An Adaptive Threshold-based Algorithm for Detection of Red Lesions of Diabetic Retinopathy in a Fundus Image

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1. Introduction

The paper proposes an algorithm for detection of Red Lesions present in a fundus image of an eye. Red Lesions include Micro-aneurysms and Hemorrhages, which are the symptoms of Diabetic Retinopathy, a widespread eye disease which affects almost every diabetic patient at some point of the patients life. The paper presents an adaptive method to detect the red lesions present in an image. The main contribution of the paper lies in the adaptive nature of finding the intensity range of the red lesions for separate fundus images. With varying qualities of fundus images, the intensity levels of blood vessels may vary with each other, but the spatial intensity levels of blood vessels and red lesions is always similar in a single fundus image. Utilising this phenomenon, an algorithm has been proposed where intensity based identification of red lesions is done in the fundus image. This approach inhibits the need of normalizing the images, which otherwise is an indispensable preprocessing step for any image processing application as reported in existing methods like. Since, the detection of the threshold value is adaptive in nature, every fundus image is treated independently, hence, accuracy of detection of red lesions is invariant to the quality of the image.

2. Proposed Algorithm

Diabetic Retinopathy is the damage caused to the retina of the diabetic patients. The initial stage of the damage to the retina is the result of blood leaked out from the capillaries, called Micro-aneurysms. These red spots blot and grow in size to be called hemorrhages. Since, visually micro-aneurysms cannot be differentiated from hemorrhages hence, both these symptoms are categorized as red lesions. As shown in the block diagram in Fig. 1, the proposed methodology can be segmented into various stages in order to accomplish an accurate scheme for detection of red lesions.

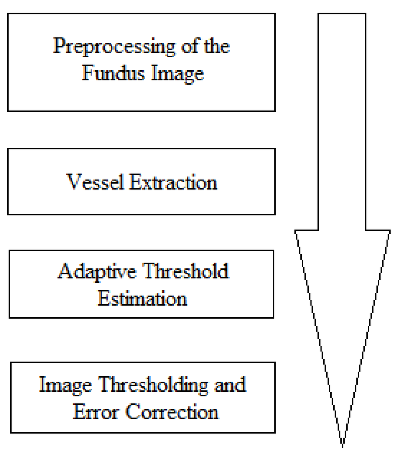

Figure 1: *Block Diagram of the proposed method*

Since, the proposed methodology is an adaptive procedure hence, major normalization steps and contrast enhancement techniques can be avoided, thus, reducing the hardware and processor requirements. However, uneven intensity in the background may adversely affect the output, hence, background shade correction is necessary as part of pre-processing. Top-hat transformation has been used for background shade correction of the fundus image.
The next step is to prepare for the thresholding of the image. To decide on the value of the threshold, certain parameters are needed to be extracted from the image. Blood vessels are one of the most important features of the fundus of a human eye. Apart from the Optic disk and Macula, which are the key features of a normal human eye, the Optic nerves, arteries and veins, grouped together as blood vessels play a pivotal role for understanding the anatomy of the human eye. The detection of retinal blood vessels is achieved through an adaptation of Matched Filter and Derivative of Gaussian.
Large variations in the quality in the fundus can be seen, as shown in Fig. 2. These largely varying fundus images, if normalized on a single scale of color patters or intensity standards may result in higher noise. Furthermore, standardization of the quality of the fundus images is also a tough task to be ensured hence, the requirement of an adaptive system.

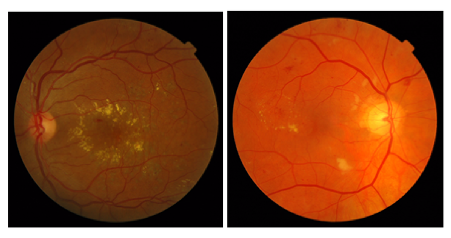

Figure 2: *Two fundus images of varying qualities*

It must be noted that, since, the red lesions are nothing but, different patterns of blood clots hence, they appear to be similar in terms of color intensity of the blood vessels. Thus, the proposed algorithm detects the blood vessels. Then, the arithmetic mean of the intensity of all the pixels detected as vessels is computed. This detected average is set as the upper limit of the threshold. Empirically, a window of 6 intensity levels (U-L = 6) was found out to be most efficient to segment the red lesions along with the blood vessels. Hence, a simple Gray-level slicing of the input image has been done, as shown in Fig 3.

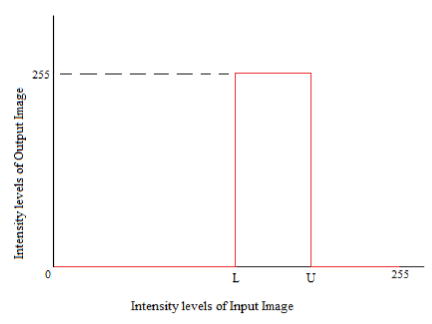

Figure 3: *Gray Level slicing*

Using the thresholds obtained previously, red lesions are detected along with blood vessels, optic nerve inside the optic disk and the central part of macula, called fovea. A logical NAND operation of the output image with the extracted blood vessels is used to remove the detected blood vessels. Furthermore, for the removal of Optic Disk and Macula from the fundus, removes any noise due to optic nerves and fovea.

3. Results and Discussion

The algorithm was successfully implemented and positive results were obtained which can be seen from the Table 1. For the fundus images graded as Normal, the sensitivity was 100% and an average specificity was approximately 99.99%. The average sensitivity for the fundus images graded as Severe Non-Proliferative Diabetic Retinopathy (NPDR) was calculated to be 90.907% with a specificity of 99.985%. The overall average sensitivity for the data set was found to be 93.17% with a specificity of almost 99.99%.

Table 1: *Sensitivity and Specificity*

SAMPLE	STAGE	SENSITIVITY %	SPECIFICITY %
Sample 1	Severe	93.742	100 %
Sample 2	Severe	86.95	99.9966 %
Sample 3	Proliferative	79.166	99.9943 %
Sample 4	Normal	100	99.999 %
Sample 5	Normal	100	99.996 %
Sample 6	Normal	100	99.990 %
Sample 7	Mild	100	99.987 %

For subjective perception and evaluation, results of some fundus images have been shown in Fig. 4 and Fig. 5. The figures include the given fundus image, along with the detected red lesions after implementing the algorithm. The regions detected as red lesions have been represented as * for a better understanding.

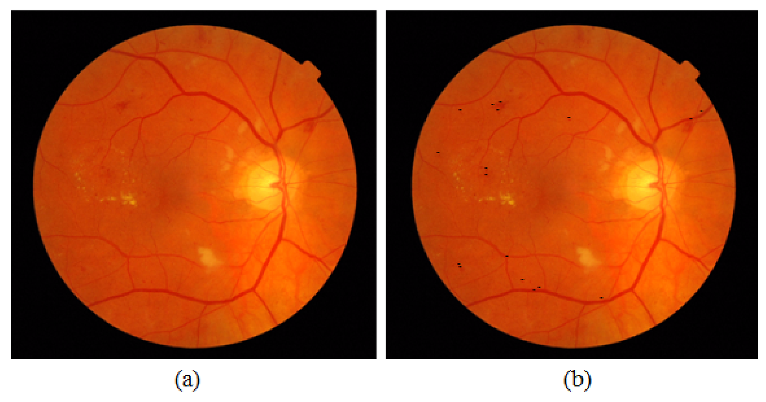

Figure 4: *Severe NPDR (Sample 1), (a) Input image, (b) Detected red lesions mapped to the input image*

Figure 5: *Normal (Sample 4), (a) Input image, (b) Detected red lesions mapped to the input image*

4. Conclusion

The most common challenge faced in detection of red lesions is the similarity of its intensity to that of blood vessels. However, the proposed algorithm utilizes this hindrance as an advantage and a solution in obtaining higher accuracy. Moreover, this algorithm is optimum for early automated detection of DR, because it gives 100% sensitivity and specificity higher than 99%, thereby accurately screening the normal eye images from a database of fundus images. Another major challenge faced in detection of red lesions is the wide variation in the quality and resolution of the given images. However, the proposed algorithm is adaptive in nature, thus every image is treated independently. Hence, the accuracy of results is not affected by variation in the quality of the image. The accuracy of the proposed method can be further improved by improving the accuracy of the detection of blood vessels.

5. Acknowledgement

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