Design New Biorthogonal Wavelet Filter for Extraction of Blood Vessels and Calculate the Statistical Features

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Abstract. World health organization predicts that in year 2012 there are about 347 million people worldwide have diabetes, more than 80% of diabetes deaths occur in different countries. WHO projects that diabetes will be the 7th major cause leading death in 2030. Diabetic Retinopathy caused by leakage of blood or fluid from the retinal blood vessels and it will damage the retina. For extraction of retinal blood vessels we have invent new wavelet filter. The proposed filter gives the good extraction result as compare to exiting wavelet filter. In proposed algorithm, we have extract the retinal blood vessels features like area, diameter, length, thickness, mean, toutrtosity, and bifurcations. The proposed algorithm is tested on 1191 fundus images and achieves sensitivity of 98%, specificity of 92% and accuracy of 95%.

Keywords: Wavelet Filter, Retinal Blood Vessels, Area, Diameter, Length, Thickness, Mean, Toutrtosity, Bifurcations.

1 Introduction

Diabetes, which can be characterized as a continuing increase of glucose level in the blood. Diabetes has become one of the most fast increasing health intimidations worldwide. Diabetic retinopathy is the highest common diabetic eye disease, occurs when blood vessels in the retina changes unusually. For extraction of diabetic retinopathy lesions the digital image processing techniques is widely used by the researcher. In proposed algorithm we have design new wavelet filter for extraction of retinal blood vessels. A wavelet is a localized function that can be used to capture informative, effective, and useful descriptions of a signal. If the signal is characterized as a function of time, then wavelets provide efficient localization in both time and either frequency or scale. Despite its short history, wavelet theory has established to be a powerful mathematical device for analysis and synthesis of signals and has found effective applications in a noteworthy diversity of disciplines such as physics, geophysics, numerical analysis, signal processing, biomedical engineering, statistics, and computer graphics. Number of basic functions that can be used as the mother

[1] Please note that the LNCS Editorial assumes that all authors have used the western naming convention, with given names preceding surnames. This determines the structure of the names in the running heads and the author index.

wavelet for wavelet transformation. Since the mother wavelet produces all wavelet functions used in the transformation through translation and scaling, it governs the characteristics of the subsequent wavelet transform [7-13].

The authors proposed a method to support a non-intrusive analysis in current ophthalmology for early detection of retinal infections, treatment assessment or clinical study. This study emphasizes on the bias correction and an adaptive histogram equalization to enhance the retinal blood vessels. Formerly the blood vessels are extracted by probabilistic modelling that is improved by the expectation maximization algorithm. For evaluation these results STARE and DRIVE fundus image database is used [1]. The proposed method use the mathematical morphology and a fuzzy clustering algorithm with purification procedure. The proposed algorithm has tested on retinal images, and experimental results show that the algorithm is very effective for retinal blood vessels extraction [2].

2 Methodology

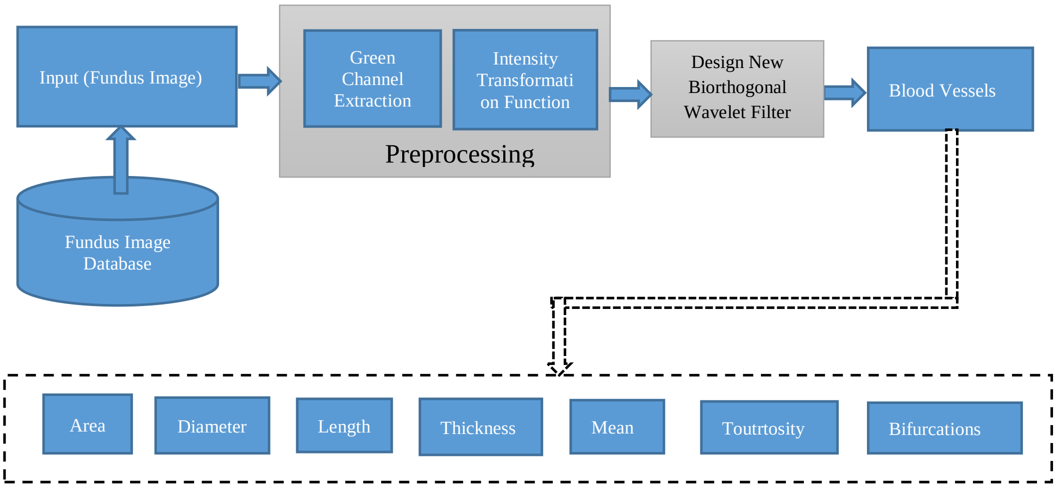

Figure 1. Workflow for extraction of retinal blood vessels and calculate the statistical features

The block diagram proposed system is depicted in the figure 1. Initially preprocessing is done for fundus image enhancement. For this preprocessing we have extracted the green channel and then apply intensity transformation function. Aftrerward design new wavelet filter for extraction of retinal blood vessels.

2.1 Biorthogonal Wavelet

The biorthogonal wavelet transform is invented of the decomposition process and the reconstruction process by using two different wavelets Ψ and $\widetilde{\Psi}$. Ψ is used in the decomposition process, and $\widetilde{\Psi}$ is used in the reconstruction method. Ψ and $\widetilde{\Psi}$ are the dual and orthogonal to each other, and this association is called biorthogonal. There are two scale functions ϕ and $\tilde{\phi}$ in the above processes, these two scale functions are also dual and orthogonal. One is used in the decomposition process, and the second is used in the reconstruction process. So, there are four filters in biorthogonal wavelet transform. They are the decomposition low-pass filter $\{h_n\}$, the decomposition high-pass filter $\{g_n\}$, the reconstruction low-pass filter $\{\widetilde{h_n}\}$ and the reconstruction high-pass filter $\{\widetilde{g_n}\}$ [5].

2.2 Discrete Cosine Transform (DCT)

As for discrete cosine transform (DCT), we have

$$C^T(i,j) = \begin{cases} \frac{1}{\sqrt{N}}, & j = 0, \quad i = 0,1,\dots,N-1 \\ \sqrt{\frac{2}{N}} \; cos\frac{j(2i+1)\pi}{2N}, & j = 1,2,\dots N-1, i = 0,1,\dots,N-1 \end{cases} \tag{1}$$

$$H_i(j) = \sum_{i=0}^{N-1} C^T(i,k)C(k,j)F(k), \quad i,j = 0,1,\dots,N-1. \tag{2}$$

When Equation (2) is applied to Equation (1),

$$H_i(j) = \frac{1}{N}\left[F(0) + \sum_{k=1}^{N-1} 2cos\frac{k(2i+1)\pi}{2N} cos\frac{k(2j+1)\pi}{2N} F(k)\right]. \tag{3}$$

Because of $H_i(j) = H_j(i)$, we get

$$Q(n) = Q(-n), n - 0,1,\dots,N-1. \tag{4}$$

Therefore, the frequency response of the system is

$$H(e^{j\omega}) = Q(0) + 2\sum_{k=1}^{N-1} Q(k)\cos(k\omega). \tag{5}$$

So, the system has strict zero phase characteristics and is an all phase filter.

2.3 Design of Biorthogonal Wavelet

2.3.1 Filter Coefficients Solver

The transfer function of Discrete Cosine Sequency Filter (DCSF) in DCT domain can be gotten with Equation (5):

$$H(z) = Q(0) + \sum_{k=1}^{N-1} (Q(k)z^k + Q(-k)z^{-k}). \qquad (6)$$

Obviously, $\boldsymbol{Q}_{1/2}$ is consistent to the coefficients of each decomposition and reconstruction filter. Because of the strict zero-phase characteristic, we know $Q(k) = Q(-k)$. It means that coefficients of the biorthogonal wavelet transform must meet the requirement of symmetry

$$h_{2k-n} = h_n, g_{2k-n} = g_n, \tilde{h}_{2k-n} = \tilde{h}_n, \tilde{g}_{2k-n} = \tilde{g}_n. \qquad (7)$$

In different wavelet transforms, $\boldsymbol{Q}_{1/2}$ is consistent to different filters $\{h_n\}, \{g_n\}, \{\tilde{h}_n\} and \ \{\tilde{g}_n\}$ the details are described as follows:

Decomposition filter: low-frequency $Q_L(k) = h_k$, input signal $x(n)$; high-frequency $Q_H(k) = g_{k+1}$, output signal $x(n+1)$.

Reconstruction filter: low-frequency $Q_L(k) = \tilde{h}_k$, input signal $x(n)$; high-frequency $Q_H(k) = \tilde{g}_{k+1}$, output signal $x(n+1)$.

Having transfer function of the system, the method for solving the coefficients of each filter is as follows:

(1) Firstly, the filter order is defined as *N*, in corresponding filters $\{h_n\}, \{\tilde{h}_n\}, \{g_n\}, \{\tilde{g}_n\}, N = \max(n) + 1$;

(2) If $\boldsymbol{Q}_{1/2}$ is recognized, the filter parameter F can be obtained.

2.3.1 Design New Wavelet Filter using MATLAB

Step 1: Create a biorthogonal wavelet of type 2

Step 2: Create the two filters linked with the biorthogonal wavelet and save them in a MAT-file.

Rf = [1/2 1/2];

Df = [7/8 9/8 1/8 -1/8]/2;

Step 3: Add the new wavelet family to the pile of wavelet families.

Step 4: Display the two pairs of scaling and wavelet functions.

Step 5: We can now use this new biorthogonal wavelet to analyze a signal/image.

After extraction of retinal blood vessels, calculate its statistical features like area, diameter, length, thickness, mean, tortuosity and bifurcation points.

3 Result

For evaluation of this algorithm use some online databases and local fundus image database following table show the details of databases.

Table 1. Fundus image database

Sr. No	Name of Fundus Database	Total images
1	SASWADE	500
2	STARE	402
3	DRIVE	40
4	Diarect DB 0	130
5	Diarect DB 1	89
6	HRF (Diabetic Retinopathy)	15
7	HRF (Glaucoma)	15
	Total	**1191**

For extraction of retinal blood vessels we have proposed the biorthogonal wavelet filter by using Matlab software [14-15]. After designing the new filter we compare the results with the existing filter such as symlet wavelet. Based on the statistical features like, area, diameter, length, thickness, mean, toutrtosity and bifurcation points of blood vessels. We can say that the proposed filter is good as compare to the existing filter. Following table shows the features of retinal blood vessels by proposed biorthogonal wavelet filter.

Table 2. Features of retinal blood vessels by proposed biorthogonal wavelet filter (RRM)

Sr. No	Area	Diameter	Length	Thickness	Mean	Tortuosity	Bifurcation Points
1	20	14	9.95	2	20	2	651
2	33	18	4.7	2	19	4	1434
3	27	17	8.5	2	19	2	677
4	31	18	6.42	2	19	4	148
5	22	15	5.66	2	20	3	309
6	40	20	5.71	2	20	2	619
7	74	27	8.26	2	20	1	509
8	37	19	6.32	2	19	2	186
9	38	20	5.86	2	20	3	404
10	42	21	6.44	2	20	3	933
11	37	19	7.55	2	19	1	205
12	78	28	8.16	2	20	3	426
13	26	16	5.5	2	20	5	907
14	48	22	6.24	2	20	3	418
15	104	32	9.95	2	20	2	651

Table 3. Features of retinal blood vessels by existing wavelet filter (symlet)

Sr. No	Area	Diameter	Length	Thickness	Mean	Tortuosity	Bifurcation Points
1	17	13	6.71	2	19	2	649
2	15	12	7.67	2	19	4	1431
3	18	14	5.8	2	20	2	675
4	20	14	10.59	2	20	2	147
5	19	14	9.37	2	19	3	306
6	18	14	9.47	2	20	2	616
7	33	18	12.63	2	19	1	500
8	25	16	10.56	2	19	2	187
9	20	14	9.83	2	20	3	405
10	27	17	10.42	2	19	3	930
11	19	14	9.04	2	19	1	203
12	42	21	12.71	2	20	3	421
13	18	14	9.33	2	20	5	903
14	27	17	10.03	2	19	3	415
15	45	21	14.75	2	20	6	649

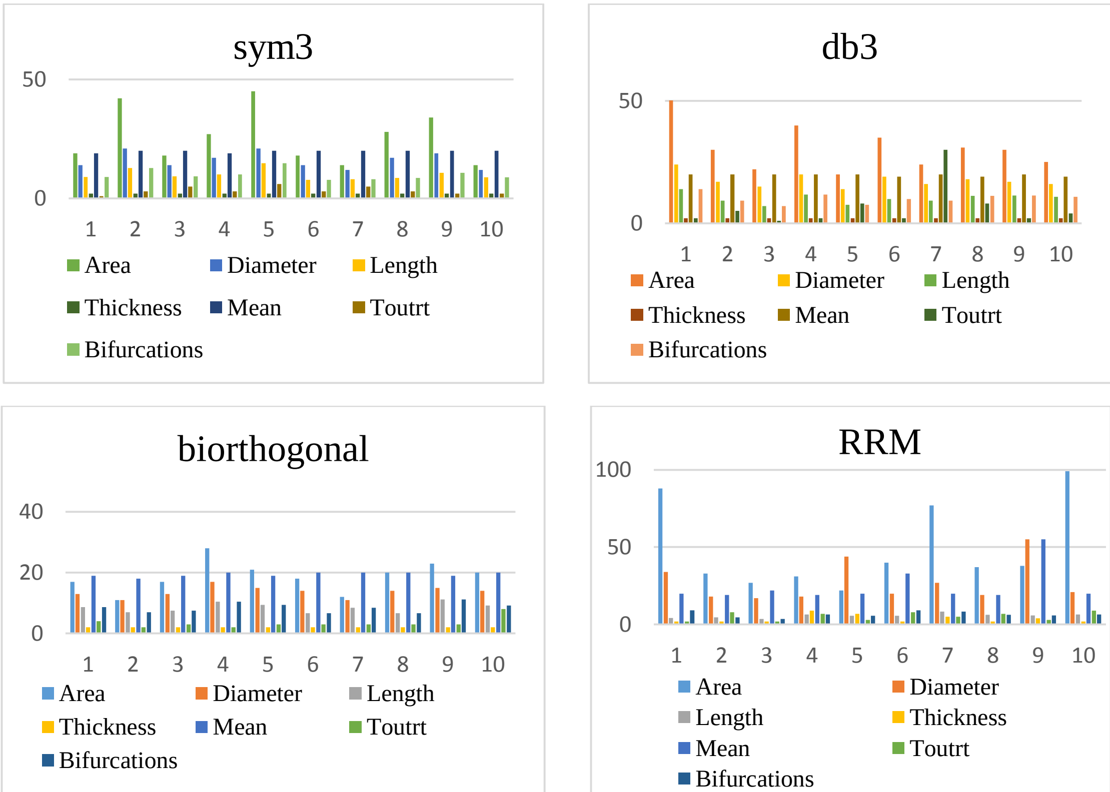

Figure 2. Features of retinal blood vessels by existing symlet filter verses proposed new wavelet filter

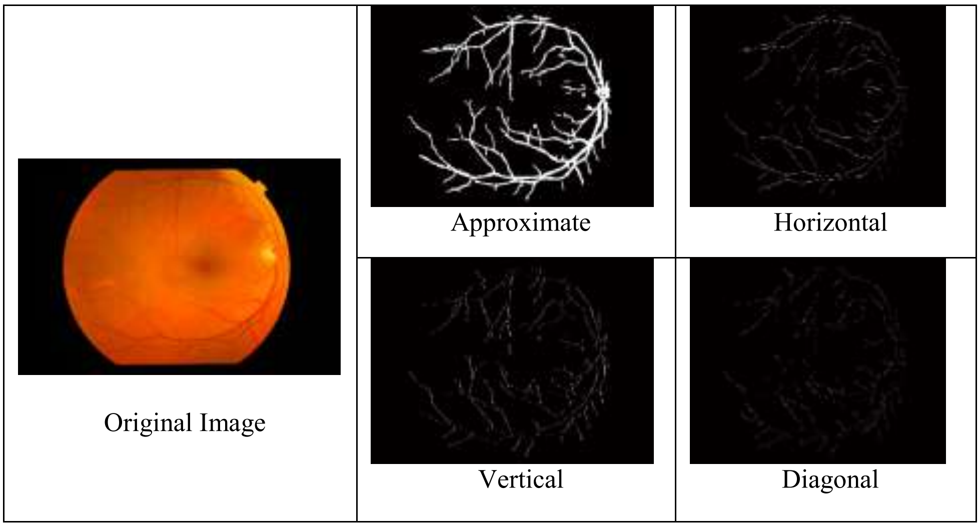

Figure 3. Retinal blood vessels extraction using proposed wavelet filter (RRM)

4 Conclusion

The result projected in this research article were obtained on SASWADE database and performance method were compared with STARE, DRIVE, DIARECT DB0, DIARECT DB1 & HRF database also. The features of retinal blood vessels which is extracted by the proposed “RRM” filter is compared with the existing “Symlet (sym3), daubechies (db3) and biorthogonal (bio3.3, bio3.5, and bio3.7)” wavelet filter for the validation purpose. And based on the statistical features (area, diameter, length, thickness, mean, toutrtosity and bifurcation points) of retinal blood vessels, we conclude that the proposed filter gives more features as compare to the existing wavelet filters. The performance analysis is done by using receiver operating characteristic curve. The proposed algorithm achieves sensitivity of 98%, specificity of 92% and accuracy of 95%.

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