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CLASSIFICATION OF RETINAL VESSELS INTO ARTERIES AND VEINS

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Abstract—Retina is found at the back side of the eye ball. Severe problems may cause in the retina . Classification of retinal vessels into arteries and veins is an essential thing .Detection of various diseases like Diabetic Retinography has take advantage. It discusses about various existing methodologies for classification of retinal image into artery and vein which are helpful for the detection of various diseases .The AVR calculatioon is the process of calculation of average diameter of arteries to veins . Diabetic Retinography causes abnormally wide veins . Diseases like high blood pressure and pancreas also have abnormal AVR. So Classification of blood vessels into arteries and veins is important in many reason.

Keywords—Retinal Image, Fundus, Preprocessing, Vessel Segmentation, Classification.

I. INTRODUCTION

There are two types of Blood vessels of retina. They are Arteries and Veins. Arteries transport blood rich in oxygen to the organs of the body .Where as the veins transport blood low in oxygen level. Arteries are brighter but Veins are darker. For diagnosis of various diseases it is more essential to distinguish the vessels into arteries and veins. Diabetes retinography, high blood pressure, pancreas have abnormal ratio of the size of arteries to veins and is one of important symptom of these various diseases. For example diabetic patients have abnormally wide veins. Where as pancreas patients have narrowed arteries .High blood pressure patients have thickened arteries. To detect these diseases the retina has to be examined routinely. Blood vessel has to be segmented before classifying the blood vessels into arteries and veins. There are four important differences between arteries and veins:

- Veins are darker where as Arteries are brighter .
- Arteries are thinner than the veins.
- For Arteries the central reflex is wider but Veins have smaller central reflex.
- Near the optic disk veins and arteries are alternate to each other before branching out. Near the optic disk one vein is usually next to two arteries.

II. VARIOUS METHODOLOGIES FOR ARTERY AND VEIN CLASSIFICATION

2.1. First Methodology for Artery and Vein Classification

Three main steps are intrduced in “Automated characterization of blood vessels as arteries and veins in retinal images” . Image ehancement techniques are applied in the first step which is used to improve the images. To separate major arteries from veins specific feature extraction process is employed. Feature extraction and vessel classification are not applied to each vessel point .It is applied to each small vessel segment. The results obtained from the previous step are improved by applying a post processing step. The post processing step uses structural characteristics of the retinal vascular network. Some incorrectly labelled vessels are correctly labelled by this method. The vessels are labelled correctly based on the adjacent vessel .

- Stages of the method
- Image Enhancement
- Feature extraction and vessel classification
- Post-processing

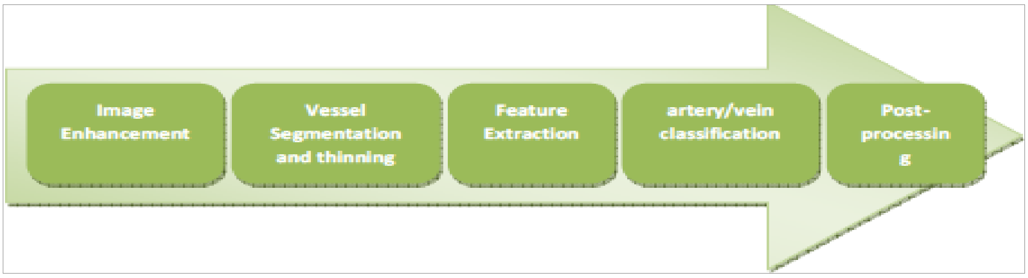

Figure 1.Stages of development

To enhance the contrast between arteries and veins in the retinal images ,Image enhancement is employed . Histogram matching algorithm is applied for normalizing the color through images. It takes two images as input. One is the source image C and the other is the reference image D and the image R is returned as output. Image C is transformed into Image R using the histogram matching algorithm. The histogram of resulted image R is approximately same as the histogram of the reference image D.

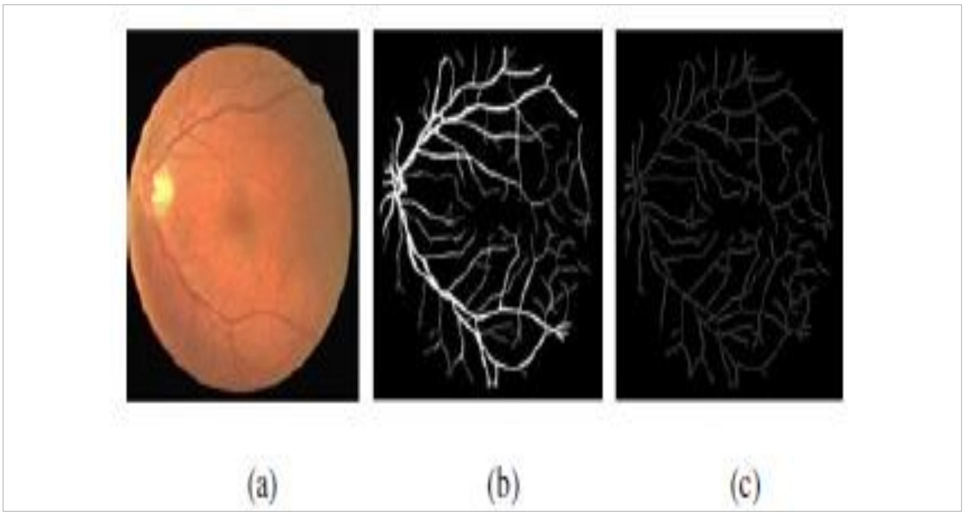

Figure 2. (a)Retinal image.(b)Vascular tree.(c)Skeleton of vascular tree

In the methodology author has used Gabor wavelets for feature extraction [8]. After the vessel is extracted, morphological structures is used to remove the vessel thinner than three pixels. Then for centerline points extraction, thinning algorithm [9,10] is applied. After extraction of centerline pixels of vessels bifurcation and cross-over points are discarded from vessel skeleton. Pixels in skeleton for which there are more than two adjacent pixels in the skeleton are cross over and bifurcation points . They indicate where two vessels pass each other or a vessel branches into two thinner vessels. Output of this step is a binary image of vessel segments .

For feature extraction forward feature selection methodology is used. It selects the most discriminant features which are used for training the classifier. Feature vector adds each and every feature. Final feature vector are found. The best features are selected and these features are used for the final classification of vessels. Green and red channels are used to select . This means arteries and veins are well differentiated in these two channels. Fuzzy clustering, SVM and LDA are examined for classification of arteries and veins. The job of this classifier is to assign an artery or vein label to each sub vessel segment.

Last step in this methodology is the Post-processing stage. First structural knowledge at bifurcation points and cross over are used to find connected vessels of same type. The structural knowledge includes two rules. If a bifurcation point has three vessel segments then all of the three vessels should beofsametype.

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2.2. Second Methodology for Artery and Vein Classification

The peculiarities of retinal images are exploited in a new algorithm for classifying the vessels. By applying a divide et impera approach a concentric zone around the optic disc are partitioned into quadrants. There by a more robust local classification analysis can be performed. Manual classification provided on a validation set were compared with the results obtained by this technique.
A previously developed algorithm is used in this methodology. This algorithm analyzes the background area of retinal image to detect changes of contrast and luminosity. Through an estimation of their local statistical properties derives a compensation for their drifts. The first task is to extract the vessel network in retinal fundus image. Vessel tracking procedure is used. To extract the vessel network Previously developed sparse tracking algorithm is used.
The retina is partitioned into four regions. Each region should

- Image preprocessing and vessel tracking
- Divide
- Feature Extraction
- Impera

have a reasonably similar number of veins and arteries. A concentric zone was identified around the optic disc. The fundus image is partitioned into four regions. Each containing one of the main arcs of the A/V network. They are superior-temporal,inferior,superior-nasal,inferior-nasal.

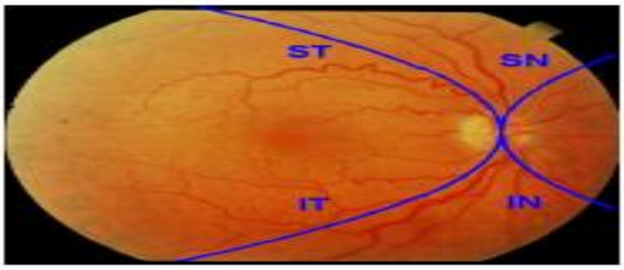

Figure 3. Principal arcades of the retinal vessel network

For this partitioning, first the position of the optic disc is identified.It's approximate diameter can be found either manually or automatically . The cardinal axes divide the retinal image into the four quadrants .That is quadi i = 1 2 3 4. The algorithm automatically detects 5 vessels having largest mean diameter which are named as S1, S2, S3, S4, and S5. Partitioned retinal image is shown in Figure 3. It avoids confusing small arterioles and venoules by selects only the main vessels . The balanced presence of veins and arteries holds in all four quadrants only if main vessels and their branches are considered.

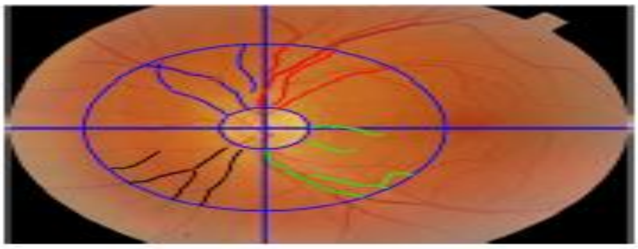

Figure 4.Partitioned retinal image

To find the most discriminant features for the A/V classification Author of this methodology [3] has performed an extensive statistical analysis. The best features to classify into an artery or vein is the mean of hue values and the variance of red values . The fact that the arteries and veins classes are differentiated by looking at their average homogeneity and hue of their red component is also in accordance with medical experience. When two vessels close to each other are compared for classification, the one having dark red is classified as vein. Then the one having lowest degree of uniformity is classified as artery.

After features extraction, vessels are labelled as arteries or veins based on the probability formulas and also by using fuzzy clustering algorithm .

2.3. Methodology for Artery and Vein Classification

"An automatic graph-based approach for artery/vein classification in retinal images" is an artery vein classification based on the graph extracted from the retinal vessel. The vascular tree based on the type of each intersection point this method classifies and assigning A/V label to each vessel segment. A vessel segment as A/V is labelled through the combination of a set of intensity features and graph based labelling.

- Overview of Methodology
- Graph Generation
- Vessel Segmentation
- Vessel Centerline Extraction
- Graph Extraction
- Graph Modification
- Graph Analysis
- A/V Classification
- Detection of Candidate New Vessels

The vascular network is represented as graph, in which each node represents an intersection point in the vascular tree, and each link between two intersection points corresponds to a vessel segment. Three-step algorithm is used by the author for generating the graph. First the vessel centrelines are extracted from the segmented images, then the graph needs to be generated from the centerline image, and finally some additional modifications are applied to the graph.

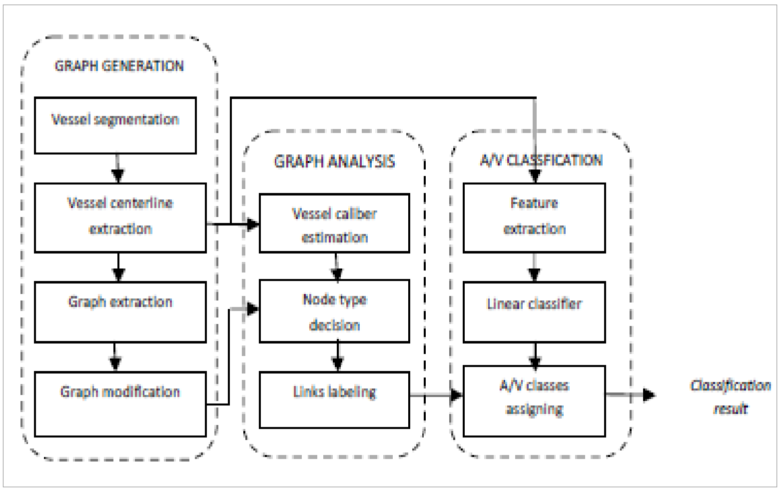

Figure 5.Block diagram for A/V classification

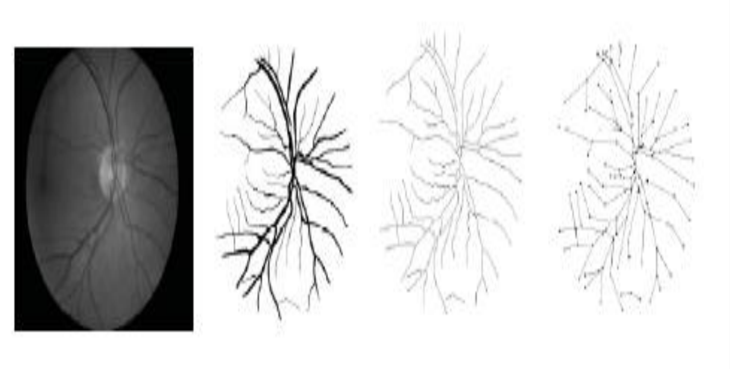

Figure 6.Graph generation

For extracting the graph, vessel segmentation result has to be used. The result is also used for estimating vessel calibers.

To obtain the centerline image an iterative thinning algorithm has to be applied to the vessel segmentation result. This algorithm removes border pixels from the segmented image. It is removed until the object shrinks to a minimally connected stroke. The segmented image is shown in Figure 4(b) where as its centerline image is shown in Figure 4 (c).

The graph nodes have to be extracted from the centerline image. By finding the intersection points and the endpoints or terminal points it is extracted. Intersection points are the pixels having more than two neighbours. Terminal points are the pixels with only one neighbor. In order to find the links between nodes , all the intersection points and their neighbors are removed from the centerline image .As result is an image with separate components which are the vessel segments. Each vessel segment is represented by a link between two nodes. The graph extracted from the centreline image Figure 4(c) is shown in Figure 4(d).

The extracted graph may include some misrepresentation of the vascular structure as a result of the segmentation and centerline extraction processes. The extracted graph should be altered when one of following errors is identified. The typical errors are

1. The splitting of one node into two nodes
2. Missing a link on one side of a node
3. False link.

The output of the graph analysis is a decision on the type of the nodes . By extracting the following node information node classification algorithm starts: node degree, the angles between the links, orientation of each link, the degree of adjacent nodes, and the vessel caliber at each link. Depending on the degree of node node analysis has four different cases. Four different cases and its possible node types are shown in Table 2. All links that belong to a particular vessel are identified and labelled. The final result is the assignment of two labels in each separate sub graph. Sub graph 1 links will be assigned with C11, C12 labels. Similarly Sub graph 2 links will be assigned with C21, C22 labels and so on.

Table 1.Four different cases and its possible node types

Cases	Possible Node Types
Case 1 – Nodes of degree 2	Connecting point Meeting point
Case 2 – Nodes of degree 3	Bifurcation point Meeting point
Case 3 – Nodes of degree 4	Bifurcation point Meeting point Crossing point
Case 4 – Nodes of degree 5	Crossing point

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The vessel structural information embedded in the graph representation is used in above described labelling phase. The final goal is now to assign one of the labels with the artery class (A) and the other with vein class (V). To allow the final classification between A/V classes the structural information and vessel intensity information are used. The 30 features listed in Table 1 are measured and normalized to zero mean for each centerline pixel. Some features shown in Table 2 were previously used . It has tested with classifiers like QDA, LDA, kNN. Here sequential forward floating selection is used for feature selection. It starts with an empty feature set and then improves the performance of the classifier by adding or removing features.

Table 2.List of features measurement for each centerline pixel

Nr.	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 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 (σ =2, 4, 8, 16) of Red and Green plane.

Several authors have described methods for segmenting normal retinal vasculature. Compared with the normal vasculature abnormal disc vessels are smaller and more tortuous. Detection is aided by the bright background of the lamina cribrosa.Which gives greater vessel/background contrast on the disc.The deep cup structure of the disc which means any distractors tend to be out of the vessel focal plane. The dark ridges formed by the vessel center lines may be detected using the ridge strength .

The Watershed transform is a morphological region-based segmentation operation. It divides an image into regions based on a topographic map of the image grey level. The watershed lines is the dividing lines between hypothetical topographical catchment areas . The grey level is inverted so that the vessel center lines form the watershed ridges. The dark vessels form topographical valleys in the retinal image.To prevent over-segmentation a 2-D Gaussian function was used to invert image .

By removing pixels at bifurcations candidate segments are separated with more than two eight-way neighbors. The Watershed transform generates closed regions connected by the watershed lines, not all of which represent vessels. To remove the non vessel segments candidates with mean values less than are discarded. Small segments consisting of fewer than seven pixels .

A SVM was chosen as the classifier for its rapid training phase and good classification performance. The original SVM algorithm is a linear classifier which finds the best hyperplane separating two classes. A kernel function can be used to transform the features to a higher dimensional space. Although the SVM finds a linear hyperplane in the transformed space, the chosen hyperplane is likely to be nonlinear in the original feature space.

III. CONCLUSION

It presents an automatic method for classification of retinal blood vessels into arteries and veins . Here only considering the major vessels for classificatioon. But for AVR measurement the method of considering only the main vessels maintains high classification rate for vessels in region of interest. The divide et impera procedure is another method.It is justified by the balanced layout of arteries and veins in retinal fundus and by using the local nature of the classification process. The result obtained on the images of the validation set is satisfactory. The graph based Artery and vein classification uses the information extracted from a graph which represents the vascular network and intensity feature for discriminating between arteries and veins.This A/V classification methodology is reliable for the calculation of several characteristic signs associated with vascular alterations.

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