Extraction of Retinal Blood Vessels from Diabetic Retinopathy Imagery Using Contrast Limited Adaptive Histogram Equalization

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Abstract – **Retinal image vessel segmentation and their branching pattern can provide us with the information about abnormality or disease by examining its pathological variance. Retinal vascular pattern are used for automated screening and diagnosis of diabetic retinopathy to assist the ophthalmologists. The early diagnosis of diabetic retinopathy, a common complication of diabetes that damages the retina, is crucial to the protection of the vision of diabetes sufferers. This paper presents a new method for blood vessel detection and extraction in digital retinal images using Contrast Limited Adaptive Histogram Equalization (CLAHE), a regional contrast enhancement scheme. This method is tested on publicly available GOLD STANDRED database of manually labeled images. We have achieve sensitivity 65.65% and specificity 98.97%.**

Keywords – *Diabetic retinopathy; retinal vessel segmentation; contrast enhancement; histogram equalisation; clahe*

I. INTRODUCTION

Diabetic retinopathy is a complication of diabetes that affects the eyes. It's caused by damage to the blood vessels of the light sensitive tissue at the back of the eye (retina). At first, diabetic retinopathy may cause no symptoms or only mild vision problems. Eventually, however, diabetic retinopathy can result in blindness. Diabetic retinopathy can develop in anyone who has type 1 diabetes or type 2 diabetes[1]. It is an ocular manifestation of systemic disease which affects up to 80% of all patients who have had diabetes for 10 years or more. Despite these intimidating statistics, research indicates that at least 90% of these new cases could be reduced if there was proper vigilant treatment and monitoring of the eyes. The longer a person has diabetes, the higher their chances of developing diabetic retinopathy. Manual detection of blood vessels is difficult since the appearance of blood vessel in a retinal image is complex and having low contrast[2]. The segmentation usually use contrast difference between blood vessels and its neighbouring background in a digital image, where all vessels are connected to each other. There are substantial researches on blood vessels detection in retinal images up till now have been published such as region growing technique[3], morphological and thresholding techniques[4], neural network based approaches[5], statistical classification based methods[6-7] and hierarchical methods[8]. In this paper, a new blood vessels detection algorithm in digital retinal images is presented based on Contrast Limited Adaptive Histogram Equalization (CLAHE). This technique increase the local contrast of pixels belonging to vasculature and pixels from the background of the image and are enhanced as candidate pixels from the background of the image. In this paper we use Contrast Limited Adaptive Histogram Equalization (CLAHE) on digital retinal images. Contrast Limited Adaptive Histogram Equalization is a special case of Adaptive Histogram Equalization. It divides the image into a number of small, non-overlapping contextual regions for processing an image.

The paper is organized as follows. Section II summarize our review to various Research Papers related to retinal Imagery. Our proposed work is introduced in section III. Results and Conclusions are mentioned in section IV and V.

II. REVIEW OF RELATED RESEARCH

Reza et al. [9] have presented an approach automatically to segment the blood vessels. Their presented algorithm employs the green component of

the image and preprocessing steps namely average filtering, contrast adjustment, and thresholding. The other processing techniques employed are morphological opening, extended maxima operator, minima imposition, and watershed transformation. Their presented algorithm is employed using the test images of STARE and DRIVE databases with fixed and variable thresholds. The images sketched by human expert are considered as the reference images. Their presented method produces sensitivity values as high as 96.7%.

Diego Marin et al. [10] have presented a new supervised method for blood vessel detection in digital retinal images. Their method uses a neural network (NN) scheme for pixel classification and computes a 7-D vector composed of gray-level and moment invariants based features for pixel representation. Their method was evaluated on the publicly available DRIVE and STARE databases, widely used for this purpose, since they contain retinal images where the vascular structure has been precisely marked by experts.

Joes Staal et al. [11] have mentioned method for automated segmentation of vessels in two-dimensional color images of the retina. Their system was based on extraction of image ridges, which coincide approximately with vessel centerlines. The ridges are used to compose primitives in the form of line elements. For every pixel, feature vectors are computed that make use of properties of the patches and the line elements. The feature vectors are classified using a NN-classifier and sequential forward feature selection. Their algorithm was tested on a database consisting of 40 manually labeled images. The method achieves an area under the receiver operating characteristic curve of 0.952.

Lei Zhang et al. [12] have proposed a modified matched filter for retinal vessel extraction that applies a local vessel cross-section analysis using double-sided thresholding to reduce false responses to nonliner edges. Their stated modified matched filters demonstrated higher true positive rate and lesser false detection than existing matched-filter-based schemes in vessel extraction.

III. PROPOSED WORK

In view of the difficulties that arise due to direct application of standard enhancement techniques to Diabetic Retinopathy, in the following we propose to apply CLAHE based image enhancement algorithm. Figure shows the overall methodology in detection of blood vessels.
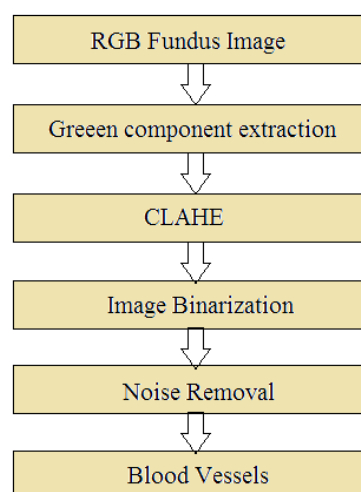

Fig. 1 : Proposed work

The input images obtained from various DR image databases.

Blood vessels are extracted in this paper for the identification of diabetic retinopathy. The contrast of the fundus image tends to be bright in the center and diminish at the side, hence preprocessing is essential to minimize this effect and have a more uniform image. The first step is to standardize the dimensions of the image.

The input images are in color image. The RGB image is converted to a form of grayscale image to filter out the noise in the image and to strengthen the appearance of blood vessels. Each color component is extracted to red, green, blue component. The green component is good for detection of blood vessels. Then next step is to extract the green component values from RGB fundus image.

This green component image is operated through CLAHE technique of histogram equalization. The step enhances the contrast of image and distinguishes the details of the vessels appearances. Finally the image segmentation is performed. The image is converted into group of white black pixels to extract the blood vessels form image.

A. Standard Histogram Equalization(SHE)

The purpose of standard histogram equalisation scheme is to optimize the overall contrast of the image by obtaining a uniform histogrammed version of the gray image. It attempts to equalize the probability of occurrence of all the gray values of the image. SHE employs a monotonic, non-linear mapping that assigns a

new intensity value to each of the pixels based on following computation:

The probability density function of a digital image of 'n' pixels with gray level range [0, L-1] is given by equation (1)

$$P(r_k) = \frac{nk}{n} \qquad (1)$$

Where $0 \le r_k \le 1$ and $k = 0,1, \ldots , L-1$, and r_k stands for the kth gray level, n_k represents the number of pixels in the kth level and n is the total pixel count. The transformation mapping of the gray level r_k to a new level s_k based on a cumulative distribution function is obtained using equation (2), which may be expressed as:

$$S_k = T(r_k) = \sum_{j=0}^{k} \frac{nj}{n} = \sum_{j=0}^{k} P(rj) \;\; k = 0,1, \ldots, L-1 \qquad (2)$$

Where 'T' stands for the transformation function. This method is particularly useful, where, both background and foreground are dark and represented by a set of narrow gray values. Images acquired from fluorescence oscilloscope are often very low in contrast, which is evident from their histograms that are narrow and concentrated only to certain gray level values. Retinopathy images contain minute details of the lesions and intra-retinal occlusions that get obscured due to limited contrast, and hence, are not easily presented before doctors. This may lead to delayed diagnosis and even wrong treatment. Histogram equalization plays an important role in several such cases, but leaves local changes in contrast unconsidered. CLAHE algorithm[13] considers the local variance of contrast and can successfully applied to DR imagery.

B. Contrast Limited Adaptive Histogram Equalization (CLAHE)

The CLAHE algorithm is defined to function adaptively on the image to be enhanced, unlike standard histogram equalization. It optimizes the contrast enhancement on local image data in a divide and conquer manner and hence efficiently tackles the global noise. In other words, the basic idea of the algorithm is to divide the image into a number of small, non-overlapping contextual regions, called "Tiles".

As a next step, the standard histogram equalization is then applied to each of these regions. Thus, each tile is contrast enhanced locally which is followed by clipping and median filtering. A comparison of the contrast enhancement capability of the proposed scheme with that of SHE, is also provided in the figure.
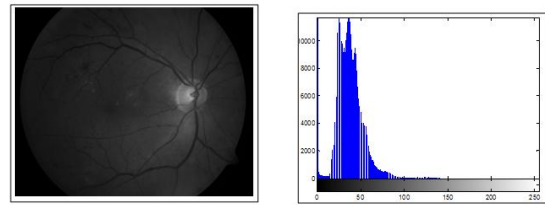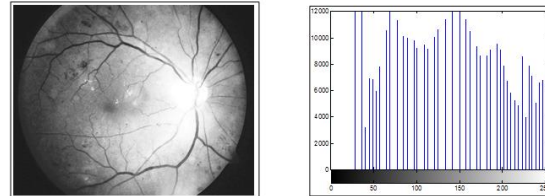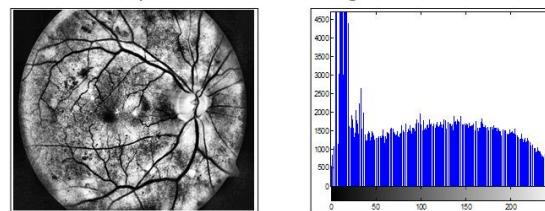

Fig. 2 : Comparison between SHE and CLAHE

IV. RESULTS AND ANALYSIS

The proposed approach is implemented in MATLAB7.12. The algorithm is tested on a database of eighty nine images for both normal and abnormal. Selection of suitable threshold in the detection of blood vessels plays an important role. Lowering the threshold value improves the sensitivity of the algorithm but decreases the predictivity. Performance measure procedure was done by comparing the segmentation results to the reference image. There are four values resulted from the validation procedure, true positive (TP), false positive (FP), true negative (TN) and false negative (FN). True positives is a number of pixels correctly detected as vessel pixels, false positive is a number of pixels incorrectly flagged, true negatives is a number of pixels correctly detected as non vessel and false negative (FN) is a number of pixels incorrectly flagged as non vessels.

TABLE I : PERFORMANCE PARAMETERS

	Vessel Present	Vessel Absent
Vessel Detected	True positive (TP)	False positive (FP)
Vessel not Detected	False Negative (FN)	True Negative (TN)

Sensitivity=TP/[TP+FN] ;

Specificity=TN/[TN+FP];

Predictivity = TP/[TP+FP];

The ground Truth data was marked by an expert opthamologists. For evaluation purpose, all the parameters are determined for each image in the data set. Sensitivity, Specificity and Predictivity are used as accuracy measures. As, mentioned above, the method tested on 89 retinal images of the db1 database. For experimental purpose we have taken 8 images from GOLD STANDARD database for analysis.

TABLE II : PERFORMANCE RESULT ON RETINAL IMAGES

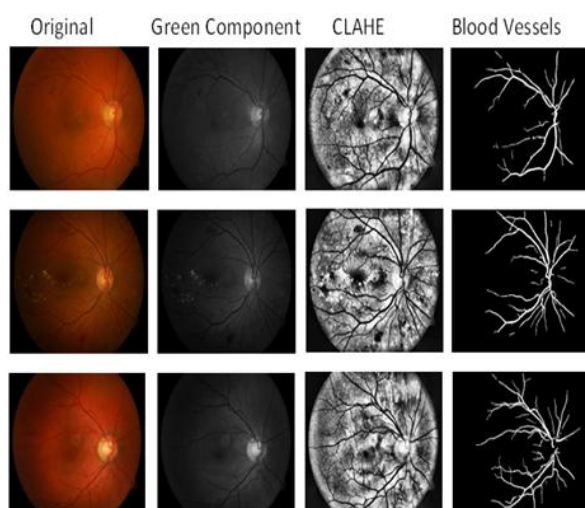| Image	Specificity	Sensitivity	Predictivity
Sample1	0.9781	0.7461	0.8405
Sample2	0.9922	0.6659	0.9268
Sample3	0.9892	0.6761	0.9115
Sample4	0.9946	0.6144	0.9477
Sample5	0.9907	0.6312	0.8622
Sample6	0.9951	0.5645	0.9417
Sample7	0.9860	0.6496	0.8811
Sample8	0.9917	0.7043	0.9358
Average	0.9897	0.6565	0.9059

Fig. 3 : Blood Vessel Extration

The specificity and sensitivity of the blood vessels detection that we received from this set of data are 98% and 65% respectively. The MATLAB code takes less than 0.2 minutes per image to run on a 2.4 GHz machine. On comparing with other methods sensitivity and specificity was intermediate for the proposed method but has a fast execution.

V. CONCLUSION

The present work considers application of a CLAHE algorithm to enhancement DR images. In this paper we take CLAHE algorithm to transform DR image and modify its values in successive stages to separate blood vessels from other parts of image. The experimental results show that the proposed algorithm is accurate and robust as well as fast to implement well in automated screening of Diabetic Retinopathy Imagery. The proposed method can be improved and the specificity of implementation can be increased by using some additional steps. The image obtained using CLAHE algorithm contains more useful information than the source images, thus enabling the ophthalmologists to locate the imperfections accurately, making the treatment easier and more accurate.

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