Automatic Exudates Detection on Thai Diabetic Retinopathy Patients’ Retinal Images

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ABSTRACT

Diabetic retinopathy is a complication of diabetes that is caused by changes in the blood vessels of the retina. The symptom can blur or distort the patient’s vision and are mainly cause of blindness. Exudates are one of the primary signs of diabetic retinopathy. Detection of exudates by ophthalmologists normally required pupil dilation using chemical solution which takes time and affects patients. This paper investigated a set of optimally adjusted morphological operators used for exudates detection on Thai patients’ non-dilated pupil and low-contrast images. The detected exudates are validated by comparing with ophthalmologists’ hand-drawn ground-truth. As a result, the sensitivity and specificity for the exudates detection were very high of 80\% and 99.4\% respectively.

Keywords: Diabetic retinopathy, Exudates, Retinal image

1. INTRODUCTION

Diabetic-related eye diseases are the most common cause of blindness in the world, especially on developing country such as Thailand. Patient’s sight can be affected by diabetes which causes cataracts, glaucoma, and most importantly, damage to blood vessels inside the eye, a condition known as "diabetic retinopathy". Diabetic retinopathy is a critical eye disease which can be regarded as manifestation of diabetes on the retina. It’s a major public health problem and it remains the leading cause of blindness in people of working age. The screening of diabetic patients for the development of diabetic retinopathy can potentially reduce the risk of blindness in these patients by 50\% [1-4]. However, it is a normal situation in Thailand that the number of ophthalmologists is not sufficiently enough to cope with all patients, especially in Thai rural area [5]. So, automatic exudates detection would be necessarily useful in order to detect and treat diabetic retinopathy in an early stage.


Most of the techniques mentioned earlier worked on dilated pupils which the exudates and other retinal features are clearly visible. In normal diabetic retinopathy screening process, pupils were dilated using Tropicamide 1\% eye drop. The process takes about 15-20 minutes to work and have an effect to patient. The examination time and patient’s effect could be reduced if the system can work on non-dilated pupil. Therefore, this paper proposed exudates detection on Thai retinal images and low quality images from non-dilated pupils.

2. METHODOLOGY

We used digital retinal images obtained from KOWA-7 non-mydriatic retina camera with a 45° field of view as our initial image dataset. The images were stored as jpeg image format (jpg) files with lowest compression rates. The image resolution is 500 x 752 pixels at 24 bit. The patient’s pupils were not dilated at the screening process.

2.1 Preprocessing

Firstly, original image’s RGB space was transformed to HSI space because HSI colour space is more appropriate since the intensity component is separated from the other two colour components. A median filtering operation was applied on the I band to reduce noise before a Contrast-Limited Adaptive Histogram Equalization [10] was applied for contrast enhancement. Exudates lesions and optic disc region are normally showing high intensity values in this channel and thus the contrast enhancement technique assigns them the highest intensity values [1, 2]. Original RGB image is shown in Fig.4 (a) and intensity channel after pre-processing is shown in Fig.4 (b).

2.2 Optic Disc Elimination

Exudates detection is our main purpose, however we have to remove the optic disc prior to the process because it is appearing in similar bright pattern, colour and
contrast [3, 9, 11]. Optic disc is characterized by the largest high contrast area. While vessels also appear in high contrast, the size of the area is much smaller. Applying closing operator (φ) on intensity channel (f) will help eliminate the vessels which may remain in the optic disc region. Fig.4 (c) is a result after closing operator (Eq. 1) was applied.

\[ O_{P_1} = \phi^{(sB)}(f) \]  

(1)

where \( sB \) is the morphological structuring element \( B \) of size \( s \).

The resulting image was binarized by thresholding, as shown in Fig.4 (d). The thresholded image was then used as a mask. All the pixels in the mask were reversed before they were overlaid on the original image to remove candidate bright regions. The result, \( O_{P_1} \), is shown in Fig.4 (e). The morphological reconstruction by dilation, \( R \), was then applied on the previous overlaid image.

\[ O_{P_2}(x) = R_{f_1}(O_{P_1}) \]  

(2)

The dilations of marker image (\( O_{P_2} \)) under mask image (\( f_1 \)) were repeated until the contour of marker image fits under the mask image. Reconstructed image is shown in Fig.4 (f). The difference between the original image and the reconstructed image was thresholded at grey level \( \alpha_2 \) as in Eq. (3). As a result, high intensities are reconstructed while the rest is removed, as shown in Fig.4 (g). Let \( T = [t_{min}, ..., t_{max}] \) be an ordered set of grey levels, we have

\[ O_{P_3} = T_{[t_{min}, t_{max}]}(f_1 - O_{P_2}) \]  

(3)

The largest area, an optic disc, was identified and dilation operator (\( \delta \), Eq. (4), was applied in order to ensure that all optic disc areas are detected.

\[ O_{P_3} = \delta^{(sB)}(\text{largest area } O_{P_2}) \]  

(4)

All optic disc regions were masked out using the previous output. The result is shown in Fig.4 (h).

2.3 Exudates Detection

Proteins and lipids leaking from the blood into the retina via damaged blood vessels is the main cause of exudates. They can be identified on the ophthalmoscope as areas with hard white or yellowish colours and varying sizes, shapes and locations, near the leaking capillaries within the retina [1].

Similar to the previous steps, high contrast vessels can be eliminated first by a closing operator before local variation operator, Eq. (5), was applied. \( E_1 \) is an image after applying a closing operator. The result image, \( E_2 \), is shown in Fig.5 (a).

\[ E_2(x) = \frac{1}{N-1} \sum_{i \in W(x)} (E_1(i) - \mu_{E_1}(x))^2 \]  

(5)

where \( x \) is a set of all pixels in a sub-window \( W(x) \), \( N \) is a number of pixels in \( W(x) \), \( \mu_{E_1}(x) \) is the mean value of \( E_1(i) \) and \( i \in W(x) \).

The resulting image was thresholded at grey level \( \alpha_2 \) in this step to get rid of all regions with low local variation. To ensure that all the neighboring pixels were also included in the candidate region, dilation operator was also applied, as indicated in Eq. 6. The result is shown in Fig.5 (b).

\[ E_3 = \delta^{(sB)}\left(T_{[\alpha_2, t_{max}]}(E_2)\right) \]  

(6)

Exudates’ candidate regions should not be only their borders, the holes was flood-filled in this step, Fig.5 (c). The previously detected optic disc region was dilated before it was used to remove the optic disc from the above resulting flood-filled image (\( E_3 \)), Eq. 7. The result is shown in Fig.5 (d).

\[ E_5 = E_4 - \delta^{(sB)}(O_{P_{seg}}) \]  

(7)

The result from Eq.7 was used as a mask, showing all possible candidate regions of exudates, to create a marker image (\( E_5 \)), as shown in Fig.5 (e). It was later morphologically reconstructed using dilation operator under original intensity image. The result is displayed in Fig.5 (f).

Using Eq. 8, the final result is obtained by applying a threshold operation at grey level \( \alpha_3 \) to the difference between the original image (\( f_1 \)) and the reconstructed image (\( E_5 \)). The resulting image is shown in Fig.5 (g).

\[ E_{seg} = T_{[\alpha_3, t_{max}]}(f_1 - E_5) \]  

(8)

The result from this step will be sent for validation, as described in next section. Fig.5 (h) displays the result superimposed on original image. Other exudates detection examples are shown in Fig.6 and the overall procedures of exudates detection is shown in Fig.3.

3. EVALUATION

Forty retinal images were processed by steps proposed in the methodology section. The resulting detected exudates by the algorithm were compared with hand-drawn ground truth images created by expert ophthalmologists as shown in Fig.1. The sensitivity and specificity of the exudates detection, calculated based on its true positive, true negative, false positive and false negative are 80% and 99.4%, respectively. Sensitivity and specificity for all the test images are shown in Fig.2. Sensitivity are represented as circle points while specificity are represented as square points.
4. CONCLUSION

In this work we have proposed a set of optimally adjusted morphological steps to automatically detect optic disc and exudates from Thai diabetic retinopathy patient’s non-dilated pupil digital images. The results were then validated by comparing with ophthalmologists’ hand-drawn prediction. The outcome is quite successful with high sensitivity and specificity of 80% and 99.4%, respectively.

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6. REFERENCES


Fig. 4: Optic Disc Location (a) RGB Image, (b) I band after Pre-processing, (c) Image after Closing, (d) Thresholded Image, (e) Marker Image, (f) Reconstructed Image, (g) Threshold on Difference Image, (h) Optic Disc Area.

Fig. 5: Exudates Detection (a) Applied Local Variation, (b) Thresholded Image, (c) Filled Image, (d) Remove Optic Disc from Image, (e) Marker Image, (f) Reconstructed Image, (g) Difference Image, (h) Superimposed on Original.

Fig. 6: Exudates Detection on Low Quality Images (a), (d) Original Images, (b), (e) Detected Exudates, (c), (f) Detected Exudates Superimposed on Original Images.