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A Novel Method for Retinal Vessel Segmentation and Diameter Measurement in High Speed Fundus Videos

Mahdieh Rezaeian[1], Ruth Oliver[2], Mark Butlin[3], Alberto Avolio[3], Mojtaba Golzan[4], Stuart Graham[1]
[1]Department of Clinical Medicine, Faculty of Medicine and Health Sciences, Macquarie University
NSW, 2109, Australia
mahdieh.rezaeian@hdr.mq.edu.au; stuart.graham@mq.edu.au
[2]School of Engineering, Faculty of Science and Engineering, Macquarie University
NSW, 2109, Australia
ruth.oliver@mq.edu.au
[3]Department of Biomedical Sciences, Faculty of Medicine and Health Sciences, Macquarie University
NSW, 2109, Australia
mark.butlin@mq.edu.au; alberto.avolio@mq.edu.au
[4]Vision Sciences Group (Orthoptics Discipline), Graduate School of Health, University of Technology Sydney
15 Broadway, UTS ULTIMO 2007, Australia
mojtaba.golzan@uts.edu.au

Extended Abstract

Retinal microvasculature provides a direct in-vivo assessment of the eye's microcirculation. Recent advancements in fundus imaging technologies has attracted interest in studying retinal vascular changes associated with ocular and systemic abnormalities including diabetes, dementia, glaucoma, and cardiovascular disorders [1][2][3][4]. While current literature focuses on processes applied to static images, dynamic analysis of a video sequence offers the possibility to assess vascular changes as a function of time, providing more disease-specific biomarkers [5][6][7]. Here, we propose a new method of segmenting retinal vessels in videos captured from the rat eye using a high-speed camera (Optronis, Germany, 125 fps). Vessel segmentation is significantly impacted by contrast variations, respiratory and eye movements. Poor illumination due to short exposure time in high frame rate videos makes the segmentation even more complex. Our proposed method is comprised of four pre-processing steps described as follows. First, a contrast limited histogram equalization is applied to enhance image contrast adaptively; Second, frames are registered to align the image sequence and compensate eye and respiratory movements; Third, image brightness is adjusted by remapping image intensities to the entire range between 0 and 255; and fourth, an anisotropic diffusion filter is applied to remove intensity artefacts without distorting vessel boundaries. Following these steps, a Canny edge detector is applied to each frame to extract the boundaries of the vessels. The semi-automated algorithm requires the user to draw a line at the point of interest crossing the vessel boundaries at both sides to measure vessel diameter. The vessel boundaries are separated using the medial line of the vessel. To extract the medial line, the vessel region is segmented using a simple thresholding process. Then, using the regional maximum of the distance transform of the resultant binary image and Hough transform, the medial line of the vessel is obtained. To further increase accuracy, in addition to the user-drawn line, the algorithm finds the intersections of the vessel boundaries with four parallel shifts of the original line in each frame. The mean of Euclidean distance between the intersections of each line with each side of the vessel boundary is then calculated as vessel diameter. The performance of the segmentation method was investigated using area under receiver operating characteristics (ROC) curve with an accuracy of 95% over 50 images. Quantification of dynamic characteristics of retinal vessels pulsations may open new avenues for further research in a wide range of diseases.

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