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# Wavelet filter techniques for segmenting retinal blood vessels

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A B S T R A C T

Retinal fundus image is generally used to examine the diabetic retinopathy symptoms, by analysing blood vessel segmentation and also access the pathologies of the eye. Retinal blood vessel details can be mined from retinal fundus images through image processing. Processing involves three stages, Pre-processing, Segmentation, and Post-processing. Among the different segmentation algorithms existing, the wavelet filter method has been shown to be highly advantageous in distinguishing blood vessels effectively. Under this method, the objects in noisy background can be segmented and hence sort out the image from the background in a finer way. Retinal images obtained from retinal databases like DRIVE and STARE can be analysed using the wavelet filter algorithm. Herein wavelet filter method will be evaluated for efficient segmentation of the retinal blood vessels using retinal images obtained from databases.

## 1. Introduction

Difference in blood vessel diameters takes place as part of the independent control of blood flow in healthy person and can be according to the altered stages in the pulse cycle (Knudtson et al., 2004), while continued change in the diameter may also point towards the existence of some pathology (Patton et al., 2006). Retinal vessel narrowing can be related to incidents of coronary heart disease in women occurrence of stroke and diabetes in men and women (Wong et al., 2002). Narrowing of the retinal vessels can also be related with hypertension, ageing, inflammation and other processes.

Investigation and recognition of fundamental alteration on the retinal blood vessel are very significant to identify and sense retinal disease such as diabetic hypertension, retinopathy, arteriosclerosis and age-related macular degeneration (AMD) (You et al., 2011). Premature symptoms of such sicknesses are pointed out by features of retinal blood vessel like length, diameter, angle, and tortuosity (Martinez-Perez et al., 2002). Retinal blood vessel is the only part of the blood circulation that could be directly observed and studied in detail (Mansour et al., 2013). Retinal imaging is additionally utilized to decide on retinal

normality and to identify or supervise retinal irregularities and defects like modifications in thickness and tortuosity of the retinal blood vessel are pointers for increased risk levels of diabetic retinopathy (Owen et al., 2011). Thus retinal irregularities and defects are mainly prominent in diabetic retinopathy (DR) which is a vascular impediment of diabetes mellitus and is a major reason of vision loss among diabetic patients. For patients suffering from diabetes, it is important that diabetic retinopathy be monitored and detected at the earliest and avoid vision loss (AOA, 2014).

Identifying malformations like venous looping or beadings is important for before time action as they are in general warning of probable sight-threatening retinopathy. To make use of these valuable descriptions of retinal blood vessels, it is imperative to evaluate their position and shapes precisely (Sharma and Kothari, 2017). In order to analyse the retinal blood vessels, retinal fundus images are collected and processed to analyse blood vessel segmentations (Mansour, 2016). The processing of these imagines includes pre-processing, segmentation and post-segmentation.

During pre-processing, noise on the retina image is removed, while during segmentation aberrations in blood vessel can be detected using various methods, such as watershed algorithm, probabilistic filters, wavelet filter algorithm, Gabor filter (Li et al., 2006). Subsequently, blood vessel abnormalities previously undiscovered in retinal imaging can be detected using these segmentation procedures (Aras

et al., 2016). Fig. 1 presents various features of the generic DR image.

Programmed segmentation decreases the time required for physical labelling and analysis of retinal images. Therefore a dependable vessel segmentation process like wavelet filter method will be important for premature detection of changes in the retina due to diseases like diabetes. The objective of the paper is to evaluate the advantages of Wavelet Filter method for segmenting retinal blood vessels during image signal processing.

## 2. Literature review

### 2.1. Overview of the segmentation process

Every retinal fundus image undergoes processing before the blood vessels can be analysed, which are divided into pre-processing stage and segmentation stage. Moreover, several databases are also maintained of such retinal fundus images, for the purpose of comparative analysis and research for practitioners and researchers.

### 2.2. Retinal image database

In medical science, an important instrument for the dependable assessment and comparison of algorithms related to image processing is a database that consists of a particular group of medical images of high-quality (Kauppi et al., 2006).

Such images serve as base for diabetic retinopathy analysis and can be extracted from retinal image database. There are many retinal databases available namely digital retinal image for vessel extraction, STARE database, HRF, ARIA and are presented in Table 1 (Aras et al., 2016).

These databases hold extensive collections of retinal images that can help researchers in analysing and comparing retinal images using different segmentation algorithms.

These databases typical consist of retinal images of healthy as well as patients suffering from diabetic retinopathy. Besides these, many other databases are also available, such as ROC Microaneurysm Set, *CHASE_DBI Database* and Retinal Vessel Tortuosity Dataset (Aras et al., 2016).

**Table 1:** Retinal images databases

| S. No. | DATABASE | DESCRIPTION |
|---|---|---|
| 1 | DRIVE Database | • Publically available database of fundus images collected from 435 people in Netherland, age group of 31-86 gathered via diabetic retinopathy screening program. <br> • 40 images in the database, of which 20 are training images and 20 test images stored in 24-bits color, size of 768 × 584 pixels (Chhabra and Bhushan, 2014). |
| 2 | STARE Database | • Facilitates blood vessel segmentation. <br> • Stores 20 images of size 700x605 pixels with 8 bit per colour channel (Zhao et al., 2014). |
| 3 | HRF | • Facilitates comparative studies on retinal images using automatic segmentation algorithms. <br> • Contains 45 images divided into three sets of fundus images: 15 of glaucomatous, 15 of healthy and 15 of diabetic retinopathy subjects (Odstrčilík, 2014). |
| 4 | ARIA Online | • Database consists of three groups: 59 images of infected retinas under diabetes group, 61 images of control group and 92 images of macular degeneration group based on age (Fraz et al., 2012). |
| 5 | Image RET | • Database divided into two sub-databases, DIARETDB0 and DIARETDB1 (Fraz et al., 2012) <br> • DIARETDB0- 130 retina images, of which 20 are normal images and remaining 110 images include images with a variety of symptoms of diabetic retinopathy. <br> • DIARETDB1- 89 retina images of which 5 images are healthy images and rest are with symptoms of diabetic retinopathy |
| 6 | Messidor | • Largest database of 1200 retina images. <br> • Images collected from 3 ophthalmology departments with the resolutions of 1440x960, 2240x1488, and 2304x1536 pixels respectively <br> • TIFF format images |

### 2.3. Pre-processing procedures

Pre-processing includes a group of procedures that are used to remove error or sound from the retina images and to augment the contrast value on fundus images and further increases the accuracy of the image via correcting the brightness and normalisation (Aras et al., 2016). Pre-processing procedures involve Brightness Level Equalization which uses green channel as feature descriptor since green channel produces highest contrast on retina image thereby distinguishing the features (Saleh et al., 2011). Further image normalisation is used for colour alteration, brightness rectification and contrast augmentation (Kumar et al., 2012). Hue channel escalates the contrast of blood vessels (Relan et al., 2014) and Homomorphic filtering is used for image improvement and rectification by regularizing the brightness of the entire image

(Mustafa et al., 2014). Finally high pass filter is used to make the image sharper and make it clearer.

Contrast Enhancement is also used as a pre-processing procedure wherein morphological operation are used for vessel development, brighten the lesions and soften the optic disc, blood vessel's enhancement (Akram et al., 2012; Sun et al., 2011). Gabor wavelet method is used to augment the slender and hardly visible patterns in vessels. Finally Histogram equalization is used to allocate intensity value of an input image to generate output with levelled intensity.

### 2.4. Post-processing procedures

Post-processing step is conducted to progress the segmented image. Post-processing process is used to enlarge, sharpen, and accurate the results of the process of segmentation and helps in accurate

analysis and detection of blood vessels. The post-processing process eliminates the redundant region and makes the vessel as major point of concentration. Correctness of segmentation can also be enhanced via post processing procedures (Li et al., 2012) after which the salt and pepper noise is removed using a 3x3 median filter. Isolated pixel can be removed using length filtering and morphological operators (Patankar et al., 2013). Further a two-stage process was proposed by Zhao et al. (2014) for final segmentation result to obtain a clear blood vessel for analysis from the retinal image. The first step involves combining is various retinal vessel segmentation results using the region growing and level set method. The step two involves eliminating fake detection of the standalone vessel pixels.
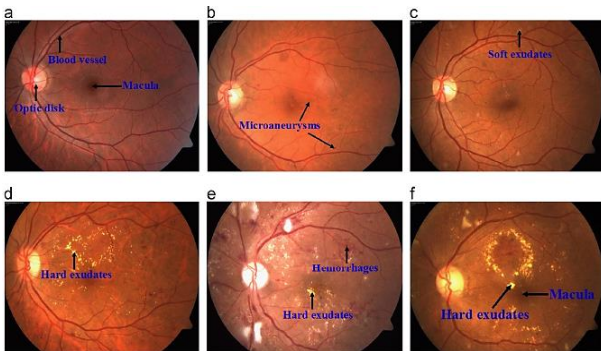


**Fig. 1:** Varied features of the diabetic retinopathy image (Mansour, 2017)

## 3. Wavelet filter method for segmentation of retinal blood vessel: Overview

Retinal images are images that are obtained by creating photographs of backside of eye and are also called fundus or ocular images (Jadhav and Patil, 2015). Retinal blood vessels measurement and detection can be used to categorize the disease' rigorousness. Segmentation procedure involves sorting out background and foreground regions in the image. The foreground regions involve the clear retina area containing the vessels while the background includes the regions outside the boundaries of the retina area which is the noise or not required area (Mansour, 2012). Retinal blood vessels segmentation contains quantifiable alteration in diameter, branching angles and length, effect of disease (Lee, 2006). Therefore, dependable method of blood vessel segmentation and extraction is important for recognition and categorization of alteration. Mainstream methods used for vessel segmentation are based on watershed algorithm, probabilistic filters, wavelet filter algorithm, Gabor filter and such methods (Li et al., 2006) out of which in this study wavelet filter method will be used for segmenting retinal blood vessels.

A wavelet is a wave-like alternation with amplitude that starts at zero, increases, and then decreases back to zero that is of limited duration instead of stating from minus infinity to plus infinity as the case of continuous sinusoidal wave. Wavelets are used to build an image pyramid which

symbolizes the entropy levels for each frequency which is used to segment objects in noisy images based on their frequency reaction in a variety of frequency bands, sorting them out from the background and from other objects. They are designed to display precise possessions that make them helpful for signal and wave processing. Thus, a wavelet filter consists of finite number of discrete points (Gavlasová et al., 2006). Joshi and Karule, (2012) gave a process to divide the retinal vessel by means of two-dimensional administered categorization and Morlet wavelet. This research creates segmentations by classifying each pixel of image as non-vessel or vessel based on the feature vector (FV) in pixel. Feature vector are concerned with strength of pixels and uninterrupted two dimensional Morlet wavelet transforms were well thought-out. In a research conducted by Akram et al. (2009) a two-dimensional advancement of Gabor wavelet was developed for programmed segmentation of blood vessels (BV) which is effectual for treatment of images in the vessels under dissimilar conditions with rational dependability and correctness for medical analysis. Shabbir et al. (2013) evaluated and estimated the automated process for blood vessels improvement and segmentation in RI. It was established that Gabor wavelet and global threshold method is better for the improvement and segmentation of vessel. Table 2 show comparison between some techniques for segmentation of retinal blood vessel.

The Figs. 2, 3, and 4 describe the Daubechies wavelet filter for different lengths. These are family of orthogonal wavelets defining a discrete wavelet transform. Further, the formula applicable in any wavelet filter algorithm is related to the basic function of the wavelet. For any $L$ function $f(x)$, the continuous wavelet transformation is defined as a function of two variables.

$$CWT_f(a,b) = (f, \psi_{a,b}) = \int f(x)\overline{\psi_{a,b}(x)}dx.$$

Here the dilation and translation parameters, $a$ and $b$, respectively, vary continuously over R\{0} × R.
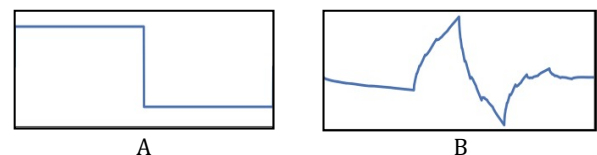


**Fig. 2:** Daubechies Wavelet External Phase filters. (A) Filter with length 2. (B) Filter with length 4
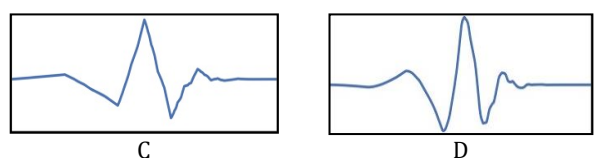


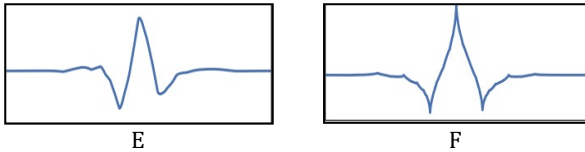**Fig. 3:** (C) Filter with length 6. (D) Filter with length 8

**Fig. 4:** (E) Daubechies Least Asymmetric filters with length 8. (F) Coiflet filter with length 6

**Table 2:** Retinal segmentation of retinal blood vessel

| Author | Original image | Segment at ion result |
|---|---|---|
| Singh and Singh (2014) | | |
| Han et al. (2014) | | |
| Cinsdikici and Aydın (2009) | | |
| Zaki et al. (2014) | | |



## 4. Discussions and conclusion

Segmentation of blood vessel serves as the basis for developing retinal screening systems since it helps in identification and categorization of features of retina. The screening of irregularities of vessel can be done using an effectual and proficient approach for automated blood vessels segmentation in retinal images. An appropriate method of image processing could give a hand in recognizing defects in retinal vessels from image of fundus. Mainstream methods used for vessel segmentation include multiple algorithms as discussed, of which wavelet filter method will be adopted. The retinal fundus images obtained from database undergo pre-processing to remove error or sound from the retina images and to augment the contrast value on fundus images, followed by segmentation for detection of the blood vessel using wavelet filter. This method includes limited oscillation waveform thus obtaining the retina blood vessel. Hence the present research evaluates the efficacy of using wavelet filters for segmentation of the retinal blood vessels by removing high frequency noise.

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