Estimation of Diabetic Retinopathy from Retinal Images Using Artificial Neural Network

Leshmi Satheesh
PG Scholar, Dept Of ECE
Mohandas College Of Engineering and Technology
Tvm, Kerala
leshmi24@gmail.com

Shally. K
Asst. Professor;Dept of ECE
Mohandas College Of Engineering and Technology
Tvm, Kerala
shallykuttan@gmail.com

***Abstract*— Diabetic retinopathy is the single largest explanation for sight loss and visual impairment in eighteen to sixty five year olds. Damage of blood vessels in the eye and the formation of lesions in the retina are the earliest signs of diabetic retinopathy. Efficient image processing and analysis algorithms have to be developed for the automated screening programs to work robustly and effectively. For the detection of vascular changes and for calculating the characteristic signs associated with diseases such as diabetes and cardiovascular conditions, the artery/vein classification of retinal blood vessel plays an important role. This paper presents an artificial neural network based diabetic retinopathy estimation with classification of vascular vessels .The retinal blood vessels are classified based on the intensity features. Here the retinal image is preprocessed, segmented and the centerline image is obtained and blood vessels are classified into artery and vein based on the intensity features. Then diabetic retinopathy estimation is done using Artificial Neural Network .The proposed method is supposed to be a diagnostic aid for ophthalmologists in the estimation of Diabetic retinopathy.**

***Index Terms*— Diabetic Retinopathy, artery/vein, artificial neural network.**

I Introduction

In the developed world one of the common cause of blindness in the working age group is diabetes. When damages occur in the retina due to diabetes, it is called diabetic eye disease or also known as ”Diabetic Retinopathy”. The risk of blindness in diabetic patients can be reduced to 50% by screening of this patients for the development of diabetic retinopathy. The vascular system of the retina is affected by diabetes and later occurs the retinal death due to absence of blood supply. Diabetic Retinopathy (DR) is one of the leading causes of blindness among people suffering from diabetes. It is observed that about 2% of the patients affected by this disorder are blind and 10% undergo vision degradation after 15 years of diabetes. As the diabetic retinopathic patients don’t perceive any symptoms in the initial stages, visual loss develops in the later disease stages and in that stage the treatment won’t be much effective.

In automatic processing, the detection of blood vessels is a major problem from retinal images. diseases which affect the retinal vessels such as diabetic retinopathy, in which abnormalities in the blood vessels are shown at early stages. Hypertension and some other cardio-vascular conditions also exhibit certain changes in retinal blood vessels. Growth of new vessels (also known as neo-vascularization), disappearance of vessel (due to occlusion), and change in dimension are some of the structural changes associated with blood vessels. In cases with hypertension, the retinal arteries dilate by about 35%. In spite of diabetic retinopathy, age and hypertension also causes changes in the structural geometry of retinal vessels.

Diabetes may cause retinal abnormalities which is known as diabetic retinopathy, abnormalities in kidneys (diabetic nephropathy), nervous system (diabetic neuropathy) and is known to be one of the major risk for cardiovascular diseases. Diabetic retinopathy is a micro vascular complication caused by diabetes which can lead to blindness. There won’t be any visible signs in the early stages of diabetic retinopathy but as the time passes the severity and number of abnormalities increases. Diabetic retinopathy typically starts with microa-neurysm, representing local enlargement of tiny retinal capillaries, which is the first detectable sign. Second stage is hemorrhage, which is caused by the ruptured microaneurysm. Lipid formations leaking from weakened blood vessels, known as hard exudates, appear after a period of time. As the retinopathy advances, the blood vessels may become obstructed causing microinfarcts / soft exudates in the retina which is also known as cotton wool spot. New fragile vessels are developed due to extensive lack of oxygen caused by microinfarcts and this phenomenon is called neovascularization which is considered to be one of the extreme condition of diabetic retinopathy and may cause sudden visual loss or even permanent blindness.

II. PROPOSED METHOD AND DATABASE

A. Database

The retinal fundus image used for this study is obtained

from publicly available database MESSIDOR .The 1200 eye fundus color numerical images of the posterior pole for the MESSIDOR database were acquired by 3 ophthalmologic departments using a color video 3CCD camera on a Topcon TRC NW6 non-mydriatic retinograph with a 45 degree field of view.

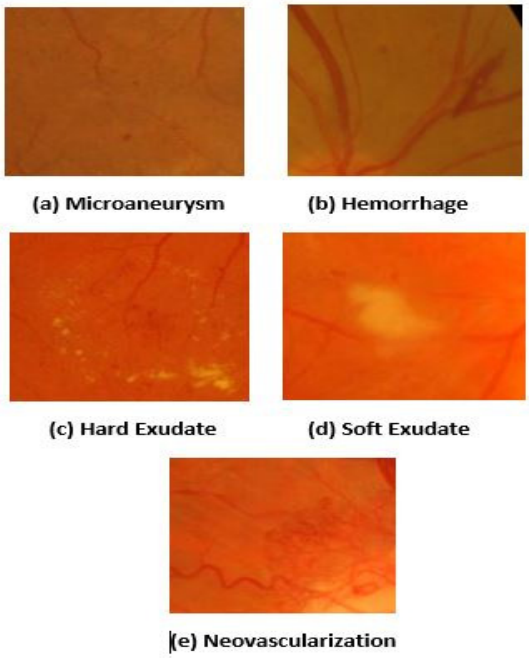

Fig. 1. Abnormal findings in the eye fundus images caused by diabetic retinopathy

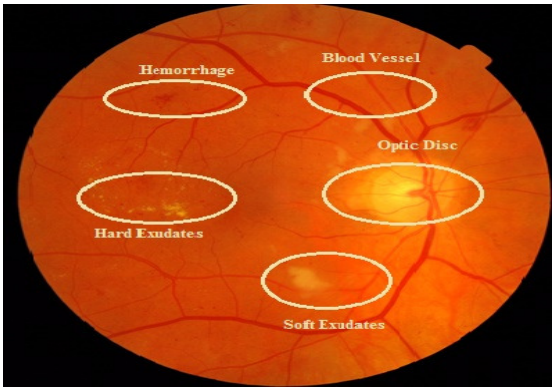

Fig. 2. Fundus image with abnormalities

The images were captured using 8 bits per color plane at 1440*960, 2240*1488 or 2304*1536 pixels.800 images were acquired with pupil dilation (one drop of Tropicamide at 0.5%) and 400 without dilation .The 1200 images are packaged in 3 sets, one per ophthalmologic department. Each set is divided into 4 zipped sub sets containing each 100 images in TIFF format and an Excel file with medical diagnoses for each image [28].

B. Proposed Method

This paper presents an artificial neural network based diabetic retinopathy estimation with classification of vascular vessels .The retinal blood vessels are classified based on the intensity features. Here the retinal image is preprocessed, segmented and the centerline image is obtained and blood vessels are classified into artery and vein based on the intensity features. Then diabetic retinopathy estimation is done using Artificial Neural Network .The results suggest that the pro-posed method could be a diagnostic aid for ophthalmologists in the estimation for Diabetic retinopathy.

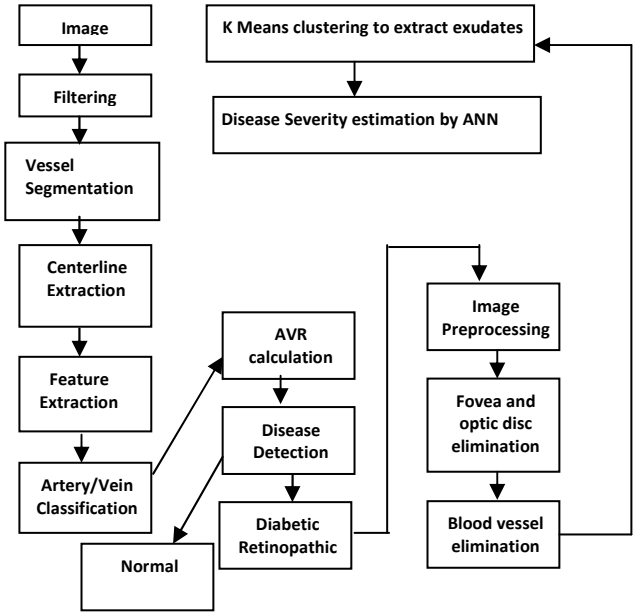

Fig. 3. Proposed Method

III.METHODOLOGY

A. Image Preprocessing

The preprocessing steps for the detection of hemorrhages and exudates are slightly different from each other. For micro aneurysm /hemorrhage detection , first the green channel of the RGB color space is extracted, as green channel has better contrast when compared to the other channels .Then contrast-Limited Adaptive Histogram Equalization (CLAHE) algorithm was applied which consist of applying histogram equalization for each region in the image as a result of which local contrast is enhanced for each region. An Alternating Sequential Filtering (ASF) is applied to remove the noise in the image.

In the first preprocessing step for Exudate detection, the original RGB retinal image is transformed to CIELab color space. CIELAB indicates the values with three axes: L*, a*, and b*where 'L' defines lightness,' a' denotes the red/green value and 'b' the yellow/blue value. As L is a value between 0 and 100, this color space is not easy to visualize. The CIElab color space allows the intensity to be treated separately from the other two components and is considered to be most appropriate for contrast enhancement .Relations for L*, a *, and b * are as follows [27]:

$$L=\{116*(Y/Y_n) \text{ for } (Y/Y_n)>0.008856$$
$$903.3*(Y/Y_n); \text{ Otherwise}$$
$$a = 500*(f(X/X_n - f(Y-Y_n))$$
$$b = 200*(f(X/X_n - f(Z-Z_n))$$

where X_n ,Y_n and Z_n are the tristimulus values of the reference white.

A median filter is applied on the L band in order to preserve edges and to reduce noise . A Contrast Limited Adaptive Histogram Equalization (CLAHE) technique is usedTo enhance the contrast and the separability between exudates and the background , a Contrast Limited Adaptive Histogram Equalization (CLAHE) technique is used which consists of subdividing the image into non-overlapping rectangular regions and then applying their local equalization histogram.

B. Blood vessel Detection and Elimination

The exact detection of artery and vein in color retinal images is a significant task in an automated retinal image analysis system .For this purpose a number of different segmentation methods can be adopted. Morphological image processing exploits features of the vasculature shape that are known a priori. The algorithms that extract linear shapes can be very useful for vessel segmentation. The centerline image is extracted from the segmented result by applying threshold based thinning algorithm. This algorithm removes border pixels .For each centerline pixel, the 30 features are measured and normalized to zero mean and unit standard deviation [1]. By using Linear classifier the blood vessels are classified as artery/ vein

The elimination of blood vessel consists of removing the blood vessels obtained in the previous stage, which contains the low intensity structures.

Number	Features
1-3	Red, Green and blue intensities of the centerline pixels
4-6	Hue, saturation and Intensity of the centerline pixels
7-9	Mean of Red, Green and blue intensities in the vessel
10-12	Mean of Hue, saturation and Intensity in the vessel
13-15	Standard deviation of Red, Green and blue intensities in the vessel
16-18	Standard deviation of Hue, saturation and Intensity in the vessel
19-22	Maximum and minimum of Red and Green intensities in the vessel
23-30	Intensity of the centerline pixel in a Gaussian blurred of red and green plane

Fig. 4. List of features measured for each centerline pixel

C. Extraction of Exudate region

The bright intensity regions in the fundus images with distinct boundaries is considered as the hard exudate. K means clustering algorithm is applied to extract these regions. The clustering algorithm have been tried for different values of k and the best result is obtained for k = 6. The papillary region and other yellow lesions, such as cotton wool spots/ soft exudates are detected, because of their similar attributes to hard exudates in terms of brightness, color and contrast [27].

D. Optic disc Segmentation and Elimination

The optic disc is considered as the exit region of the optic nerves and blood vessels from the retina. It appears as a bright yellowish or white region, circular or elliptical form. The size of optic disc varies from one person to another, occupying about one tenth to one fifth of the image. From the retinal network removed image, the optic disc segmentation is done by applying threshold operation .In order to eliminate the optic disc a subtraction operation is done between this image and a binary dilated version of the segmentation result of the optic disc.

E. Elimination of Fovea

For improving the detection accuracy the fovea region is removed from image obtained in the previous stage. Based on characteristics of the anatomy of the retina, a method to identify the center of fovea is applied, which considers the spatial relationship between the diameter of the optical disc and the region of the fovea. Fovea Center is obtained, which has only a pixel with value 1, which identifies the center of the fovea. After that, a morphological dilation with a disc shaped structuring element it is performed and the fovea is removed by subtracting from previous image [27].

F. Artificial Neural Network

Artificial neural networks (ANNs) are a family of statistical learning algorithms which is inspired by biological neural networks. Generally, from large number of unknown inputs ANN can estimate or approximate functions. A large number of neurons, which can compute values from input, are interconnected to form an artificial neural network. Neural networks are similar to biological neural structures. A neural networks starts as a model

neuron which consists of multiple inputs and a single output. The input is modified by a weight, which multiplies with the input value. Then the neuron will combine these weighted inputs. These are used to determine its output with reference to a threshold value and activation function. The concept of neural networks is inspired from Human's central nervous system. In Artificial Neural Network [23] the artificial nodes which are known as "neurons", "processing elements" or "units" are connected together to form a network this mimics a biological neural network.

A neural network performs functions collectively and in parallel by the units, than there being a clear delineation of subtasks to which various units are assigned in a way which is similar to biological neural network. The term "neural network" usually refers to models employed in statistics cognitive psychology and artificial intelligence [23]. In this study the ANN consisted of three layers: an input layer and output layer connected by a hidden layer. The hidden layer consists of a number of nodes connected to the input and output nodes by mathematical algorithms (weights). By presenting the network with many examples of data of known output, training is achieved . Once the weights in the hidden layer have been adjusted by training, the network can be shown a previously unseen input and categorize this into the appropriate output. Once the network has been trained to recognize the digitized visual fields, which has not previously been seen can be presented. The selected features are fed into the constructed neural network to train it to identify features.

The artificial neural network models can be used to infer a function from observations made. This is mostly useful in applications where the complexity of the data or task makes the design of such a function by hand impractical. Neural networks have performed successfully where other methods failed in, predicting system behavior, recognizing and matching complicated, vague, or incomplete data patterns.

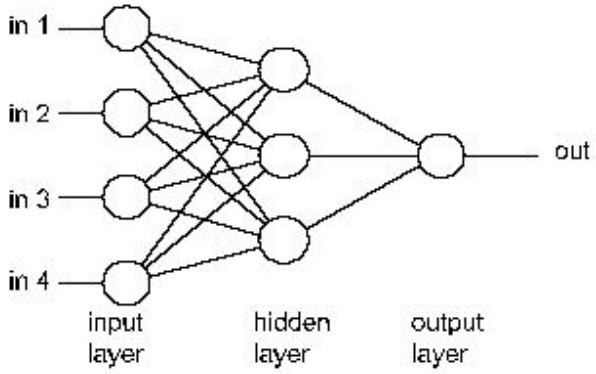

Fig. 5. Artificial Neural Network

ANNs is applied to pattern recognition,diagnosis, interpretation, prediction, planning, debugging, monitoring, repair, control and instruction. Because of the prediction capability of ANNs, they can be used in diagnosis in medical field. Neural network Toolbox1 for MATLAB is one of the most well-known toolboxes for constructing and training neural networks. This toolbox provides GUIs for designing, training and simulating a number of different neural network types and allows custom extension of the toolbox [23].

IV. RESULTS AND CONCLUSIONS

This paper presented an artificial neural network based diabetic retinopathy estimation with classification of vascular vessels .The retinal blood vessels are classified based on the intensity features into arteries and veins. Here the retinal image is preprocessed, segmented and the centerline image is obtained and blood vessels are classified into artery and vein based on the intensity features. Then diabetic retinopathy estimation is done using Artificial Neural Network .The results suggest that the proposed method could be a diagnostic aid for ophthalmologists in the estimation of Diabetic retinopathy.

Fig.6.Input Image

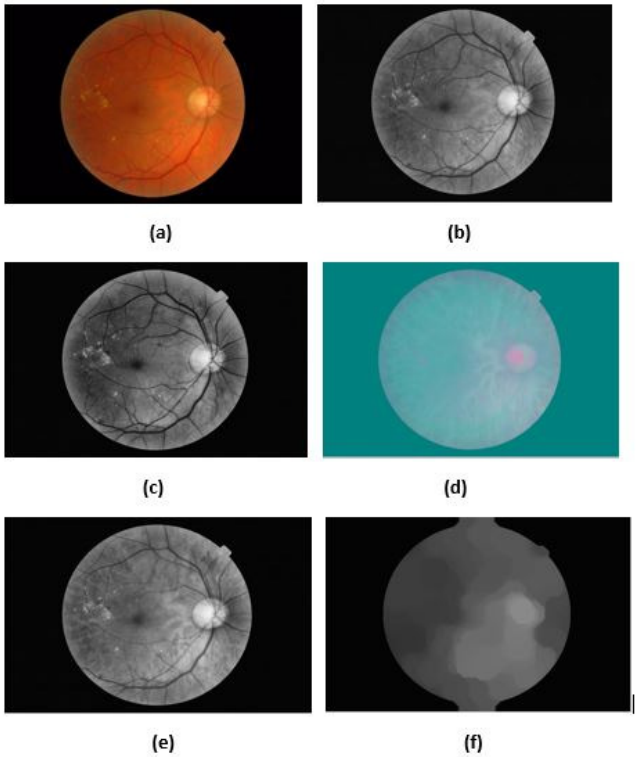

Fig. 7. Preprocessing results: (a)Input image (b)CLAHE (c) Median filtered image (d) CIElab Conversion (e)L band Image (f) ASF filtered image

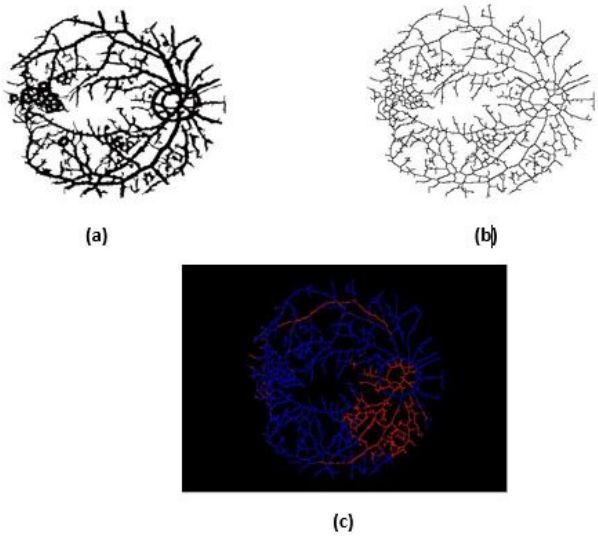

Fig. 8. Vessel Classification : (a)Segmented image (b)Centerline Image (c)Artery/ vein classified Image

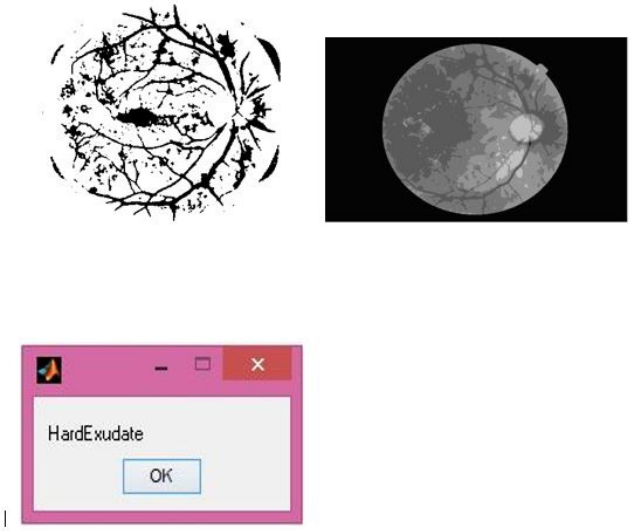

Fig. 9. (a)Detection of fovea (b)Result of k means with k=6 (c)Diabetic Retinopathy estimation by ANN

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