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An Innovative Method for Automatic Grading of Retinal Blood Vessel Tortuosity

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Abstract: The curvity is among the first alterations in the retinal vessel network to appear in many retinopathies , such as those due to hypertension. An automatic evaluation of retinal vessel tortuosity would help the early detection of such retinopathies. Quite a few techniques for tortuosity measurement and classification have been proposed, but they do not always match the clinical concept of tortuosity. This justifies the need for a new definition, able to express in mathematical terms the tortuosity as perceived by ophthalmologists. We propose here a new algorithm for the evaluation of tortuosity in vessels recognized in digital fundus images. It is based on partitioning each vessel in segments of constant sign curvature and then combining together each evaluation of such segments and their number. The algorithm has been compared with other available tortuosity measures on asset of 30 arteries and one of 30 veins from different images. These vessels had been preliminary ordered by a retinal specialist by increasing perceived tortuosity. The proposed algorithm proved to be the best one in matching the clinically perceived vessel tortuosity.

Keywords: - *Curvity, Ophthalmologists, Retinopathy, Tortuosity.*

I. INTRODUCTION

The clinical observation of the ocular fundus is an important tool for identifying and monitoring many pathological manifestations coming from the major cardiovascular , central nervous and endocrine-metabolic system diseases[1] .Most retinopathies, e.g., from hypertension or diabetes, could be diagnosed early and effectively treated if an accurate and objective analysis of symptoms at their initial onset could be performed. The analysis should be sensitive enough to detect minor pathological signs, and robust enough to be able to compare results with accepted clinical standards and with results obtained from the same patient at different times. This latter requirement is of paramount importance when assessing the effect of therapeutic treatments and even more when evaluating in a quantitative way the efficacy of new drugs during their development.

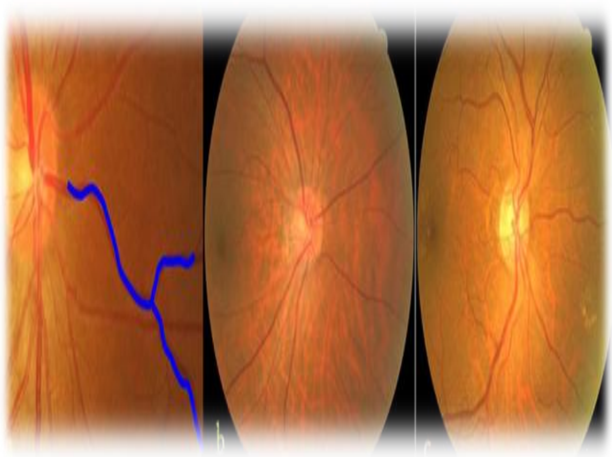

Figure1: Retinal vessels increased by tortuosity

II. MODIFICATIONS OF THE TEMPLATE DISK METHODS

A.Arc Length over Chord length Ratio methods :Describes an automated method to locate and outline blood vessels in images of the ocular fundus. Such a tool should pove useful to eye care specialists for purposes of patient screening, treatment evaluation, and clinical study. The authors' method differs from previously known methods in that it uses local and global vessels features cooperatively to segment the vessel network. The authors evaluate their method using hand –labeled ground truth segmentations of 20 images. A plot of the operating characteristics shows that the authors' method reduces false positives by as much as 15 times over basic thresholding of a matched filter response [MFR] ,at up to 75% true positive rate. For a baseline, they also compare the ground truth against a second hand –labeling ,yielding a 90% true positive and 4% false positive detection rate, on average .These numbers suggest there is still room for a 15% true positive rate improvement ,with the same false positive rate ,over authors' method. They are making all their images and hand labeling publicly available for interested researchers to use in evaluating related methods.

B. Methods of Curvature:

Direct volume rendering of scalar fields uses a transfer function to map locally measured data properties to opacities and colors. The domain of the transfer function is typically the one-dimensional space of scalar data values. This paper advances the use of curvature information in multi-dimensional transfer functions with a methodology for computing high-quality curvature measurements. The proposed methodology combines an implicit formulation of curvature with convolution-based reconstruction of the field. We give concrete guidelines for implementing the methodology, and illustrate the importance of choosing accurate filters for computing derivatives with convolution. Curvature –based transfer functions are shown to extend the expressivity and utility of volume rendering through contribution in three different application areas: non-photorealistic volume rendering, surface smoothing via anisotropic diffusion and visualization of iso-surface uncertainity.

III. TORTUOSITY EVALUATION

Tortuosity evaluation- In this topic, an algorithm for automatic evaluation of tortuosity in retinal pictures are offered. As the curvature calculation is the root of this algorithm, hence all the three curvature estimation given are used for testing their performance. The steps that is to be followed in this algorithm are:

a) Vessel detection
b) Extraction of vascular skeleton
c) Elimination of crossovers and bifurcations
d) Local and global tortuosity measurement

Vessel Detection - This algorithm is used to detect vessel map by extracting the green layer of the RGB representation of the image. As the vessel and the background possess the highest contrast therefore it becomes the significant property of this plane. Now this plane is divided into number of overlying blocks and by locating a circular mask each blocks Radon transform can be calculated. When the local sinogram reaches its maximum value then the angle is the direction perpendicular to the vessel. By checking the presence of the vessel, a linear resemblance of the vessel is illustrated and the consolidation of these local linear vessels gives the vessel network.*Extraction of vascular Skeleton*- The vessel map should be thinned and the vessel skeleton should be extracted which is necessary, to use the curvature calculation methods. Morphologic thinning algorithm is

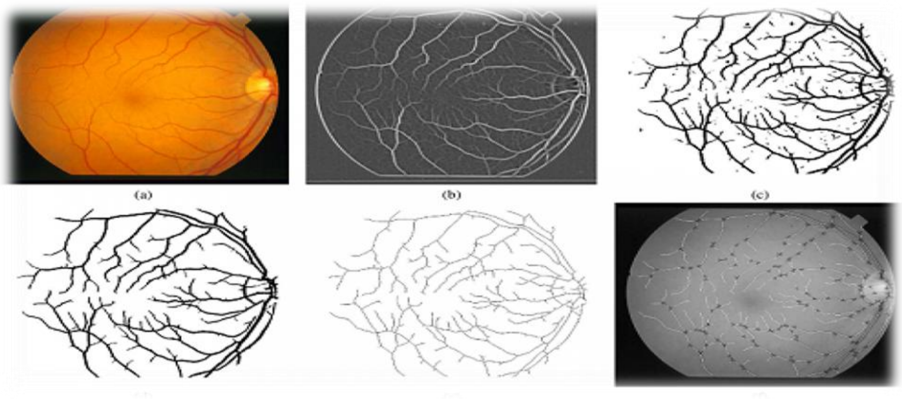

Figure 2: Different levels of Toruosity Evaluation

Elimination of crossovers and bifurcations - The tortuosity evaluation process gets troubled because of the bifurcations and crossovers of the vessel. So, proceeding to curvature estimation procedure, all areas consisting of bifurcation and crossover should be eliminated. To identify such areas, a circle is drawn at every point on the map and the total number of crossover of the disk and the map is calculated. If the number is three or four the bifurcation and/or crossovers in that location will be detected.

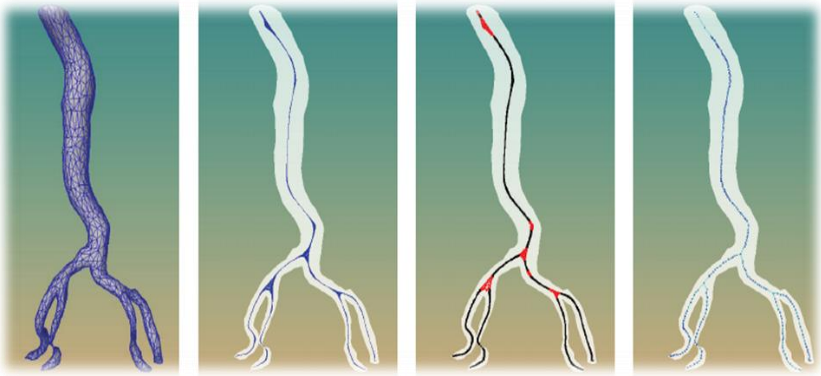

Figure 3 :Elimination of crossovers and BifurcationsLocal and global tortuosity Measurement- Here the global tortuosity of a vessel map is calculated by first determining the local tortuosity for each point on the map.

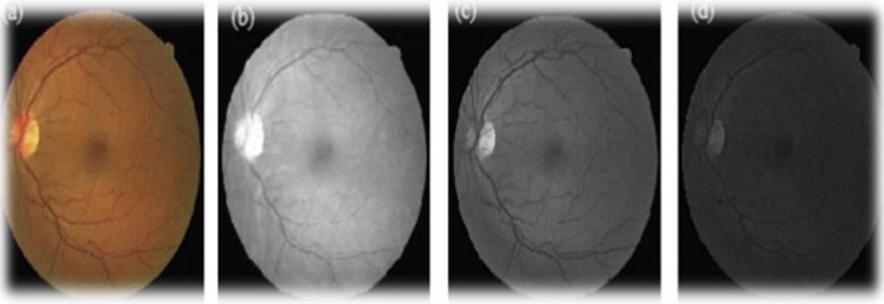

Figure 4: Local and global Tortuosity Measuremen

IV. RESULTS AND CONCLUSION

The performance of the algorithm with the state of art is compared. This comparison is made on both the vessel level and on the vessel network level. When the tortuosity of single vessels is considered the best state of art matches this algorithm. Further, this algorithm is compared with subjective results for the vessel network case. Spearman's rank correlation is used to assess correlation with subjective results, which is an indicator of the linear relation between two datasets.

Vessel level Tortuosity - RET-TORT data bank is conducted to calculate the vessel level performance of this algorithm. This data bank was introduced by Grisan et al as the image bank. It contains 30 pictures of arteries and 30 pictures of veins, sorted depending on the tortuosity level of the pictures. The output may suggest a strong nonlinear relation between perceived tortuosity of the arteries and curvature.

Vessel level Network-The purpose of introducing a tortuosity measurement algorithm is to estimate the whole vessel network tortuosity of the retina. Based on the vessel level test, Grisan's algorithm has the best performance. It is the best candidate for extension to the vessel network case. The issues that is to be considered to extend Grisan's algorithm to the entire vessel network are:

1. The description and segregation of all vessels is most likely a requirement for vessel network implementation.
2. The duty of tortuosity is not clear for vessel bifurcation.
3. It needs segmentation of a vessel depending on the convexity change. Arc and chord length estimation of each segment is required for calculating the tortuosity of each level.

To figure out the achievement of this algorithm when measuring vessel network tortuosity in DR, we use data bank that contains ten full images of the retina. The correlation reveals the capability of this algorithm in classifying the tortuosity of retinal blood vessel networks. The nonlinear method is more adequate in following the assumption of each expert rather than the linear methods. The strong correlation reveals the capability of this algorithm in determining the good cases of tortuosity in ROP pictures.

A fully automatic algorithm for calculating tortuosity in retinal pictures has been conferred. This algorithm is a curvature based algorithm. To precise the nonlinearity of template disk method and assessed the linearity of results with numerous tests two adjustments are conferred. No concern for designation of vessels as opposed to vessel depended measures, low computational burden is some of the major features of this algorithm.

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