Original Article

Three-Dimensional Segmentation of Retinal Vessels in Optical Coherence Tomography with the Help of Scanning Laser Ophthalmoscopy

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Abstract

Purpose: To evaluate a new approach based on luminance changes by combining the scanning laser ophthalmoscopy and optical coherence tomography imaging techniques to acheive 3D segmentation of the retinal vessels and improve the retinal vasculature imaging.

Methods: A multifaceted process for the 3D segmentation of retinal blood vessels in optical coherence tomography slices of fundus ophthalmic images with the help of scanning laser ophthalmoscopy was devised. The proposed algorithm has two distinct clauses, which include 2D and 3D segmentation of the retinal blood vessels based on the calculation of the 2D features of the blood vessels.

Results: Our method for three-dimensional segmentation of retinal vessels in optical coherence tomography images with the help of scanning laser ophthalmoscopy imaging achieved a better reconstruction of retinal vessels in optical coherence tomography image.

Conclussion: Our method was able to improve the imaging of retinal vesels. Further studies in the field of retinal imaging are recommended to achieve better imaging of retinal vesels.

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Introduction

Medical image processing has long been one of the areas of activity for medical engineers. One of the medical imaging modalities is optical coherence tomography (OCT) [1]. This type of imaging is used to examine the human retina. One of the main parts in the image obtained using OCT is the blood vessels in the retina, which include arteries, veins, and capillaries. The illustration of these blood vessels is of great importance in the differential diagnosis of many retinal diseases. For examole it is used in the diagnosis of diabetic retinopathy, assessing the progression of retinal failure, narrowing of the arteries, and diagnosing the vein curvature. OCT images taken from the inner tissue of the eye also provide information about the the location of retinal nerve branches [2]. Ophthalmologists use OCT, and fundus images to diagnose eye vascular diseases, and conditions that cause deformations and thicknesses of the various retinal layers [3,4]. The essential processing priority in OCT images is the segmentation of these images into two or three dimensions [5]. Although OCT technology has evolved since 1991, segmentation of data obtained in OCT has only been discussed in recent years, and it is considered as one of the most challenging steps in analyzing the data [6]. No segmentation method that can be useful for all applications has been proposed so far. The proposed methods for segmenting OCT images are methods applicable to A-scan, methods applicable to B-scan, active contour-based methods (usually in 2D models), artificial intelligence analysis methods, and methods based on three-dimensional graphs for applying to 3D volumetric data in OCT [7]. The purpose of the present study was to evaluate a new approach based on luminance changes by combining the scanning laser ophthalmoscopy (SLO) and OCT imaging techniques to acheive 3D segmentation of the retinal vessels and improve the retinal vasculature imaging.

Methods

In this study, a multi-dimensional approach for 3D segmentation of retinal blood vessels in optical coherence tomography slices was investigated. The proposed algorithm has two steps: in the first step the 2D segmentation of the blood vessels in SLO imaging is improved by feed back information from OCT incisions and removing the false positive around the optic nerve. In the second step the three-dimensional segmentation of the vessels will be achieved based on the calculation of the two-dimensional characteristics of the blood vessels.

The data used in this study included one hundred and twenty 3D OCT images and corresponding SLO images. These images were obtained using an HRA and OCT (Heidelberg Engineering, Heidelberg, Germany) imaging system and scanner. Data were collected at Noor Eye Hospital, Tehran, Iran.

SLO image preprocessing

The SLO image is very bright, so in the first step, it is necessary to extract blood vessels from this image. For this purpose, the method provided by Martinez-Perez et al., [8] was used, which is based on the first-order derivative (slope) and the second-order derivative (curvature).

OCT image preprocessing

In OCT images, all the arteries are located in the retinal layers, so it is nesessary to remove spaces before and after the retina. For this purpose, we calculated the OCT image columns and perfected the images by applying the threshold of the upper and lower regions [9].

Vascular extraction in OCT scans

For this purpose, we selected the parts related to each OCT in the SLO image and specified the areas that contained the vein, then determined and marked these areas in the OCT images and the retinal pigment epithelium (RPE) and outer nuclear layer (ONL) layers [10].

Vascular reconstruction in OCT images

Three-dimensional images of vascular distribution in the retina was created by the volumetric display of marked OCT images and their threshold [11].

Results

Results of preprocessing of SLO images using the method provided by Martinez-Perez for retinal artery extraction are shown in figure 1.
Results of OCT image preprocessing are shown in figure 2 and 3.
Results of vascular extraction in OCT scans are shown in figure 4.

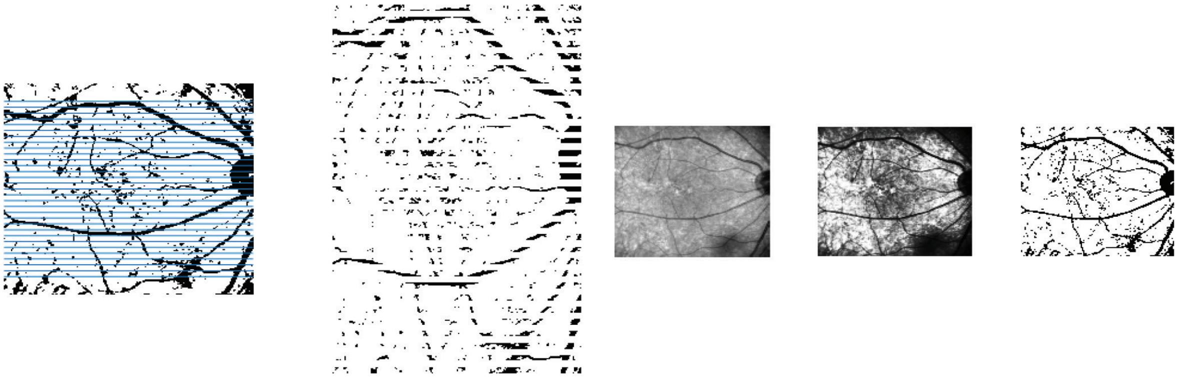

Figure 1: Preprocessing of SLO images by extraction of retinal arteries using the Martinez-Perez SLO image preprocessing method

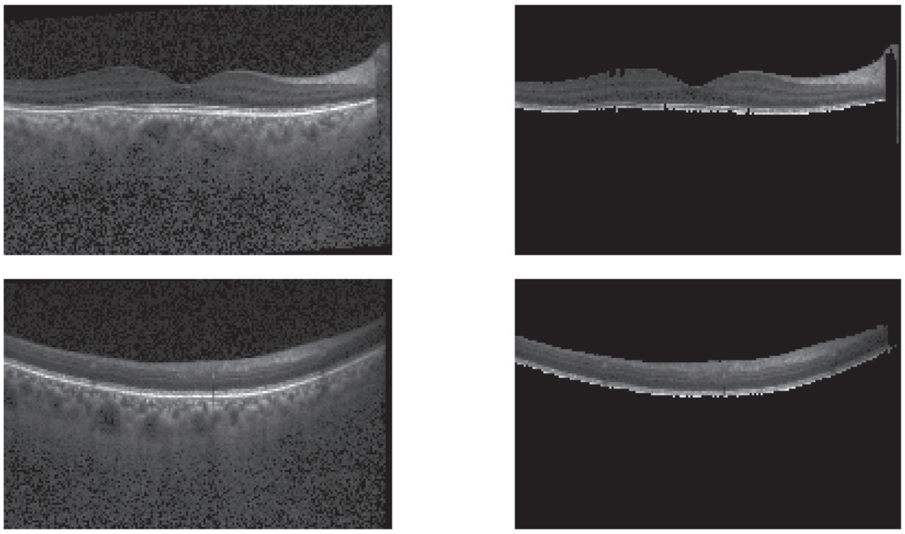

Figure 2: Two examples of OCT image preprocessing with initial and final parts modified

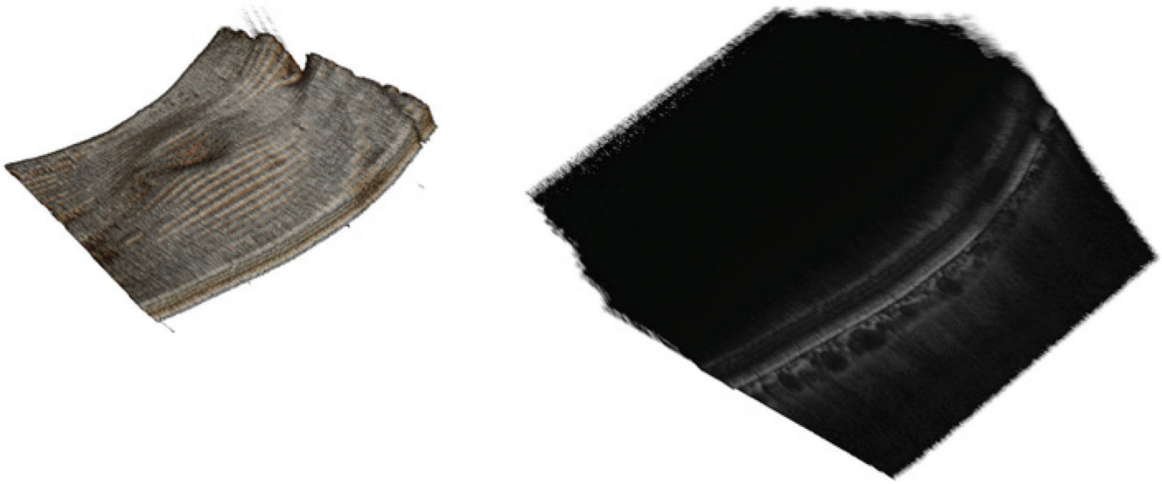

Figure 3: Volume extracted retina after preprocessing of OCT images

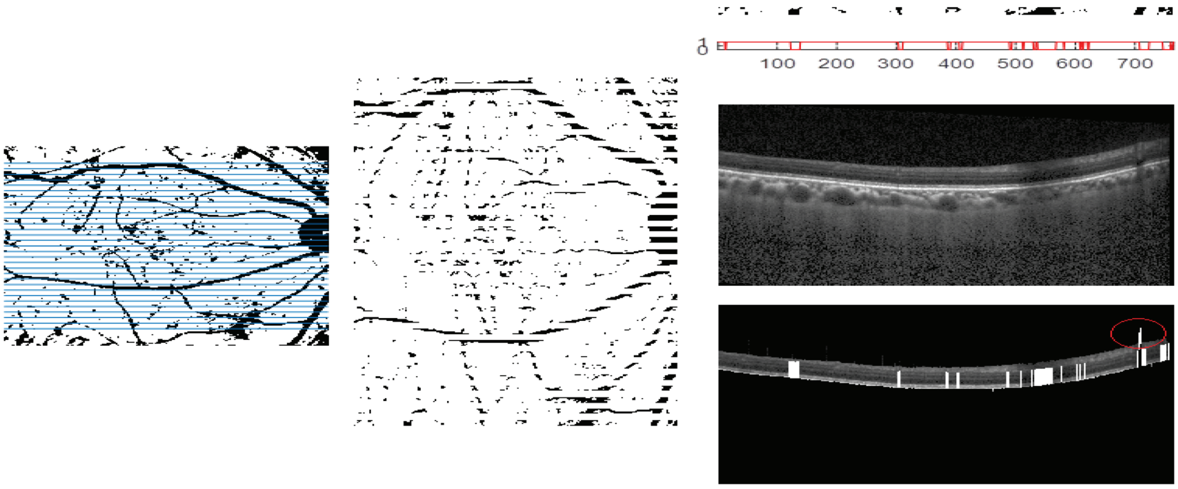

Figure 4: To perform vascular extraction in OCT scans we specified the vessels in the OCT images based on the location of the vessels in the SLO images

Results of vascular reconstruction from OCT images are shown in figures 5 and 6.

Discussion

Image processing and analysis can be defined as a functional and technical structure for capturing, correcting, enlarging, and reshaping images [12]. The purpose of this operation is to increase the relative quality of the information that will be extracted later. Today, significant progress have been made in the field of retinal image processing to provide automatic systems to diagnose retinal diseases such as diabetic retinopathy, age-related macular degeneration, and premature retinopathy [13]. Such systems, in addition to enabling the processing of retinal images in large volumes and with minimal time and cost, are free from the fatigue and other weaknesses that a clinician may experience.

A main parts of the retina are the blood vessels including arteries, veins, and capillaries [14]. Identifying large arteries in retinal images is relatively easy due to the high contrast to the background, but identifying smaller arteries is much more difficult due to the profound difference and top rotations [15]. Some of the

Figure 5: Volumetric display of OCT images and 3D display of arteries

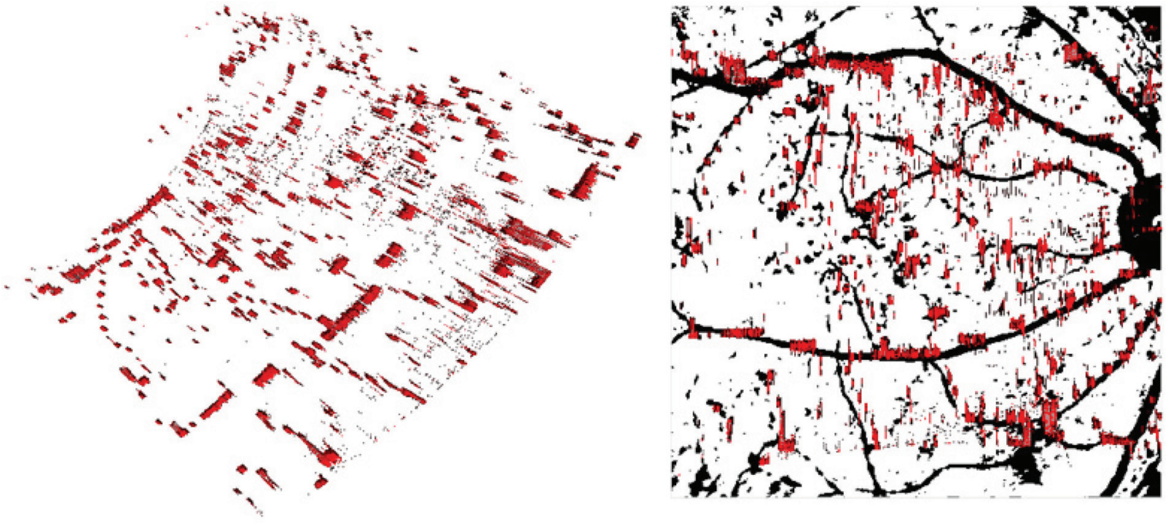

Figure 6: Reconstructed vessels in OCT and its comparisson with the distribution of vessels in SLO image

reported clinical goals for better imaging of retinal arteries include diagnosing of diabetic retinal failure and its progression, detecting macular degeneration, and narrowing of arteries [10]. Retinal blood vessels imaging is also used to discover high-pressure retinal failure, cardiovascular disease, and in computer-assisted laser surgery [16]. Another indirect applications for retinal segmentation include the automatic production of retinal maps to treat age-related macular degeneration [17].

In the present study we evaluated a new approach based on luminance changes by combining the SLO and OCT imaging techniques to acheive 3D segmentation of the retinal vessels and improve the retinal vasculature imaging with acceptable outcomes. This method achieved a better reconstruction of retinal vessels in OCT image with help from the SLO data.

Conclusion

Our method for three-dimensional segmentation of retinal vessels in OCT images with the help of SLO imaging was able to improve the imaging of retinal vesels. Further studies in the field of retinal imaging are recommended to achieve better imaging of retinal vesels.

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References

1. Montero JA, Ruiz-Moreno JM. Optical coherence tomography characterisation of idiopathic central serous chorioretinopathy. Br J Ophthalmol. 2005;89(5):562-4.
2. Gabriele ML, Wollstein G, Ishikawa H, Kagemann L, Xu J, Folio LS, et al. Optical coherence tomography: history, current status, and laboratory work. Invest Ophthalmol Vis Sci. 2011;52(5):2425-36.
3. Gao SS, Jia Y, Zhang M, Su JP, Liu G, Hwang TS, et al. Optical Coherence Tomography Angiography. Invest Ophthalmol Vis Sci. 2016;57(9):OCT27-36.
4. Bhende M, Shetty S, Parthasarathy MK, Ramya S. Optical coherence tomography: A guide to interpretation of common macular diseases. Indian J Ophthalmol. 2018;66(1):20-35.
5. Kafieh R, Rabbani H, Kermani S. A review of algorithms for segmentation of optical coherence tomography from retina. J Med Signals Sens. 2013;3(1):45-60.
6. Puliafito CA, Hee MR, Lin CP, Reichel E, Schuman JS, Duker JS, et al. Imaging of macular diseases with optical coherence tomography. Ophthalmology. 1995;102(2):217-29.
7. Schmitt JM. Optical Coherence Tomography (OCT): A Review. IEEE J Sel Top Quantum Electron. 1999;5(4):1205-14.
8. Martinez-Perez ME, Hughes AD, Thom SA, Bharath AA, Parker KH. Segmentation of blood vessels from red-free and fluorescein retinal images. Med Image Anal. 2007;11(1):47-61.
9. Ruminski D, Sikorski BL, Bukowska D, Szkulmowski M, Krawiec K, Malukiewicz G, et al. OCT angiography by absolute intensity difference applied to normal and diseased human retinas. Biomed Opt Express. 2015;6(8):2738-54.
10. Srinivasan VJ, Radhakrishnan H, Lo EH, Mandeville ET, Jiang JY, Barry S, et al. OCT methods for capillary velocimetry. Biomed Opt Express. 2012;3(3):612-29.
11. Ang M, Baskaran M, Werkmeister RM, Chua J, Schmidl D, Aranha Dos Santos V, et al. Anterior segment optical coherence tomography. Prog Retin Eye Res. 2018;66:132-56.
12. Kipli K, Hoque ME, Lim LT, Mahmood MH, Sahari SK, Sapawi R, et al. A Review on the Extraction of Quantitative Retinal Microvascular Image Feature. Comput Math Methods Med. 2018;2018:4019538.
13. Abràmoff MD, Garvin MK, Sonka M. Retinal imaging and image analysis. IEEE Rev Biomed Eng. 2010;3:169-208.
14. Campbell JP, Zhang M, Hwang TS, Bailey ST, Wilson DJ, Jia Y, et al. Detailed Vascular Anatomy of the Human Retina by Projection-Resolved Optical Coherence Tomography Angiography. Sci Rep. 2017;7:42201.
15. Mudassar AA, Butt S. Extraction of Blood Vessels in Retinal Images Using Four Different Techniques. J Med Eng. 2013;2013:408120.
16. Liew G, Wang JJ, Mitchell P, Wong TY. Retinal vascular imaging: a new tool in microvascular disease research. Circ Cardiovasc Imaging. 2008;1(2):156-61.
17. Köse C, Sevik U, Gençalioğlu O. Automatic segmentation of age-related macular degeneration in retinal fundus images. Comput Biol Med. 2008;38(5):611-9.

Footnotes and Financial Disclosures

Confict of interest:

The authors have no conflict of interest with the subject matter of the present study.