresholding and morphological operation (3) Evaluation based on positive predictive value (PPV) as shown in Fig. 2. In pre-processing step, the original image in RGB format is processed by extracting channel to separate red, green and blue channels. The red channel is chosen to process in further. Next, complement operation is applied to the red channel followed by contrast stretching. Segmentation process is conducted by applying four steps, i.e. filtering, phase strength transforms (PST), thresholding and morphological operation. Having obtained segmented optic disc, then it is validated against ground truth image to obtain evaluation result by measuring positive predictive value (PPV).

A. *Pre-processing*

The proposed approach is validated using retinal colour fundus images from Drishti-GS1 dataset [9]. The colour channel of fundus images are extracted to obtain red, green and blue channels. The red channel is chosen for further process since it has the highest contrast among the other channels [10, 11]. Afterward complement operation is employed to red channel and followed by contrast stretching. In binary scale, complement operation changes value of ones become zeros and zeros become ones. Whilst in greyscale or RGB image, pixel values of output image are obtained by subtracting maximum pixel value to each pixel values of input image.

For example:
Input image = [255 200 55; 50 35 150]
Output image = [0 55 200; 205 220 100]

Complemented image is then processed by contrast stretching to enhance contrast image [12] as formulated in Eq. 1. In this work, the default limit for stretching contrast image of [0 1] is used.

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

Where pixel value before and after transformation are declared by $u(i,j)$ and $o(i,j)$, respectively. The maximum value is defined by L, while the minimum and maximum input values are defined by c and d, respectively [13].

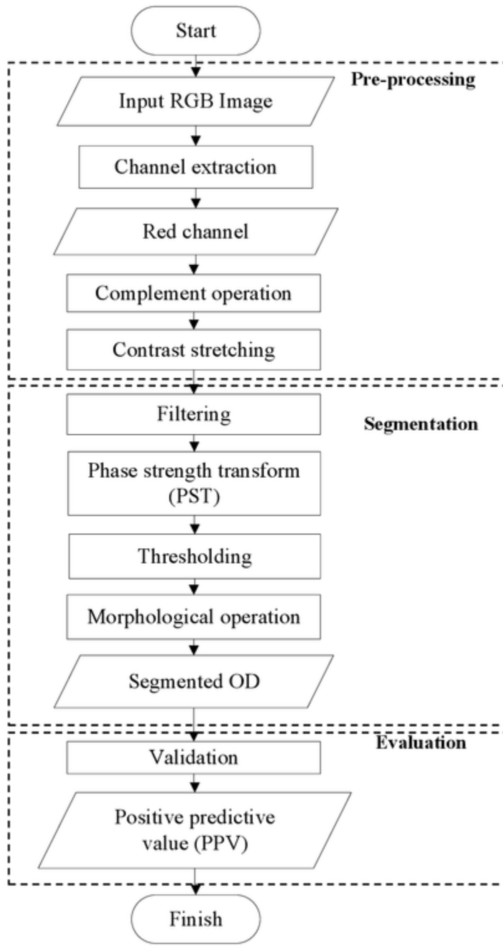


Fig. 2. Flowchart of the approach

B. *Segmentation*

Firstly, smoothing operation is imposed on the stretched image using certain localisation kernel based on low-pass filtering. Further process, candidate area of optic disc is segmented by carrying out phase strength transform (PST).

PST implements two-dimensional phase functions in the frequency domain. It is expressed mathematically in Eq. 2.

The amount of phases applied to the image depends on the frequency. The lower the frequency component of the image the smaller the phase is applied, and vice versa. PST enhances the edges in the image by applying larger amount of phase to them, since the edges possess higher frequency features.

$$A[n,m] = \measuredangle\left\langle IFFT\left\{\tilde{K}[p,q].\tilde{L}[p,q].FFT2\left\{B[n,m]\right\}\right\}\right\rangle \quad (2)$$

Here, the output phase image is denoted by $A[n,m]$ while angel operation is denoted by $\measuredangle\langle . \rangle$. Two dimensional fast fourier transform and inverse two dimensional fast fourier transform are expressed as FFT2 and IFFT2, respectively. Frequency response of localization kernel and non-linear frequency dependent phase warped phase kernel is denoted by $\tilde{L}[p,q]$ and $\tilde{K}[p,q]$, respectively [8].

PST image is then generated by thresholding the output image and followed by a series of morphological operations as post processing [8]. In this work, the parameters that required for low-pass filtering and morphological operation is 0.001 and 0, respectively. While PST and thresholding parameters refer to [8] that used phase strength 0.48 and warp strength of 12.48; the minimum and maximum thresholds are -1 and 0.0019, respectively.

C. Evaluation

The performance of the proposed approach is evaluated by statistical measurement based on positive predictive value (PPV). PPV is defined as follows.

$$PPV = \frac{TP}{TP + FP} \quad (3)$$

Here, true positive (TP) is a number of optic disc pixels correctly detected while false positive (FP) is a number of non-optic disc pixels which are incorrectly detected as optic disc pixels) [14].

III. Results and Discussion

Drishti-GS1 dataset contains 50 training images that have been signed by four ophthalmologists. Images were captured with 30 degree field of view (FoV) in PNG format with resolution of 2896 x 1944 pixels. In this work, 36 images are used.

Red channel from original RGB images are firstly extracted to obtain red channel matrix pixels on each images. Red channel has the highest contrast among green and blue channels. The results of channel extraction process are depicted in Fig. 3.

Red channel (Fig. 3 (b)) is selected since green channel (Fig. 3 (c)) does not contain enough information to detect optic disc. Whilst in blue channel (Fig. 3 (d)) information tends to be lost. Having converted into red channel, complement operation followed by contrast stretching is applied. The complemented and stretched images are presented in Fig. 4 and the histograms of them are depicted in Fig. 5.

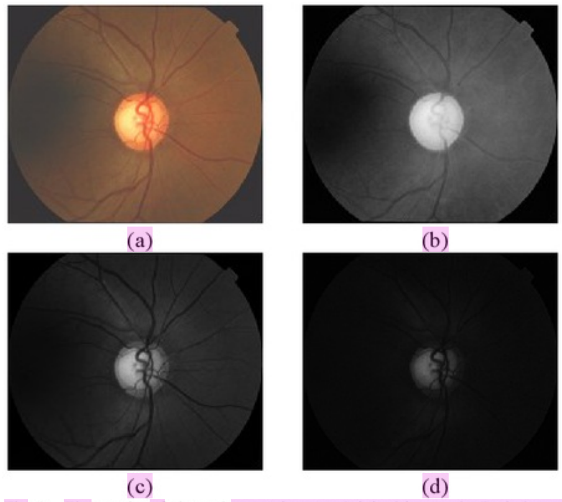


Fig. 3. The results of channel extraction: (a) Original image (b) Red channel (c) Green channel (d) Blue channel

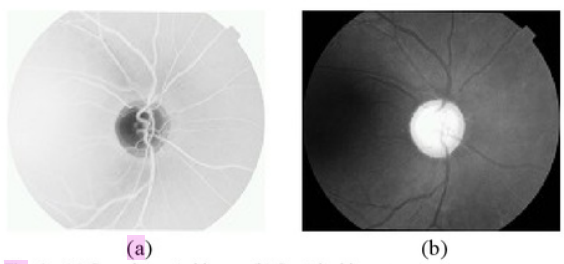


Fig. 4. (a) Complemented image (b) Stretched image

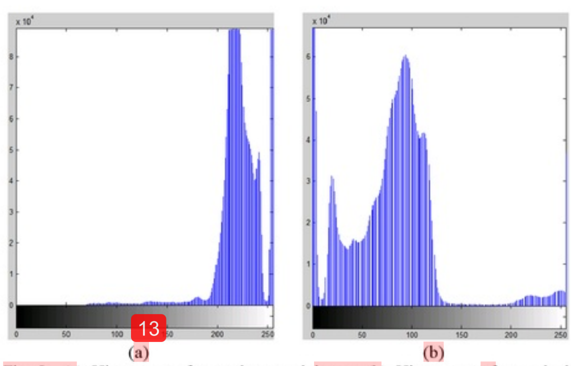
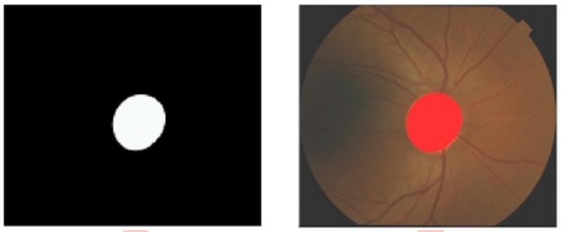


Fig. 5. (a) Histogram of complemented image (b) Histogram of stretched image

Contrast stretching is conducted to make optic disc area be clearly different from its surrounding as can be seen in Fig. 4 (b).

Phase strength transformation based is carried out to the result of previous step (stretched image) to obtain segmented area of optic disc. The segmented OD image is converted to binary scale as shown in Fig. 6 (a). The final detection of optic disc area in retinal fundus image is presented in Fig. 6 (b).



(a) (b)

Fig. 6. (a) Segmented optic disc (b) Detected optic disc

Optic disc area that has been detected is validated with ground truth image that has labelled by 4 ophthalmologists with variance clinical experience (3, 5, 9 and 10 years respectively). Validated result is shown in Fig. 7. In which, red area is segmented optic disc by proposed method while green area is segmented optic disc by ophthalmologists in ground truth image.

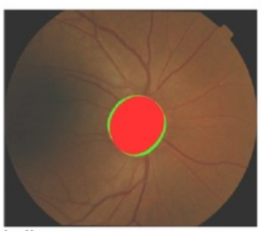


Fig. 7. Validated optic disc

The proposed approach is employed on 36 retinal colour fundus images taken from Drishti-GS1 dataset. The performance of the approach is measured based on positive predictive value (PPV). Several parameters are counted known as true positive (TP) and false positive (FP). The result shows that PPV for optic disc detection by comparing detected optic disc with ground truth image is 97.74%. The detail result of evaluation parameter is shown in Table 1.

TABLE I. EVALUATION RESULT

TP	FP	PPV
77736.11	2184.083	97.74%

IV. CONCLUSIONS

This paper proposes an approach to segment optic disc area in of three steps, i.e. pre-processing, segmentation based on phase strength transformation and evaluation. The proposed approach is validated and evaluated on 36 retinal fundus images provided by Drishti-GS1 dataset. This approach achieves positive predictive value (PPV) of 97.74%. This result indicates that the proposed approach successfully detect optic disc and is able to assist the ophthalmologists in analysing retinal fundus image to diagnose glaucoma and diabetic retinopathy.

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