Automated Detection and Classification of Exudates in Retinal Images Using Discrete Wavelet Transform and Artificial Neural Network

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***Abstract* - Retinal (eye fundus) images are widely used for diagnostic purpose by ophthalmologists. The normal features of eye fundus images include optic nerve disc (OD), fovea, and blood vessels. Diabetic Retinopathy (DR) is common diabetic disease condition that is caused to human eye. Early detection of DR is crucial to prevent blindness. This paper proposes an algorithm to develop an automated system to analyze the retinal images for extraction of exudates which are the elemental and initial signs of DR. This is done by eliminating optic disc (OD) and blood vessels which have a similar characteristic with exudates. Blood vessels are segmented using Multi-Level Adaptive Thresholding. OD is segmented using morphological operations. Hard exudates are extracted using Discrete Wavelet Transform (DWT). Artificial Neural Network (ANN) is implemented to detect soft exudates and for classification.**

***Key terms* – Diabetic Retinopathy, Multilevel Adaptive Thresholding, Morphological Operations, Discrete Wavelet Transform, Artificial Neural Network**

I. INTRODUCTION

Diabetes is a common disease condition that is familiar now a day. It arises when the blood sugar level is high either due to inadequate production of insulin in body or the cells do not respond properly to insulin. If detected in earlier stage diabetes related eye diseases which are the major cause of blindness in the world can be reduced. Due to diabetes body blood vessels may get weakened and it can also affect different regions of physical structure. When glucose level in retinal blood vessels is high, the sight will be affected and obscured and cause blindness. This is known as Diabetic Retinopathy (DR) [1]. The blood vessels in the retina are susceptible to dampening and can go through a series of changes. These variations include leaking or closure from tiny blood vessels known as capillaries or may include growth of weak, new capillaries. In some other cases abnormal new blood vessels are grown on the surface of the retina. According to the research, the screening of DR at the earlier stage can reduce the risk of blindness by 50% [2]. The symptoms of DR include blurred vision, vision loss of one eye suddenly, seeing rings around light, black spots etc.

Generally diabetes is classified into two main phases and they are Non Proliferate DR (NPDR) and PDR Proliferate DR (PDR) [3]. Earliest stage of DR is NPDR and it is the condition where blood vessels are in damaged condition and it will leak extra fluid and low amount of blood into the eye. Eye with NPDR lesions include small red points (microaneurysms), deposits of cholesterol and other fatty tissues (exudates), tiny spots of blood that leak in to retina (hemorrhages). According to the degree to which these are affecting the eyes the NPDR is classified as mild, moderate or severe NPDR. PDR is the condition where blood vessels in the retina close, preventing enough blood flow. Retina responds to this condition by forming new blood vessels which is termed as neovascularization. PDR effects both central vision and peripheral vision and hence it cause severe vision loss when compared to PDR. One of the elemental sign of DR is exudates and they are seen in retina as yellow spots. These exudates are of two types hard exudates and soft exudates. Hard exudates are seen in the initial stage and normally they appear as small yellow in color or white waxy patches. As time consume these deposits become large in area and yellowish in color which are called as soft exudates. This paper presents an algorithm to easily detect and classify these exudates

There are many existing works on automated detection of DR which include extraction of retinal features such as blood vessels and OD and extraction of abnormalities such as exudates. T. Vandarkuzhali et.al [4] identified abnormalities in the fovea using fuzzy logic and neural network and fuzzy k-means is used to identify exudates. Accuracy was much better when compared to method used by Sophark et.al [5], where fuzzy c-means clustering is used to detect exudates and OD is identified using entropy feature which consumed more time. Preethi N.Patil et.al [6] proposed an algorithm to identify and classify the exudates as hard and soft using morphological operations but the algorithm was unable to distinguish between OD and exudates if they have same area and intensity. In this paper a new algorithm is to efficiently detect and classify exudates by eliminating OD and blood vessels.

II. PROPOSED SYSTEM

This system proposes an algorithm for early automatic detection of Diabetic Retinopathy using digital fundus images. Intention is to detect exudates in the fundus images which are the early sign of DR. Gray levels of optic disc are comparable with that of exudates. Moreover optic disc contains the highest pixel values in an image elimination of optic disc is necessary to extract exudates. This paper proposes a method to detect and eliminate optic disc in fundus image using morphological operation and thresholding. Then a method to segment blood vessels from fundus an image using a multilevel adaptive thresholding is implemented which uses different threshold values iteratively. Hard exudates are identified using discrete wavelet transform. Problem rise in the case of soft exudates which are in close proximity to OD that have more area when compared to hard exudates. So Artificial Neural Network (ANN) is implemented to distinguish between soft exudates and OD and same is used to classify hard exudates and soft exudates.

A. PRE-PROCESSING

Usually input images contain noise which makes work complex. So elimination of such noises is necessary. Several methods are available for noise elimination and image enhancement. Here median filter and CLAHE (Contrast Limited Adaptive Histogram Equalisation) is used [8]. Median filter is non-linear type and is used to reduce the effect of noise without effecting or blurring the sharp edge of an image. This filter will first arrange the pixel in their ascending or descending order and neighbourhood pixels median value is computed.

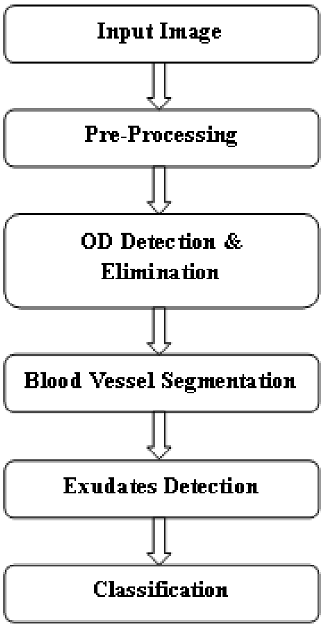


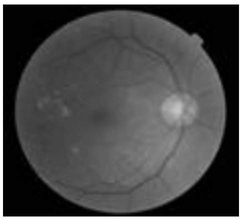
Figure 2. Block diagram of proposed system

Sometimes contrast of input image will be poor and as a result retinal features such as exudates and blood vessels cannot be easily distinguishable from background. So a contrast enhancement step will make this problem simple. In this work CLAHE is used for image contrast enhancement. CLAHE will divide the images in to contextual regions and after that histogram equalisation is applied to each portion. Histogram equalisation will provide a good method for modifying dynamic range and contrast of an image. It provide a non-linear monotonic mapping method which reassigns the intensity value of the input image so that output image contains a uniform distribution of intensity

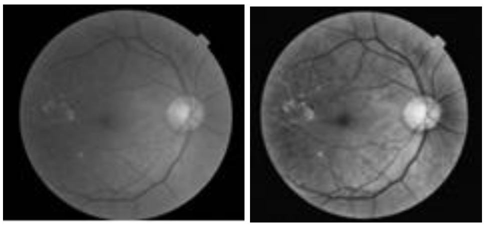
B. OPTIC DISC DETECTION AND ELIMINATION

In the processing of retinal images mathematical morphology can be used. The main four processes in the mathematical morphology are dilation, erosion, opening and closing [9]. These four processes involve a mechanism of combining two sets of pixels, one set consist of image being processed and other consist of structuring elements.

Structuring elements are the matrix consisting of only 0's and 1's and can have arbitrary shape and size. Closing operation is usually referred to as dilation followed by erosion, and this operation tends to narrow smooth section of the contour and thereby eliminating small holes and filling up gaps in contour.



(a)



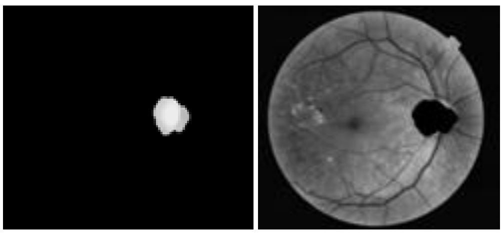
(c) (d)

Figure 3. (a) Gray scale of input image (b) Median filter output (d) CLAHE output

Opening is referred to as erosion followed by dilation and it generally smoothens the contour of an image. For detection of optic disc morphological opening is used with structuring element disk of size 10 for the image after pre-processing. For better result image is again dilated with structuring element octagon of size 36 to fill up the holes or gaps of optic disc portion. Then thresholding is done to locate the area of optic disc and finally optic disc is eliminated from initial image.

$$\text{Opening } F \circ B = (F \ominus B) \oplus (B)$$

$$\text{Closing } F \bullet B = (F \oplus B) \ominus (B)$$



(a) (b)

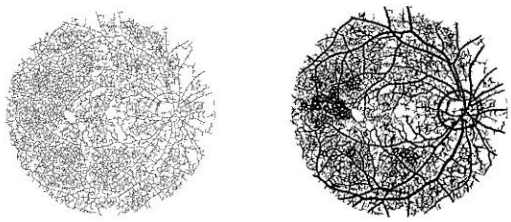
Figure 4. (a) Located OD (b) Image after eliminating OD

C. BLOOD VESSELS SEGMENTATION

A Multi level adaptive thresholding technique is used to extract blood vessels from retinal images. It applies different threshold values iteratively and keep of vessels in each layer [10]. At the initial step, first threshold value T_{MAX} is calculated from the histogram of image in such a way that it only keeps those pixels in first segmented image which is greater than T_{MAX}. Then morphological thinning operator is used to skeletonise I_{THIN}, the segmented image I_{SEG} which results in vessels which are only one pixel wide. Now edge image I_{EDGE} which highlights the edge pixels of all vessels is identified using equation below. For every pixel p in I_{THIN}

$$\text{Edge}(p) = \frac{1}{2}\sum_{i=1}^{8} \left| I_{THIN}(p_{i mod 8}) - I_{THIN}(p_{i-1}) \right|$$

where p_0 to p_7 represents the pixels belonging to an clockwise ordered sequence of pixels defining the 8-neighborhood of p and $I_{THIN}(p)$ is the pixel value. $I_{THIN}(p) = 1$ for vessel pixels and zero for all the other conditions. Edge(p) = 1 and Edge(p) = 2 for vessel edge point and intermediate vessel respectively. Then reduce the threshold value by 1 and calculate I_{SEG} for next iteration and all the above steps are done iteratively until T_{MAX}-1 is zero.



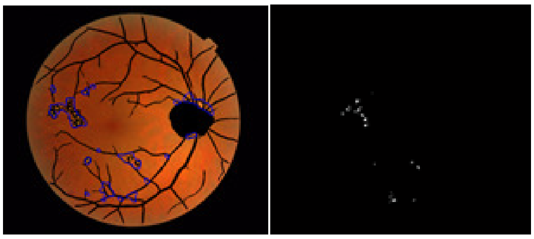
(a) (b)

(c)

Figure 5. (a) Thin image (b) Thick image (c) segmented blood vessel

D. EXTRACTION AND CLASSIFICATION OF EXUDATES

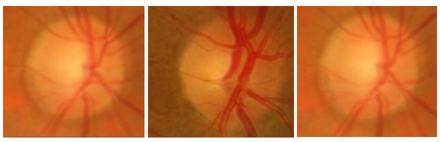
Hard exudates are identified using DWT and soft exudates using ANN [11]. Idea was to detect both exudates with one method, but soft exudates are more close to OD in appearance and have more area than hard exudates. Hence one method does not work. Single level 2D-DWT is used to extract hard exudates. It is implemented by iterating 2D analysis filter bank on input images and 2D synthesis filter on sub-band images. For a image having R rows and C columns, apply 1D analysis filter bank to each column resulting in two sub-band images each having R/2 rows and C columns. Then apply 1D analysis filter bank to each row of both sub-band images resulting in four sub-band images each having R/2 rows and C/2 columns. These four sub-band images are combined by 2D synthesis filter resulting in original image having size RxC.



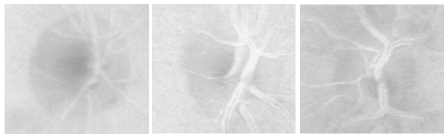
(a) (b)

Figure 6. (a) Located exudates (b) Detected hard exudates by DWT

Problem arises when OD and exudates are in close proximity to each other as both has almost same intensity. Such conditions usually arise in the case of soft exudates. ANN resolved the problem by clearly distinguishing between OD and exudates. The ANN for this approach was feed forward network and it used supervised learning to train the neural network [11] [12]. Supervised learning is a technique in which network is trained by providing with input and matching with a desired output. In this algorithm network is trained with patterns of OD and exudates, since optic disc of all fundus images has a specific circular pattern different from that of exudates. Training vector corresponding to each pattern is generated by using SFTA (Segmentation based Fracture Texture Analysis) algorithm. Each input is then compared with trained patterns by ANN to conclude whether it is soft exudates or optic disc. Finally classification of exudates as hard and soft is also done by ANN.



(a)



(b)

(c)

Figure 7. (a) OD pattern (b) Saturated OD (c) soft exudates pattern

III. RESULT & DISCUSSION

Proposed methods are applied to 100 images available from MESSIDOR database. Images from the database are pre-processed using CLAHE and median filter which resulted in a noise free and contrast enhanced image. Morphological opening provided good result in detection of optic disc. Blood vessel segmentation was efficiently done with multi-level adaptive thresholding. Exudates extraction and classification was effectively done with DWT and ANN. Performance of algorithm was evaluated using four performance measures such as accuracy, sensitivity or True Positive Rate (TPR), specificity or False Positive Rate (FPR) and precision or Positive Predictive Value (PPV). These measures follows from the definitions of parameters like true positive (TP): number of abnormal images correctly identified as abnormal, true negative (TN): number of normal images correctly identified as normal, false positive (FP): number of abnormal images wrongly identified as normal images and false negative (FN): number of normal images wrongly identified as abnormal image.

$$TPR=\frac{TP}{TP+FN}$$

$$FPR=\frac{FN}{FN+FP}$$

$$PPV=\frac{TP}{TP+FP}$$

$$Accuracy=\frac{TP+TN}{(TP+FP+FN+TN)}$$

Table I

TPR	FPR	PPV	Accuracy
.95	.33	.904	.97

IV. CONCLUSION

An automated detection system for DR from digital fundus images with severe disease condition is investigated and was successfully implemented with the images available from MESSIDOR database.. This technique provides an efficient method for early detection of DR by detecting exudates. DWT provides fast result in hard exudates detection and ANN resulted in good classification between hard and soft exudates and also in distinguishing soft exudates and OD which makes the system very efficient. Multi-level adaptive thresholding resulted in good segmentation of blood vessels from background. Morphological operations resulted in good separation between optic disc and exudates and it is a good technique to detect and eliminate optic disc.

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