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A New Fast Curvelet Transform with Morphological Operations based method for Extraction of Retinal blood vessels using Graphical User Interface

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Abstract— Retinal blood vessels can give information about us abnormality or disease by examining its pathological changes. Retinal image vessel segmentation and their branching pattern are used for automated screening and diagnosis of diabetic retinopathy to assist the ophthalmologists. Vascular pattern is normally not visible in retinal images. Currently, diabetic retinopathy is one of major cause of human vision abnormalities or even blindness. We present a new method that uses fast curvelet transform via wrapping to enhance and sharpen the vascular pattern respectively. Our technique extracts the vessels using curvelet transform followed by sharpening the retinal image and applies morphological operation for their refinement. This technique is tested on publicly available DRIVE database of manually labelled images. Since the curvelet transform is well-suited to handle curve discontinuities, we achieve sensitivity 89.47% and specificity 98.125% demonstrates improved performance of proposed algorithm compared with known techniques.
Index Terms— retinal image, logfilter, curvelet transform, morphological operation(skeleton)

1 Introduction

Diabetic retinopathy is retinopathy (damage to the retina) caused by complications of diabetes mellitus, which can eventually lead to blindness. It is an ocular manifestation of systemic disease which affects up to 80% of all patients who have had diabetes for 10 years or more. Despite these intimidating statistics, research indicates that at least 90% of these new cases could be reduced if there was proper vigilant treatment and monitoring of the eyes. The longer a person has diabetes, the higher their chances of developing diabetic retinopathy. Manual detection of blood vessels is difficult since the appearance of blood vessel in a retinal image is complex and having low contrast [1].The segmentation usually use contrast difference between blood vessels and its neighbouring background, where all vessels are connected each other[2].This work aims at developing a novel solution for easy diagnosis. Finally each process involved in detecting blood vessels, take up a icon in a single window called Graphical user interface. Up to now there are have been substantial researches on blood vessels detection in retinal images such as region growing technique[3], morphological and thresholding techniques[4], neural network based approaches[5], statistical classification based methods[6-7] and hierarchical methods[8]. In this paper , a novel blood vessels detection in digital color retinal images is presented based on fast discrete curvelet transform. Using this technique, pixels belonging to vasculature are separated as candidate pixels from the back ground of the image. In this paper, we use curvelet transform to increase contrast between vessels and background in retinal images. Curvelet transform is a new geometric multi-scale transform. It decomposes the image into a series of high pass and low pass bands which is same as wavelet transform.

Fig 1.Input image

The wavelet transform extracts directional details that capture horizontal, vertical and diagonal activity. The second generation curvelet transform is introduced in this paper which is simpler, faster and less redundant. The paper is organized as follows. our proposed work is introduced in section 3.Section 3.1 introduces curvelet transform.A detailed description of adaptive histogram for contrast enhancement is presented in section 3.2.In section 3.3 we introduce log filter (Laplacian and

Gaussian). Finally the results are presented in section 4 and this paper is concluded in section5.

2 REVIEW OF RELATED RESEARCH

M.Wilson et al. [9] have proposed an Java Based System for Segmentation and analysis of Retinal Images. This system monitors the progression of pathologies in retinal images with much greater precision than is possible with totally manual techniques. The detection results were applicable to selected images.

Katia Estabridis *et al.*[10] have discussed and analyzed a blood vessels detection via a multi window parameter transform. Localised adaptive thresholding and a multi-window Radon transform are utilised to detect the vascular system in retinal images. The algorithm was tested with 20 images, 10 normal and 10 abnormal and the results demonstrate the robustness of the algorithm in the presence of noise. An average true positive rate of 86.3% with a false positive rate of 3.9% is accomplished with this algorithm, when tested against hand labelled data.

K.Y.E.Aryanto *et al.* [11] have proposed a extraction of retinal blood vessels using Branches filtering approach. Processing time is less than 5 seconds. Low accuracy was obtained by this method is caused by intensity factor in the end of vessels where its contrast is relatively low compared to neighbouring pixel's background.

. Reza *et al.* [12] have presented an approach automatically to segment the blood vessels. Their presented algorithm employs the green component of the image and preprocessing steps namely average filtering, contrast adjustment, and thresholding. The other processing techniques employed are morphological opening, extended maxima operator, minima imposition, and watershed transformation. Their presented algorithm is employed using the test images of STARE and DRIVE databases with fixed and variable thresholds. The images sketched by human expert are considered as the reference images. Their presented method produces sensitivity values as high as 96.7%.

Don Youssef et *al.* [13] have presented an approach new feature based detection of blood vessels and exudates in color fundus images based on closing the image with two different sizes of line structuring elements and subtracting their results. Finally extend the process for enhancing the detection and build an integrated diagnostic system.

Cemil Kirbas *et al.* [14] have proposed window based techniques for the extraction of the blood vessels by comparing the intensity value of the candidate pixel against those of the pixels within the window. It allows simultaneous detection of dark and bright vessels, when applied to fluorescein angiograms of the human retina. L.Lecornu, *et al.* [15] have discussed tracking based techniques for blood vessel detection, exploit local image properties to trace the vessel form an initial point to an end point.. The common element between both of these classes of techniques is the use of vessel edge information.

O.Chutatape *et al.* [16] have proposed a automated feature extraction of retinal blood vessel by a model based approach. The achievement of 80% sensitivity and 95% specificity in existing methods based on image processing is a vital role. The method addressed in the survey meet only 50% of the expected result which produces complications in diagnosing the disease. These methods based on grey level and high contrast. But these features varied from different patients and to the photographs which will not work in all the images used in clinical environment.

3 PROPOSED WORK

Fig2. Proposed work

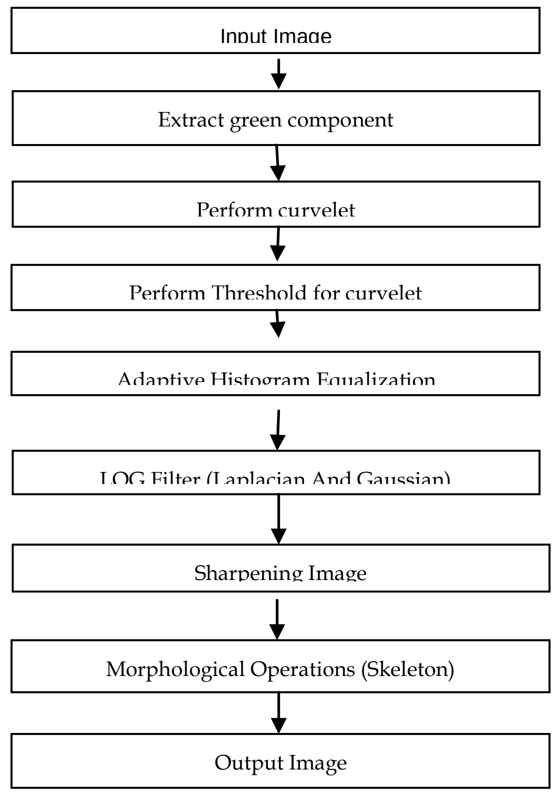

Fig 2. shows the overall methodology in detection of blood vessels. The input images obtained from drive data base.The input images are in color image. A form of grayscale image is enhanced to knock out the noise in the image and to strength the appearance of blood vessels. Each color component is extracted to red, green, blue component. The green component is good for detection of blood vesses. The first step is to extract the green component values. The second step is to perform curvelet on the extracted green component image and and fix the thresholding value. To distinct the vessels appearance, the contrast of the image are enhanced using adaptive histogram equalisation method. The third step, using log filter for image sharpening. Finally morphological operation (skeleton) has been done to extract the vessels.

3.1 CURVELET TRANSFORM

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The Curvelet transform (CVT) is a multi-scale transform proposed by Candes and Donoho and is derived from the Ridgelet transform [17]. The Curvelet transform is suited for objects which are smooth away from discontinuities across curves. Fourier Transform doesn't handle point's discontinuities well because a discontinuity point affects all the Fourier Coefficients in the domain. Moreover, Wavelet transform handles point discontinuities well and doesn't handle curve discontinuities well. Curvelet transform handles curve discontinuities well as they are designed to handle curves using only a small number of coefficients. Curvelet transform has several applications in various areas such as image denoising, image fusion, Seismic exploration, Turbulence analysis in fluid mechanics and so on [18-21]. The multi-wavelet transformation provides betters spatial and spectral localization of image when compared with other multi-scale representations.

The Curvelet transform includes four stages and is implemented as follows.

A. *Sub-band Decomposition*

The image is first decomposed into $\log_2 M$ (M is the size of the image) wavelet sub-bands and then Curvelet Sub-bands are formed by forming partial reconstruction from these wavelet sub-bands at various levels.

The subband decomposition is denoted as

$$f \rightarrow (P_0 f, \Delta_1 f, \Delta_2 f, \ldots) \qquad (1)$$

where $P_0 \rightarrow$ Low-pass filter

$\rightarrow$Band-pass (high-pass) filters

The image is divided into resolution layers P_0, (Δ_s, s ≥0). Each layer contains the details of different frequencies.

B. *Smooth Partitioning*

Each subband is smoothly windowed in to 'squares' of an appropriate scale. A grid of dyadic squares is defined as:

$$Q_{(s,k_1,k_2)} = \left[\frac{k_1}{2^s}, \frac{k_1+1}{2^s}\right] \times \left[\frac{k_2}{2^s}, \frac{k_2+1}{2^s}\right] \in Q_s \qquad (2)$$

Let w be a smooth windowing function. For each square, W_Q is a displacement of W localized near Q. Multiplying $\Delta_s f$ with $W_Q (\forall Q \in Q_s)$ produces a smooth dissection of the function into 'squares'.

$$h_Q = w_Q . \Delta_s f \qquad (3)$$

In this stage, this windowing dissection is applied to each of the sub-bands isolated in the previous stage of the algorithm

$$\Delta_s f \rightarrow\rightarrow \; w_Q \Delta_s f \quad Q \in Q_S \qquad (4)$$

C. *Renormalization*

Each resulting square is renormalized to unit scale. For a dyadic square Q, let

$$T_Q f \quad x_1, x_2 \; = 2^s f(2^s x_1 - k_1, 2^s x_2 - k_2) \qquad (5)$$

denote the operator which transports and renormalizes f so that the part of the input supported near Q becomes the part of the output supported near the unit square [0, 1] x [0, 1]. In this stage each 'square' resulting in the previous stage is renormalized to unit scale.

$$g_Q = T_Q^{-1} h_Q \qquad (6)$$

D. *Ridgelet Analysis*

Ridgelet transform is performed on each square resulting from the previous stage. The Ridgelet transform belongs to the family of discrete transforms employing basis functions. To facilitate its representation mathematically, it can be viewed as a wavelet analysis in the Radon domain. The Radon transform itself is a tool for shape detection. So, the Ridgelet transform was primarily a tool for ridge detection or shape detection of the objects in an image. The Ridgelet transform deals effectively with line singularities in 2-D. The basic idea is to map a line singularity in the two-dimensional (2-D) domain into a point by means of the Radon transform. Then, a one-dimensional (1-D) wavelet is performed to deal with the point singularity in the Radon domain.

The Ridgelet basis function is given by

$$\psi_{a,b,\theta} = a^{-1/2} \psi\left(\frac{x_1 \cos\theta + x_2 \sin\theta - b}{a}\right) \qquad (7)$$

The Ridgelet coefficients are represented by

$$R_f(a,b,\theta) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \psi_{a,b,\theta}(x_1,x_2) f(x_1,x_2) dx_1 dx_2 \qquad (8)$$

Ridgelet transform is invertible and the reconstruction formula is denoted by

$$f(x_1,x_2) = \int_0^{2\pi}\int_{-\infty}^{\infty}\int_0^{\infty} R_f(a,b,\theta) \psi_{a,b,\theta}(x_1,x_2) \frac{da}{a^3} db \frac{d\theta}{4\pi} \qquad (9)$$

The Radon transform for an object f is the collection of line integrals indexed by $(\theta, t) \in [0, 2\pi) \times R$ and is given by:

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$$R_f(\theta,t)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x_1,x_2)\times\delta(x_1\cos\theta+x_2\sin\theta-t)dx_1dx_2 \quad (10)$$

Thus, the ridgelet transform can be represented in terms of the Radon-transform as follows:

$$R_f(a,b,\theta)=\int_{-\infty}^{\infty} R_f(\theta,t)a^{-1/2}\left(\frac{t-b}{a}\right)dt \quad (11)$$

where the angular variable θ is constant and t is varying.

3.2 ADAPTIVE HISTOGRAM EQUALISATION

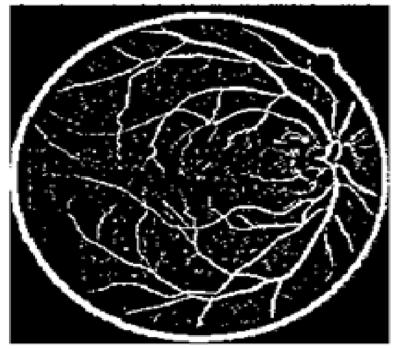
Adaptive histogram equalization (AHE) is a computer image processing technique used to improve contrast in images. It differs from ordinary histogram equalization in the respect that the adaptive method computes several histograms, each corresponding to a distinct section of the image, and uses them to redistribute the lightness values of the image. It is therefore suitable for improving the local contrast of an image and bringing out more detail.

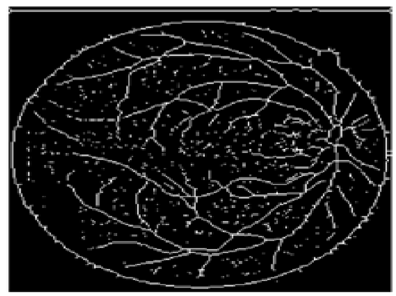
Fig 3 curvelet transform followed by Adaptive histogram Equalisation.

3.3 LOG FILTER & MORPHOLOGICAL OPERATION:

The LOG module performs a Laplacian of Gaussian filter. This filter first applies a Gaussian blur, then applies the Laplacian filter and finally checks for zero crossings (i.e. when the resulting value goes from negative to positive or vice versa). The end result of this filter is to highlight edges. The first stage of the filter uses a Gaussian blur to blur the image in order to make the Laplacian filter less sensitive to noise. If you run the Laplacian filter on a noisy image the result is an edge image with many small edges that detract from the larger more meaningful edges. Finally morphological operation(skeleton) is done to extract vessels.

Fig 4. image sharpening(log filter)





. Fig5.Morphological operation(skeleton)

4 EXPERIMENTAL RESULTS AND COMPARISION

The proposed approach is implemented in MATLAB7.8. The algorithm is tested on a data base of twenty five images for both normal and abnormal. selection of suitable threshold in the detection of blood vessels plays an important role. Lowering the threshold value improves the sensitivity of the algorithm but decreases the predictivity. Performance measure procedure was done by comparing the segmentation results to the reference image. There are four values resulted from the validation procedure, true positive(TP),false positive(FP), true negative(TN) and false negative(FN). True positives is a number of pixels correctly detected as vessel pixels, false positive is a number of pixels incorrectly flagged, true negatives is a number of pixels correctly detected as non vessel and false negative(FN) is a number of pixels incorrectly flagged as non vessels.

Sensitivity=TP/[TP+FN] ;

;Specificity=TN/[TN+FP];

Predictivity = TP/[TP+FP];

The ground truth data was marked by an expert opthamologists. For evaluation purpose, all the parameters are determined for each image in the data set. Sensitivity, Specificity and Predictivity are used as accuracy measures. As, mentioned above, the method tested in 25 retinal images on the drive database. For experimental we have taken 8 images for analysis.

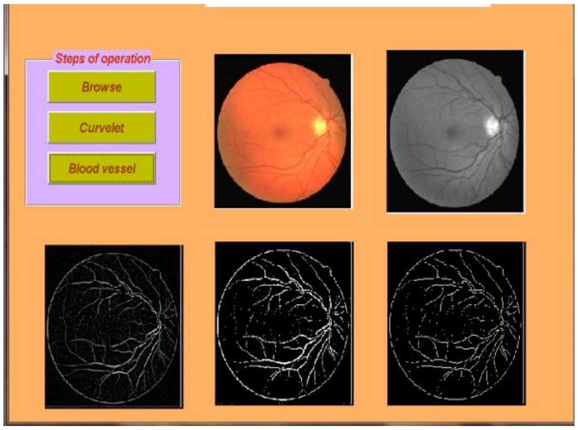
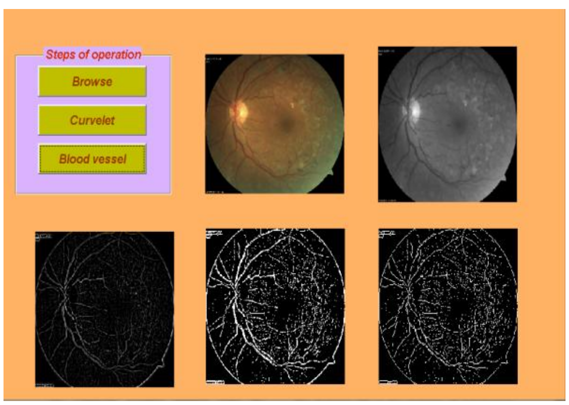


Fig6. output for test image

1st row 2nd column input image, 1st row 3rd column curvelet o/p image, 2nd row 1st column adaptive histogram equalization, 2nd row 2nd column log filter o/p for sharpening, 2nd row 3rd column morphological operations o/p .(normal-eye)

Fig7.output for test image(abnormal eye)



Images	Specificity	Sensitivity	Predictivity
1	0.9802	0.8762	0.8164
2	0.9829	0.9688	0.9163
3	0.9886	0.9088	0.9554
4	0.9881	0.9036	0.9681
5	0.9633	0.9075	0.8423
6	0.9920	0.8711	0.866
7	0.9733	0.8125	0.8423
8	0.9816	0.9093	0.9636
overall	0.98125	0.8947	0.8963

Table 1. Performance of the proposed method for Extraction of Retinal Vessels.

Table2. Comparision with the other methods

Method	Average Specificity	Average Sensitivity
Proposed method	0.98125	0.8947
Human observer	0.9725	0.7761
Jiang	0.9626	0.6478
Niemeijer	0.9801	0.6898
Staal	0.9773	0.7194
Zaana	0.9769	0.6696

The specificity and sensitivity of the blood vessels detection that we received from this set of data are 98% and 89% respectively. The MATLAB code takes less than 3 minutes per image to run on a 1.8 GHz machine. On comparing with other methods sensitivity and specificity was increased for the proposed method.

5 CONCLUSION

Curvelet transform gives a sparse representation of objects. So, in this paper we take curvelet transform of image and modify its coefficients in several stages to separate blood vessels from other parts of image. The experimental results show that the proposed algorithm is more accurate and robust to work well in clinical environment. The proposed method can be improved and the specificity of implementation can be increased by using some additional steps such as applying a simple classification method. The image obtained using Curvelet transform contains more useful information than the source images, thus enabling the radiologists to locate the imperfections accurately, making the treatment easier and perfect. By using curvelet transform, We achieve sensitivity 89.47% and specificity 98.125%.

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