An Automatic System of Retinal Blood Vessel Detection from Fundus Image for Diabetic Retinopathy Patients

Rajib Kumar Chanda, Mithun Chandra Dey, Mehedi Hasan Talukder
Department of Computer Science and Engineering,
Mawlana Bhashani Science and Technology University (MBSTU), Santosh, Tangail, BANGLADESH.

Abstract: Fundus imaging is one of the most frequently used techniques for screening of eye diseases and find abnormalities related to vessels. Early treatment can prevent major vision loss that caused by diabetic retinopathy. Blood vessel segmentation is a helpful tool in diabetic retinopathy. There are many methods for blood vessel segmentation and they used different techniques like morphological operations, gabor wavelet transformation, ant colony system etc to segment blood vessels and then used different types of classifiers to detect whether the detected vessels are blood vessels or not. So, an automatic evaluation of fundus image can be used to support immediate diagnosis in ophthalmology and this will also release some pressure from ophthalmologists. In this work, an automatic method for blood vessel segmentation is presented. The segmentation of retinal vessels is obtained with the help of morphological operations. This method uses GLCM features, some Grey level features and Local Binary Pattern as feature vector for classification. Here, neural network (NN) scheme is used for classification. The methodology of this paper is applied and analyzed on publicly available Database drives. Though, it is an automatic detection system so this will help more than many methods.

Keywords: Diabetic retinopathy; blood vessel segmentation; automatic system; retinal fundus image; classification

I. Introduction

Diabetic retinopathy is one of the causes of blindness among people of working age in many countries [2]. The global prevalence of diabetes was 2.8% in 2000 and is expected to rise to 4.4% in 2030 [3]. Retina is the light sensitive layer of the eye that converts light into electrical signal. The signals are sent through the optic nerves and we see the image by the interpretation of brain. For this retina needs a continuous supply of blood which it receives by tiny blood vessels. High blood sugar level causes the blood vessels more narrow that cause’s insufficient supply of blood.

In initial stage, retinopathy does not cause any significant symptoms until visual loss develops usually in the later stages when treatment is less effective. So it is important to ensure that the treatment is received in time, the patient needs annual eye screening [4]. The screening for diabetic retinopathy of diabetic patients can reduce the risk of blindness up to 50%. If the number of patients is large then it is needed to have the number of ophthalmologist larger to cope with all the patients. But it is difficult for many countries to have large number of ophthalmologists or the workload of local ophthalmologists is high. 98% of vision loss from diabetic retinopathy can be prevented if treated early [1]. So, an automated detection system will be helpful for the patients and it will release pressure from ophthalmologists. An automated detection system based on some features on segmented retinal blood vessel image is used in this system. Blood vessel segmentation technique based on some morphological and other techniques is described in this paper.

II. Related Works

In this section we will provide some methods on retinal blood vessel segmentation:

In [5] D.Siva Sundhara Raja used morphological based operation and then get absolutely difference image from it. Then they extracted features from the processed image. Finally, they trained SVM classifier to classify each pixel as vessel and non-vessel.

In [6] D. Marin et al. presented a robust method for blood vessel segmentation in digital retinal image. In preprocessing step they used some robust techniques that consist of some filtering, morphological operations and some basic operations. Then they extracted 7-D features based on grey level and moment invariants and trained neural network tool by this 7-D feature vectors to classify the vessels as vessel or non-vessel.
In [7] V. B. Soares et al. proposed a segmentation method based on some features. Features are extracted based on pixel intensity and Gabor wavelet transformation which is capable of tuning to specific frequencies. They used Bayesian classifier to classify blood vessels.

In [8] Ahmed Hamza Asad et al. proposed two improvements on ant colony system for automatic segmentation of blood vessels in retinal images. First improvement is done by using new discriminate feature and the second improvement is done by applying new heuristic function based on probability theory on ant colony system. In [9]-[15], different methods for blood vessel detection and segmentation are presented.

III. Proposed Methodology

This paper proposes an automatic evaluation for diabetic retinopathy. The necessary feature vector is computed from preprocessed retinal image. The following process stages may be identified: 1) Preprocessing of retinal grey level image, 2) Feature extraction for pixel, 3) Application of classifier.

We do following works:
First, we extract green channel from RGB image. The green channel represents the best contrast of an RGB image while the red channel has the brightest color channel and has low contrast, and the blue channel has poor dynamic range. Thus, we can get vessels that are best represented and get high contrast in green channel [16].

A. Preprocessing

Fundus image often shows uneven lightening, noise and low contrast. To reduce these problems and to generate more suitable features here some preprocessing steps are proposed: 1) Removal of vessels central light reflex, 2) Background homogenization, 3) The enhancement of vessels.

Removal of Vessel Central Light Reflex
To remove the brighter part of the image the green part of the image is filtered by morphological opening operation using a three diametric disk as structuring element. For future use we mark this image as $I_1$.

Background Homogenization
Fundus image often contain background intensity variation. Since the feature vector used to represent a pixel in the classification formed by grey scale values, this effect may worsen the effect of classification. To remove this background lightening variations a shade corrected image is accomplished from a background estimate. This image is the result of filtering operation as following:

Firstly, a 3*3 mean filter is applied then this image is convoluted with a Gaussian kernel of dimension 9*9. Then the difference $D$ between $I_1$ and $I_B$ is calculated for every pixel,

$$D(x,y) = I_1(x,y) - I_B(x,y)$$

Finally, a shade corrected image $I_S$ obtained by linearly transforming the values into integers covering the whole range of gray levels. Then a homogenized image $I_H$ is produced by the following transformation function [6]:

$$g_{output} = \begin{cases} 
0, & \text{if } g < 0 \\
255, & \text{if } g > 255 \\
g, & \text{otherwise}
\end{cases}$$

Where,

$$g = g_{output} + 128 - g_{output\_max}$$

Here, $g_{input}$ and $g_{output}$ are the input and output images ($I_S$ and $I_H$ respectively) variable $g_{output\_max}$ defines the highest number of pixels in $I_S$.

Enhancement of Vessels
Here, Top-Hat transformation is applied on complimentary image of $I_H$, $I_H^C$. 

Figure 1 Flowchart for proposed methodology

Retinal Image \[\xrightarrow{\text{Preprocessing}}\] Vessel central light removal

\[\xrightarrow{\text{Background Homogenization}}\]

\[\xrightarrow{\text{Vessel Enhancement}}\]

Result \[\xrightarrow{\text{Classification}}\] Feature Extraction
Where $\gamma$ is morphological opening operation which uses 8 pixels parametric disc.

### B. Feature Extraction

#### Local Binary Pattern

The Local Binary Pattern (ELBP) features, GLCM and Grey level features extracted from the preprocessed image. It can be computed as following:

$$LBP = \sum_{p = 1}^{8} 2^{p} K = 1 \text{ if } I_N - I_c \geq 0$$

$$LBP = \sum_{p = 1}^{8} 2^{p} K = 0 \text{ if } I_N - I_c < 0$$

Where $P$ represents the number of surrounding pixels, $I_N$ denotes the neighboring pixels in a square window (3*3), $I_c$ is the center pixel in the 3*3 mask and denotes K $(I_N - I_c)$ is estimated as:

$$K = (I_N - I_c) = \begin{cases} 1, & \text{if } I_N - I_c \geq 0 \\ 0, & \text{if } I_N - I_c < 0 \end{cases}$$

### GLCM Features

Energy, Contrast, Correlation, Homogeneity are used as GLCM features.

<table>
<thead>
<tr>
<th>Table I List of GLCM features</th>
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<tbody>
<tr>
<td>GLCM features</td>
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<tr>
<td>Energy</td>
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<tr>
<td>Contrast</td>
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<tr>
<td>Correlation</td>
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<tr>
<td>Homogeneity</td>
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### Grey Level Features

A set of gray-level based feature is extracted from homogenized image $I_H$. Here $S_{x,y}^w$ stands for set of coordinated in a w*w sized square window whose centered point in (x,y) [7].

$$F_1(x,y) = I_H(x,y) - \min_{(s,t)\in S_{x,y}^w} \{I_H(s,t)\}$$

$$F_2(x,y) = \max_{(s,t)\in S_{x,y}^w} \{I_H(s,t)\} - I_H(x,y)$$

$$F_3(x,y) = I_H(x,y) - mean\{I_H(s,t)\}$$

$$F_4(x,y) = \frac{\sum_{(s,t)\in S_{x,y}^w} \{I_H(s,t)^2\}}{\sum_{(s,t)\in S_{x,y}^w} \{I_H(s,t)^2\}}$$

$$F_5(x,y) = I_H(x,y)$$

### C. Classification

We use neural network as our classification tool. Here, we train our tool using feature vectors that are extracted in the feature extraction section. We use images from publicly available Drive and Stare database.

### D. Algorithm

Algorithm for discussed method is given below:

**Step 1:** Retinal Image Acquisition

**Step 2:** Green Channel Extraction

**Step 3:** Vessel Central Light Reflex Removal

Using erosion
Step 4: Background Image
Using filters of different window size

Step 5: Shade Corrected Image
Using equation of Background Homogenization portion’s first equation

Step 6: Background Homogenized Image
Using equations of Background Homogenization portion’s 2 equations from the last

Step 7: Vessel Enhanced Image
Using Top-Hat transformation and equation used in Enhancement of Vessels portion

Step 8: Feature Extraction to Train Classifier

Step 9: Train Classifier Using Features Extracted in Step 8

Step 10: Classification

IV. Result and Discussion

The proposed method has been verified on images from Drive and Stare database. In this approach, we proposed a method to automatically extract blood vessels from fundus images using described methodology. Images are classified on the basis of features using neural network tool. Though previous methods that are discussed in literature review section are only vessel segmentation method but our method is an automatic detection for retinal vessels so the proposed method will be very useful. All the work is done using MATLAB. Performance is verified by evaluating True Positive (TP) that refers to the correctly detected blood vessels, False Negative (FN) that refers to the number of abnormal pixels that are not detected, True Negative (TN) that refers to the wrongly detected blood vessels and False Positive (FP) that are wrongly detected as abnormal blood vessel.

Figure 2 Blood vessel segmentation of normal image (a) Normal retinal image (b)Green channel image (c)Shade corrected image (d) Vessel enhanced image (e)Segmented image

Figure 3 Blood vessel segmentation of abnormal image (a) Abnormal retinal image (b)Green channel image (c)Shade corrected image (d) Vessel enhanced image (e)Segmented image

V. Conclusion

The automatic blood vessel detection is important for diabetic retinopathy diagnosis at earlier stage. In this paper a new method is presented for detection of normal and abnormal blood vessels. The classification is done by neural network tool. The vessel detection can be applied on clinical setting of computer assisted diagnosis. But it must be remembered that it is not for replacing ophthalmologists or physicians but it can help them.

References


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