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Measurement of Retinal Vascular Tortuosity for Diabetic Retinopathy Screening

Sourajit Chowdhury[1], Ujjwal Sarkar[1], Arijit Dawn[1], Sukdeb Paul[2], Tamal Kanti Das[2], Debasis Maji[3]
1. Student, Department Of Electrical Engineering, Camellia Institute Of Engineering, Kolkata, India
2. Student, Department Of Electrical Engineering, Camellia Institute Of Technology, Kolkata, India
3. Assistant Professor, Camellia institute of technology, Department of Electrical Engineering

Abstract— A new supervised method for blood vessel detection in digital retinal image analization .Tortuous arteries and veins are commonly observed in humans and animals. While mild tortuosity is asymptomatic, severe tortuosity can lead to ischemic attack in distal organs. Tortuosity of retinal blood vessels is an important symptom of diabetic retinopathy (DR) or retinopathy of prematurity (ROP). Measurement of blood vessel tortuosity is a useful capability for automatic ophthalmological diagnostic tools. Screening of Retinopathy of Prematurity (ROP), a disease of eye that affects premature infants, for example, depends crucially on automatic tortuosity evaluation. Quite a few techniques for tortuosity measurement and classification have been proposed, but they do not always match the clinical concept of tortuosity. In this paper, we propose the alternative method of automatic tortuosity measurement for retinal blood vessels, an automatic image based method for measuring single vessel and vessel network tortuosity of these vessels.

Index Terms— Diabatic retinopathy, Retinal vascular diseases, Detection of retinal tortuorsity.

1 Introduction

Diabetes is a group of diseases that affect the body's ability to produce or use insulin, a hormone that allows your body to turn glucose into energy. It causes damage in blood vessels. Vessel damages in heart muscles are related to ischemic heart diseases and heart attacks; and vessel damages in the retina cause reduction of sight. The latter called diabetic retinopathy (DR) is one of the most severe causes of reduction of sight.It is important to remember that diabetic retinopathy is a process. It has a beginning, a middle and an end. The end point of diabetic retinopathy results in total loss of vision (or blindness). Fortunately the beginning part (and to some extent the middle part) can often be successfully treated or at least stopped from getting worse.Unlike a movie screen (that is usually a piece of vinyl) our retina is a piece of living tissue. This means it needs a good blood supply to keep it healthy. If things go wrong with this blood supply it can damage pieces of the screen. If the damage is too bad the whole of the screen can be wiped out. This results in total blindness.In diabetes it is mainly damage to the blood vessels in the retina that can cause problems. The blood vessels can become leaky, blocked, or too small to let through enough blood.Presence of numerous micro aneurysms is the earliest sign ofDR [1]. As the disorder develops, retinal blood vessels becomethicker, more twisted and turned [2]. In more advanced levels,neovascularization through inability to provide the requiredamount of nutrition and oxygen for the retina occurs [3]. These newly generated vessels are very fragile. Therefore, they cause internal bleeding in the retina which endangers the visualsystem and might ultimately result in blindness.Experimentally, it has been shown that when there is no critical symptom of retinal damage, an

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escalation in retinal blood vessel tortuosity is an early sign of DR. Presence of tortuous retinal blood vessels is an indicator of retinopathy of prematurity (ROP) in preterm infants. It is well-known that in serious cases, ROP causesretinal detachment and blindness. For a detailed review on applications of image processing to diagnosing ROP and comparison of different methods see [5], [6].

We propose a method for segmenting blood vessels in retinal images based on the shear let transform. Shear lets are a relatively new directional multi-scale framework for signal analysis, which have been shown e active to enhance signal discontinuities such as edges and corners at multiple scales. We provide an experimental analysis of our approach on a benchmark dataset and we show very good performances in comparison with other multi-resolution methods.

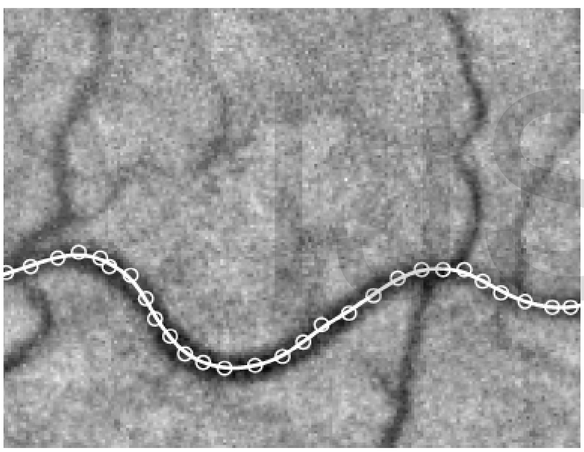

Fig. 1: **Retinal Vessel Tortuosity**

METHODOLOGY :

For quantitative measurement of tortuosity, the vessel is modeled as a smooth connected curve. Based on this model, different tortuosity measurement algorithms have been proposed in the literature. Our approach is a curvature-based tortuosity measurement. To illustrate the method, we define curvature as a mathematical tool for measuring local inflection. To calculate curvature, a novel approach called the template disk method is commonly used.

- For curvature calculation we have followed the **Template Disk Method** which has been utilized in most of the state of the art. However, we show that this method does not possess linearity against curvature and by proposing two modifications, we have improved the method.
- The basic and the modified methods to measure tortuosity are used by us on a publicly available data bank and two data banks of our own.
- While interpreting or illustrating the results, we pursue three goals-
  1. To show that our algorithm is more efficient to implement than the state of the art.
  2. To show that our method possesses an excellent correlation with subjective results (0.94 correlation for vessel tortuosity, 0.95 correlation for vessel network tortuosity in diabetic retinopathy and 0.7 correlation for vessel network tortuosity in ROP).
  3. To show that the tortuosity perceived by an expert and curvature possess a nonlinear relation.
- This method uses a **Neural Network (NN) Scheme** for pixel classification and computes a 7-D vector composed of gray-level and moment invariants-based features for pixel representation.
- The method was evaluated on the publicly available DRIVE and STARE databases, widely used for this purpose, since they contain retinal images where the vascular structure has been precisely marked by experts.
- Method performance on both sets of test images is better than other existing solutions in literature .The method proves especially accurate for vessel detection in STARE images. Its application to this database surpasses all analyzed segmentation approaches.
- The effectiveness and robustness with different image conditions make this blood vessel segmentation proposal suitable for retinal image computer analyses such as automated screening for early diabetic re-

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tinopathy detection.

Therefore we propose a method for segmenting blood vessels in retinal images based on the shear let transform. Shear lets are a relatively new directional multi-scale framework for signal analysis, which have been shown e active to enhance signal discontinuities such as edges and corners at multiple scales. We provide an experimental analysis of our approach on a benchmark dataset and we show very good performances in comparison with other multi-resolution methods.

➢ Block diagram:

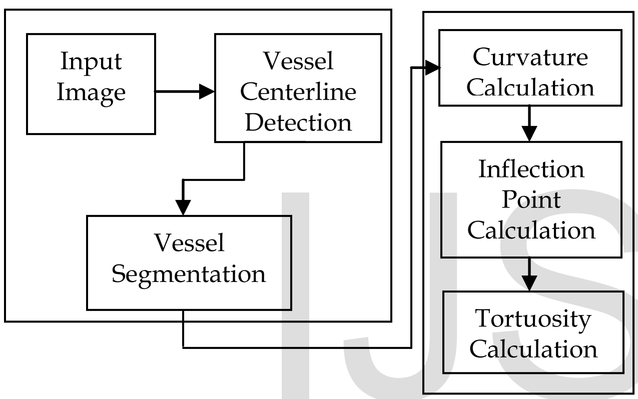


Fig. 2**. Implementation methodology of retinal vessel extraction algorithm**

The segmentation of blood vessels from a retinal image plays a key role in as-sessing the vessels morphological properties such as length, width, tortuosity and/or branching pattern and angles. These properties are wildly used for the diagnosis, treatment, and evaluation of various cardiovascular and opthalmo-logic diseases such as diabetes, hypertension, arteriosclerosis among others.

In a nutshell, the process of blood vessel segmentation consists in generating a binary mask in which pixels are labeled as vessel or background. The goal is to capture as much detail (ne vessels) as possible, simultaneously avoiding false positives and, ideally, preserving the vessel connectivity.

Many di erent approaches for automated vessel segmentation methods have been reported in the literature over the years. In a recent survey, those methods have been divided into six main categories; (i) pattern recognition techniques, (ii) matched ltering, (iii) vessel tracking/tracing, (iv) mathematical morphology, (v) multi-scale approaches, (vi)model based approaches and (vii) parallel/hardware based approaches. Of our special interest are those methods based on multi-scale image representations, where the idea is to better extract blood vessels having varying width at di erent scales .

➢ Result:

In this work, we address the problem of detecting and segmenting the blood vessel in a retinal image by using the fast nite shearlet transform.

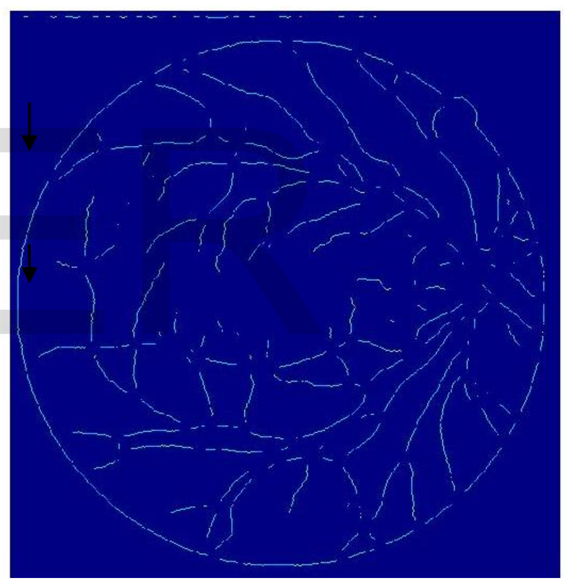
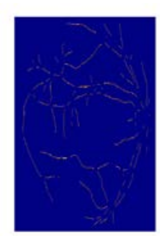


Fig.3**: Extraction of Vascular Skeleton**

<u>Bifurcation and Crossover detection for vessel map</u>



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Method	Tortuosity_tr	Tortuosity_cp	Tortuosity_b
SRCC(Spearman's rank correlation coefficient)	0.5687	-0.2952	-3816

Results of vessel network tortusity

Rafieetary	Tortuosity_tr	Tortuosity_cp	Tortuosity_b
2	564.5454	4.0614	101468
1	625.3121	4.1861	103761
4	624.3259	4.1129	102495
3	605.9547	4.1576	104188
7	705.3422	3.5612	87042
5	652.2373	3.9901	98973
9	805.6606	4.1993	102834
6	623.2743	3.7735	93363
10	699.7988	4.0397	99708
8	681.043	3.9562	97632

CONCLUSION :

We developed new vessel tortuosity descriptors based on curvature estimations from best exponential curve fits in orientation scores. Validation on synthetic images showed high accuracy of our approach. Application to clinical retinal image datasets showed strong positive associations of the proposed tortuosity descriptors with diabetes and different stages of diabetic retinopathy (DR). As such, we see high potential of the method to be used in a screening setting for diabetes and DR detection. In this paper, we have proposed a new algorithm for evaluating tortuosity of retinal vessels able to solve the theoretical drawbacks of some of the algorithms proposed in the literature, arising from the particular geometry of the retina. All the methods that, to the best of our knowledge, were proposed in the literature to evaluate retinal vessel tortuosity have been implemented and comparatively evaluated in the present work.

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