Wavelet Based blood Vessel Segmentation in Retinal Image Analysis

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***Abstract*—Retinal image analysis is currently a very vivid field in biomedical image analysis. Retinal image can be analyzed to detect a number of cardiovascular diseases as well as diseases of the eye proper. One important component of the retinal image analysis is blood vessel segmentation. Blood vessels carry a lot of information regarding various disease conditions. Blood vessels segmentation can be carried out by a number of methods. Of this methods the wavelet based methods are found to be most efficient as it provides both time and frequency components. Here we propose a wavelet based technique for blood vessel segmentation. We take manually generated blood vessel segmented images as the ground truth and compare our results with it to attain various parameters such as sensitivity, specificity and accuracy. The images generated by our method can be utilized for taking decisions regarding disease symptoms of which are known using using retina images.**

I. INTRODUCTION

Retinal images carry information about various opthalmological disorder conditions as well as cardiovascular diseases. Extracting this information can enable us to detect such disorders at an early stage so that they can be diagnosed and managed. The clinically important features of the retina are -Optic disc, macula and the blood vessels .The ophthalmologists check this features to detect various eye related disease. A fundus camera is used for capturing the image of the retina [2] .Then this image can be further processed to extract the various clinically important features. Retinal images can be analysed for detection of the optic disc, the macula, the blood vessels or the pathogens. Of this blood vessel segmentation holds the most importance.Blood vessel segmentation algorithms are a fundamental component in retinal disease screening systems. Blood vessel segmentation also enables us to detect the other clinically important features i.e. the macula and the optic disc. Our contribution to the work is identifying which sub-bands carry the most information about blood vessels during wavelet decomposition and using the same to reconstruct the blood vessel segmented image and then checking the quality of the segmented image in terms of various parameters such as sensitivity and accuracy [4] In the paper we have given a brief introduction about wavelet Decomposition [6]. Then we have discussed the system model implemented by us to segment the blood vessels. Finally we have set certain parameters to determine the quality of our output images.

II. THEORETICAL BACKGROUND

The multiresolution or multiscale property of DWT offers, features that are difficult to detect at one scale may be easily detected at another scale. The multiresolution analysis (MRA) technique [3] which helps to produce localized image features with good space-frequency resolution can be explored for the analysis of image components. The retinal images contain fine anatomical features such as blood vessel structure and coarse features [1] or regions with slowly varying pixel values such as the optic disc and homogeneous retinal background. The anatomical structure of the retina is dominated by the blood vessel structure and they have a high diagnostic impact. In a retinal image, different blood vessels have different resolutions. The main thick vessel branches into thin vessels and spreads all over the retina.

Multiresolution property of wavelets can be used to analyze the retinal vessel features. The directional property is another important characteristic of the vessel structure. Since two dimensional DWT (2D DWT) can decompose the image in several directions, the vessel details in different orientations can also be studied. A wavelet transform is implemented as a bank of filters that decompose a signal into multiple signal bands. It separates and retains the signal features in one or a few of these sub bands. Thus, one of the biggest advantages of using the wavelet transform is that signal features can be easily studied. The wavelet decomposition of an image produces several sub images or sub bands. Each of the sub band contains information at a specific scale/frequency and along a specific direction. These subbands may contain significant information or less relevant information to describe image features (content). Hence an N-level DWT will yield (3N+1) subbands and each level contains H, V and D subbands. The approximation band of the final decomposition level and three detail bands of each level together forms a decomposition vector written as [A(N), H(N), V(N), D(N), H(N-1), V(N-1), D(N-1), ... , H(1), V(1), D(1)]. It is important to know the importance of each sub-band with respect to the blood vessel information carried by it [5].

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I. SYSTEM MODEL

This image was decomposed to 5-levels using biorthogonal filter (bior6.8)[2]. This filter was chosen after evaluating the performance of different wavelet filters for retinal image processing. After 1st level wavelet decomposition the image is decomposed into 4 sub-bands mainly approximation, horizontal, vertical and diagonal band. Each horizontal, vertical and diagonal band carry information of the blood vessels in the horizontal, vertical and diagonal directions respectively and all of them are high frequency bands. The approximation band is the low frequency band which is used to reconstruct the original image. The WLD process gives the multiresolution property which helps in extracting out the image features in more details. A 5 level decomposition is applied to the image to get a total of (3*5) 15 sub-bands and one approximate band of the 5th level. So all the 15 high frequency sub-bands have detailed blood vessel features of the image. Each level is reconstructed making its significant sub-band zero as shown in Figure. 1 It can be observed that levels 2, 3 & 4 have relatively more blood vessel [7] information than the other levels i.e. 1 & 5. A background image is reconstructed making the sub-bands of the level 2, 3 & 4 zero as shown in Figure. 2(b) this background image consist mainly of the background pixels which carry minimal blood vessel information. Next the background image is subtracted from the original image to get the difference image having only the blood vessel information which is being normalized to get a normalized difference image having pixel values in the range [0, 1]. This helps in making all the small valued pixels as background pixels. Figure. 2(c) shows the normalized difference image. So, finally post processing of the image is done where a mask image of the corresponding image which being used in the process is multiplied to the normalized difference image to remove the edges. A histogram of the image shown in Figure. 3(a) is generated to chose a threshold value for segmenting the blood vessel pixels from the background pixels. Finally the segmented blood vessel images shown in Figure. 3(b) is compared with manually generated blood vessel segmented images shown in Figure. 4 and various parameters such as sensitivity and accuracy are calculated.

III. RESULTS

The result of vessel segmentation in retinal images is a pixel classification based process. Each pixel is classified either as foreground (vessel) or background (no vessel). This leads to four possible events: true positive (TP), true negative (TN), false positive (FP) and false negative (FN) [4] The correctly classified pixels as a vessel or no vessel are indicated by TP and TN whereas misclassifications are indicated by FP

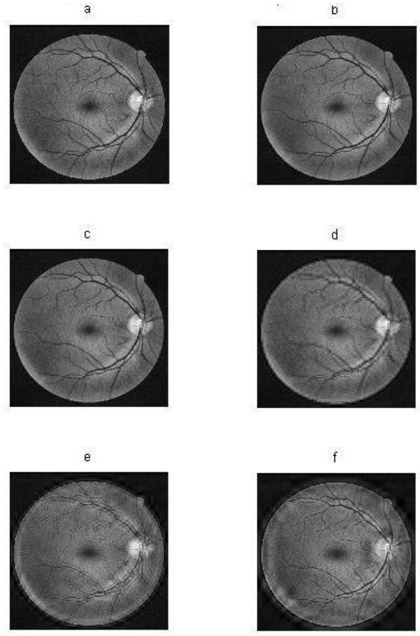

Fig. 1. (a) Original image and reconstructed images when subbands coefficients' of (b)L1, (c)L2, (d)L3, (e)L4 and (f)L5 are made zero.

And FN respectively. In the present work, the proposed vessel segmentation performance is assessed in terms of sensitivity (Se), specificity (Sp) and accuracy (Acc). These metrics are defined as, These metrics are defined as,

1) $Se = TP/(TP + FN)$

2) $Sp = TN/(TN + FP)$

3) $Acc = (TP + TN)/'(TP + FN + TN + FP)$

After we get the normalized error image, a simple thresh holding is performed, as mentioned above,to separate the actual vessel pixels from those actually belonging to the background. To perform the thresholding we have to consider a threshold value which is a important parameter in the process [1]. To set the threshold value we use the histogram of the vessel image. We make a number of observations by changing the threshold value. We observe for different threshold values as the sensitivity increases, accuracy decreases. So we have to reach a trade-off to get the best possible output. It is observed that for a threshold value of 0.085 we get the most suitable output [8]

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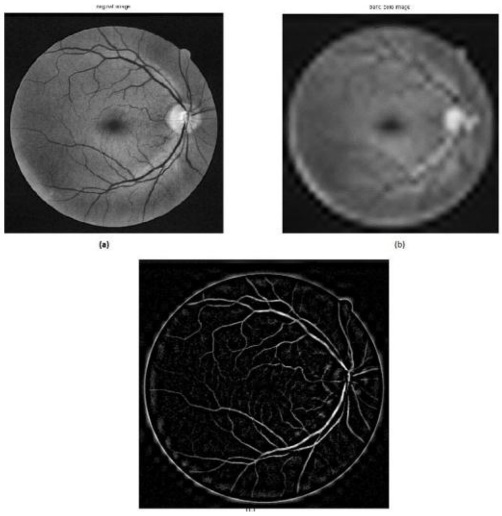

Fig. 2. (a) Original image (b) Background retinal image generated (c)After background subtraction and normalization

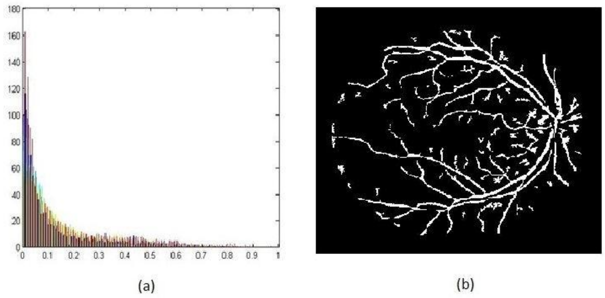

Fig. 3. (a) Histogram image (b) Blood Vessel segmented image.

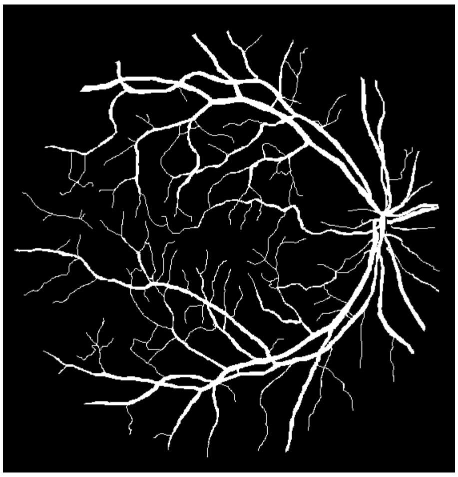

Fig. 4. Manually segmented image.

TABLE I SENSITIVITY,SPECIFICITY AND ACCURACY TABLE

Threshold	Sensitivity	Specificity	Accuracy
.080	.6791	.9690	.9297
.085	.6472	.9811	.9569
.090	.6068	.9846	.9581
.095	.6523	.9837	.9615

I. CONCLUSION

We have done the retinal image analysis by BV segmen- tation as it is useful in early detection of retinal diseases. Retinal images are taken from the DRIVE database and the proposed method is implemented on all the 40 images of the database [2].We have calculated specificity, sensitivity and accuracy for each image and the average value of all three parameters are determined and shown in the table above. Five-level decomposition is performed on the retinal images generating fifteen detail subbands and one approximation band. The fifteen details sub band can be put into 5 groups according to the level of transformation: level-1(L1),level- 2(L2),level-3(L3),level-4(L4) and level-5(L5) [10].Each of the subbands contains information about the retinal image. The diagnostic importance of each level subbands is examinees by zeroing the coefficients of the subbands and keeping all other sub band coefficients unchanged. The analysis of retinal images using the DWT shows that the significant information about blood vessels is captured by only a few subbands while other subbands carry minimum information of the blood vessels. This observation is exploited to propose a new method for the segmentation of blood vessel. The retinal images from the DRIVE database are used for evaluating the performance of the vessel segmentation method [10] and the performance of the method is analysed.

For each of the images a corresponding manually segmented image is provided. The manually segmented vessels provided in both the databases are used as gold standard for analyzing the performance of our method. We take various parameters such as sensitivity, specificity

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and accuracy to determine the quality of our output results. The output images generated by our method can be utilized in various ways such as to determine the A/V ratio used to determine the presence of cardiovascular diseases.

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