Classification of Blood Vessels as Arteries and Veins for Diagnosis of Hypertensive Retinopathy

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***Abstract*—Vasculature abnormalities are the indicator of different diseases in the human body. Retinal blood vessels are very sensitive to blood pressure changes. Diameter abnormalities of retinal blood vessels are the first clinical finding in many retinal diseases such as glaucoma, Diabetic retinopathy, hypertensive retinopathy and macular degeneration. Automated and accurate classification of blood vessels into arteries and veins may help the ophthalmologist to find the retinal disorders. In this paper, we present a novel method for automated detection of hypertensive retinopathy. The proposed system classifies the vessel into arteries and veins using different machine learning techniques and then detects hypertensive retinopathy by computing arteriolar to Venular ratio. The proposed system is tested on one publicly available database and one locally gathered database. The quantitative results show the validity of proposed system**

I. Introduction

High blood pressure may cause many retinal disorders. One of them is hypertensive retinopathy. Hypertensive retinopathy is characterize by elevated blood pressure (systolic blood pressure is consider to be more than 140 mm Hg ,while diastolic blood pressure is more than 90 mmHg).Condition goes worst and emergency occurs when systolic blood pressure raise up to 200 mmHg and diastolic blood pressure is over 140 mm Hg. Most of the patient remain undiagnosed of this silent killer. Hypertension symptoms [2] include Arteriolar narrowing, Arteriovenus (AV) niking which are shown in Figure 1 while other major signs are flame shape retinal hemorrhage and Cotton wool spots.

Hypertensive retinopathy has four stages such that every increasing stage includes the symptoms of previous stages. Patients suffered from stage 3 and 4 have brighter reflex in arteries and have increasing possibility of hypertensive retinopathy then patients with stage 1 and 2.Such patients may become victims of permanent blindness, if it is not cured properly. Therefore timely diagnosis of hypertensive retinopathy is basic need for accurate treatment.

Blood vessels are classified into arteries and vein. Arteries carries oxygenated blood and are brighter while vein carries deoxygenated blood to lungs and liver and darker then arteries (figure 3). Hypertension cause changes in these blood vessels like veins are abnormally wide in diabetic retinopathy which is primarily a retinal disorder [5] .Arteries get narrowed in pancreatic disorder and high blood pressure results in thickened arteries and cause other disorders like hypertension and stroke which is not primarily retinal disorder but changes do occur in

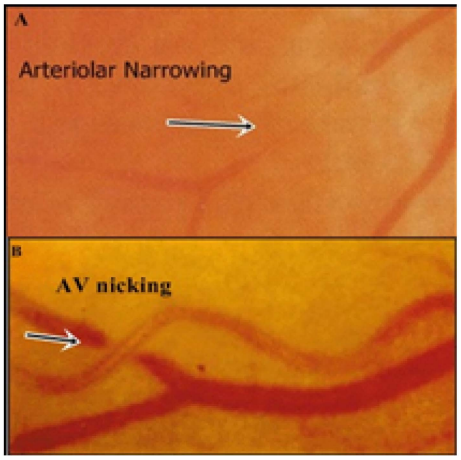

Fig. 1. Arteriolar Narrowing [A] and Av nicking [B])

the morphology of retinal blood vessels. Retina is examined in routine for the detection of such diseases [5, 3]. Hypertensive retinopathy [4] patients have major change in arteries which can be detected by finding A/V ratio. Hypertensive leads to abnormal ratio of average diameter of arteries to veins. It is more common in adult (60%) then adults (25%).

Usually vessels used to measure A/V ratio, run to upper and lower temporal region from optic disc [5].According to Japanese's guidelines for the calculation of A/V ratio retinal vessels in region from quarter disc to one disc diameter from optic nerve head margin should be considered [6]. A/V ratio is normally measured in large vessels .Small vessels with the diameter less than 2 is removed or not consider for calculation of A/V Ratio [4]. Therefore accurate measurement of AVR is vital and classification of blood vessels into arteries and vein is indispensable for the detection of retinal disorder. Fig 2 shows difference between arteries and veins. Proposed system include preprocessing step for, image better visibility , vessels extraction model followed by ROI detection Model and finally computation of AVR for detection of hypertensive Retinopathy.

This paper comprises of five sections. An overview of existing techniques is given in section 2. Section 3 contains proposed methodology followed by experimental results in section 4. Section 5 contains conclusion.

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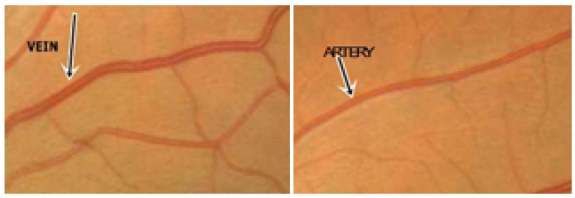

Fig. 2. Blood vessels highlighted as arteries and veins

II. Related Work

Retinal blood vessels show variety of structural changes during different diseases. Great contributions have been done by authors in presenting different techniques for the automated detection of HR by classifying blood vessels into arteries and veins.

Computer aided diagnostic techniques are used by Authors in [24]. They presented a method for HR detection in which vessels are segmented using moment based and gray level feature and support vector machine (SVM) for classification. Used For classification of vessel as artery and vein they used Intensity and color information which is then used to calculate vessel width and in turn AV ratio. K. Noronha et al. [21] used Radon transform method for segmentation of blood Vessels while Hough transform method is used for the detection of optic disk and finally AVR is calculated.

Ortiz et al. [22]. Used Gabor wavelet and morphological operations to measure vessel diameter in order to compute AVR. G. C. Manikis et al. [23] proposed a system for detection of Hypertensive Retinopathy. Vessels are segmented using multi scale filtering and region based identification. Vessels width is estimated in region of interest and AVR is calculated to find HR.

III. Proposed Methodology

Hypertensive Retinopathy is the retinal disorder caused by the high blood pressure. Disease leads to permanent blindness if not diagnosed and cured timely. In Proposed system main contribution is in the classification of vessels into arteries and veins to find AVR and to detect hypertensive retinopathy using fundus images. It contains five steps, images acquisition, vessel Extraction model, ROI detection Model, AVR computation model, then diagnosis of hypertension. Fig 3 represents the diagram of proposed methodology.

A. Image Acquisition

In pre processing step fundus Image is acquire and background is separated from the foreground by using variance based method [9]. Purpose is to remove unnecessary pixels from the background for the clear separation of vessels form the background.

B. Vessel extraction Model

Vessel segmentation plays high up role the detection of Hypertensive Retinopathy by finding A/V ratio. For A/V ratio computation, enhancement of vessels is done by using 2-D Gabor wavelet for enhanced visibility. Second step is

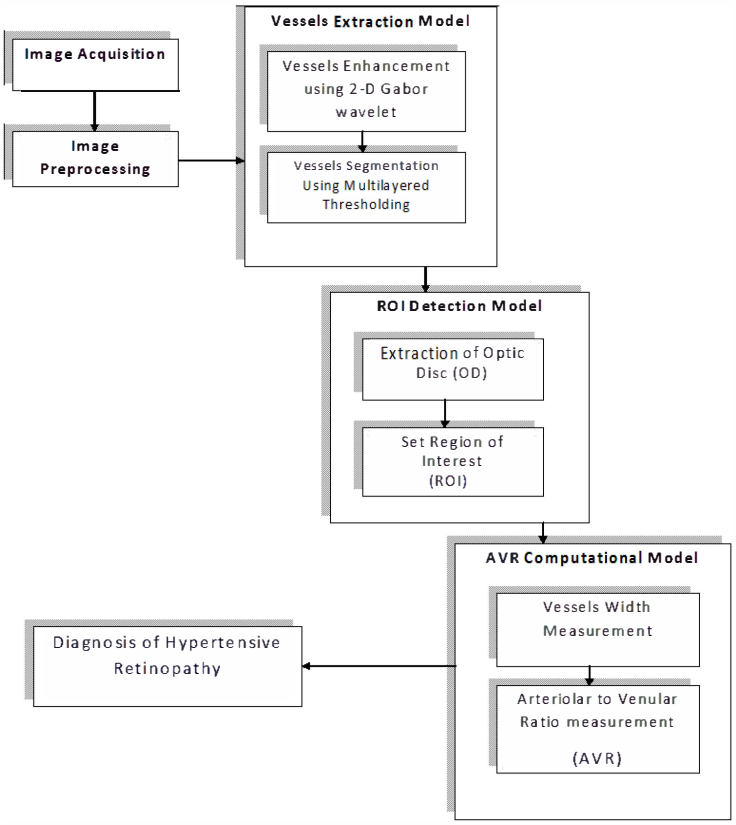

Fig. 3. Flow diagram of proposed system

vessels segmentation. For better accuracy proposed system uses multilayered thresholding approach to make sure the extraction of small vessel along with large one [10].Result of 2-D Gabor wavelet and Multilayer thresholding is shown in fig 4.

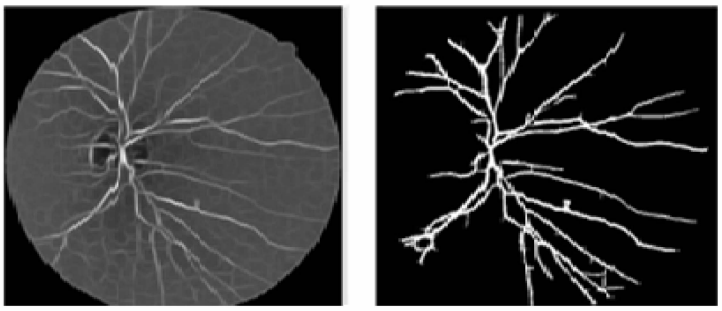

Fig. 4. a) Blood vessel enhancement using 2-D Gabor wavelet b) vessel segmentation using multilayered thresholding

C. ROI Extraction

ROI is the standard area for the measuring the vessels .OD (yellow brightish disk from where the blood vessels emerge) is used to find the ROI (Region of interest) .OD is first

highlighted by using maximum intensity level and then ROI is set three time greater the radius of OD. Retinal vessels within ROI has to be classified as arteries and veins [18].

D. Classification of Arteries and Veins

Classification of blood vessels into arteries and vein can be done by using different classifiers. Before applying classification, a number of features are extracted for blood vessels to classify them as arteries and veins.

1) Feature Set Formulation: The feature vector is composed of the following features;

- Mean intensity of each vessel in red channel of RGB (d1)
- Mean intensity of each vessel in enhanced green channel of RGB (d2)
- Variance of vessel pixel intensities in A channel of LAB color space (d3)
- Variance of vessel pixel intensities in B channel of LAB color space (d4)
- Mean intensity of Hue and Saturation Channels in HSI color space (d5 and d6)
- Variance of vessel pixels in red channel of RGB color space (d7)
- Energy of vessel pixels in red channel of RGB (d8)
- Entropy of boundary vessel pixels and background (d9)

2) Classification: For classification of blood vessels four data mining classification techniques (Artificial neural network (ANN), naïve bayes, support vector machine (SVM)) and decision tree) are analyzed on Dataset.

a) Naïve Bayes Classifier: Naïve Bayes is a probabilistic model which on the basis of Bayesian decision rule determine that which particular region belongs to a artery or vein It assumes that the presence (or absence) of a particular feature in class does not affect the presence (or absence) of any other feature in [13].

b) Support Vector Machine (SVM): SVM is supervised learning separates arteries and veins from each other with maximum margin by using a separating hyperplane. SVM Performs classification tasks by maximizing the margin separating both classes while minimizing the classification errors. SVM is method for classification of both linear and non-linear data. It uses a non-linear mapping to transform the original training data into a higher dimension [12].

c) Artificial neural networks (ANN): In computer aided diagnosis, neural network application represent main milestone of computational intelligence in medical imaging. ANN is non linear data mining classifier designed to solve various problems. Rather than getting model equation itself, ANN can be used to estimate only the behavior of a function from observations. Thus, if the ANN is fed with images having hand labeled blood vessels, proper classification of new images can be done by discovering the inherit properties of image [20].

d) Decision Trees: Decision trees are influential classification algorithms. In decision tree input observation is separated into two or more subgroups. At every node this division is repeated until the complete tree is constructed. The intention of the splitting algorithm is to stumble on a variable-threshold pair that maximizes the homogeneity of the resulting two or more subgroups of samples Figure 6 illustrates the outputs of SVM classifier.

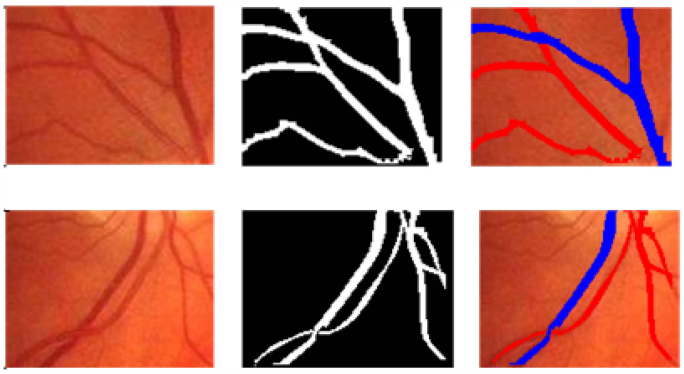

Fig. 5. Vessel classification: Sub images from original image and their corresponding binary vessel masks and classification in arteries (red) and veins (blue)

E. Computation of AV ratio

Parr-Hubbar formulas are used for computation of of AVR. These formulas provide more reliable measurements and are defined as follows According to [16, 19],the Central Retinal Artery Equivalent (CRAE) is derived as.

$$CRAE = \sqrt{(0.87W_a^2 + 1.01W_b^2 - 0.22W_aW_b - 10.73)} \quad (1)$$

Where W_b is the median value of "Arteriole" and W_a is the value in the same list exactly before the median. CRVE (Central Retinal Vein Equivalent) is computed as,

$$CRVE = \sqrt{(0.72W_a^2 + 0.91W_b^2 + 450.02)} \quad (2)$$

Where W_b is the median of "Venule" and W_a is the value in the list exactly before W_b. AVR is computed by

$$AVR = \frac{CRAE}{CRVE} \quad (3)$$

F. Grading of Hypertensive Retinopathy

HR is graded on a scale of 1 to 4. Keith Wagener Barker (KWB) grades [**?**] for various stages of HR are given in table 2 along with AV ratio.

TABLE I
GRADING OF HR

Degree of HR	A/V ratio	Symptoms
Normal Retina	0.667-0.75	None
Grade 1	0.5	Mild compression of venules
Grade 2	0.33	Compression of elevation of venules
Grade 3	0.25	Right angled crossing of vessels
Grade 4	< 0.2	All above symptoms along with papilledema

TABLE II
RESULTS FOR VESSEL CLASSIFICATION AS ARTERIES AND VEINS USING DIFFERENT CLASSIFIERS

Classifiers	Accuracy	Specificity	Sensitivity	AUC	Recall	Precision	PPV	NPV
ANN	0.76	0.716	0.797	0.839	0.71	0.76	0.785	0.73
Naïve Bayes	0.75	0.849	0.681	0.809	0.84	0.68	0.854	0.671
Decision Tree	0.68	0.773	0.623	0.691	0.77	0.66	0.781	0.611
SVM	0.81	0.811	0.811	0.865	0.80	0.77	0.848	0.767

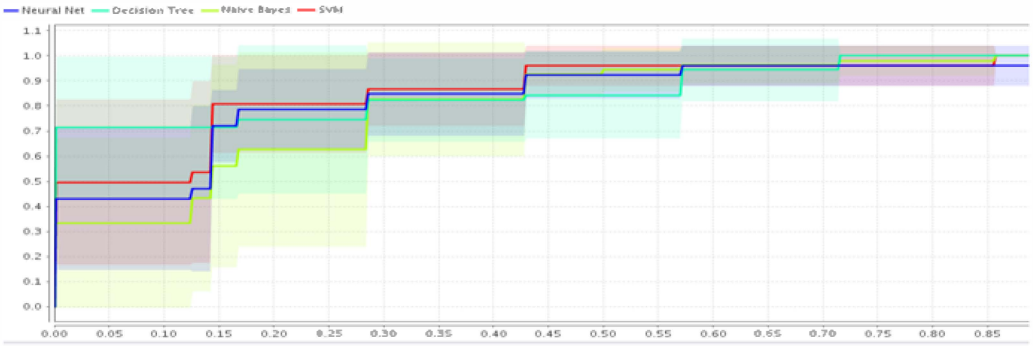

Fig. 6. ROC curves for different classifiers

IV. EXPERIMENTAL RESULTS

The quantitative assessment of the proposed system of HR detection is done by using locally available retinal image dataset. The dataset consists of 100 images of different patients suffering from hypertensive retinopathy. The images are captured using Topcon 50EX, mydriatic camera with a resolution of 1504x1000. A MATLAB based annotation tool is used by our ophthalmologist to annotate vessels as arteries and veins in red and blue color respectively for comparison with our vessel classification results. This annotation is used as ground truth.

The vessel classification is performed using different classifiers. Their performance is measured on the base of accuracy , specificity, sensitivity, precision (PPV) and negative predictive value (NPV). The sensitivity shows the percentage of correctly classified abnormal cases while percentages of correctly classified normal cases are shown by specificity. Area under ROC (Receiver operating characteristic) curves (AUC) is also used as a performance measure Analysis. Experimental results are given in Table 2, showing performance on bases of different parameter.

ROC is curve [25] technique for visualizing, organizing and selecting classifiers based on their performance. The ROC is a graph of sensitivity (y-axis) vs 1 - specificity (x-axis). An ROC graph of four classifiers(ANN,Decission Tree, Nave bayes and SVM) is shown in figure 7, depicting relative tradeoffs between TP (number of blood vessels correctly classified) and FP (number of blood vessels wrongly classified) values.

V. CONCLUSION

Hypertension is cause of many retinal disorders; one of them is hypertensive retinopathy, which causes change in diameter of vessels. It can be detected by finding AVR ratio. Locally available database can be use to obtain Retinal fundus images for this purpose. In this research paper 2-D Gabor wavelet is used for the image enhancement and for segmentation of vessels is done by using multilayered thresholding approach. For computation of AVR, detection of optic disk is necessary .For this purpose, OD (area form where blood vessel emerge) is highlighted first and then ROI is find in which vessels are classified. Data mining classification tool Rapid miner with version 5.3 was used. Four different classifiers (Decision Tree, Artificial Neural Networks (ANNs) and Support Vector Machine (SVM) were applied on set of 100 images, taken form locally available database and SVM gave best results.

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