DEVELOPMENT OF ALGORITHMS FOR AUTOMATIC COMPUTATION OF ARTERIOLAR-VENULAR RATIO IN RETINAL FUNDUS IMAGES

Thesis submitted by

Sandip Sadhukhan

Doctor of Philosophy (Engineering)

Electrical Engineering Department
Faculty Council of Engineering & Technology
Jadavpur University
Kolkata, India

2024

Abstract

This thesis aims to develop the algorithm for Automatic Computation of Arteriolar-venular Ratio in Retinal Fundus Images. Arteriolar-venular ratio (AVR) is correlated with many diseases like coronary heart disease, stroke, atherosclerosis etc. A high AVR has been associated with higher cholesterol levels, high blood pressure diseases of the pancreas etc. A low AVR is caused by abnormal widening of the veins which results chronic high blood sugar levels. Globally around 314 million individuals suffer from glaucoma, hypertensive retinopathy, and diabetic retinopathy. These conditions gradually contribute to vision loss, which is a significant concern in developing nations. Timely detection of these vascular changes may allow preventive treatments to reduce the risk of vision loss. These data can be used in telemedicine and remote diagnostic areas. Manually classifying arteries and veins requires expertise in retinal image interpretation and is a very labour-intensive process. Different tasks associated with automatic computation of AVR in a fundus image. They are - a) Automated detection of Region of Interest (ROI) from where the vessels of interest will be taken into consideration, b) Artery-vein patch extraction based on vessel central-line, c) Classification of vessels into artery and vein and finally d) Computation of AVR. Below section gives a brief description of each task and approach we have followed:

Automated detection of Region of Interest (ROI) - For this accurate detection and localization of Optic Disc (OD) in the fundus image is the major task. We utilized a fully convolutional network based on the U-Net architecture to segment the optic disc (OD). The U-Net design proves highly effective in image segmentation, especially in scenarios with limited availability of input images. After successful segmentation of OD and removal of false positives, based on the diameter of the OD, the region of interest is identified. It is an annular region that falls under two concentric circles of radius 1 and 1.5 times the diameter of the optic disc.

Artery-vein patch extraction based on vessel central-line - The next step is extraction of artery vein mask from the fundus image dataset. In this case, we have used INSPIRE-AVR dataset for which artery-vein vessels mask ground truth is available. he centre-line coordinates were then determined using these masks. Subsequently, separate patches for arteries and veins were generated, each measuring 32×32, based on the received artery and vein centre-line coordinates.
Classification of vessels into artery and vein and finally - A robust automatic method for classifying arteries and veins (A/V) is necessary to automate large-scale retinal image processing. We have addressed this classification task by employing residual attention-based deep neural networks. The attention mechanism reduces the impact of irrelevant features while selectively amplifying important ones, allowing the network to improve features at different levels. The Deep Convolutional Neural Network's overall performance has been enhanced through the use of both residual and attention learning processes.
Computation of AVR - The AVR value is calculated from the calibers of the vessels inside the region of interest (RoI). For this purpose, six largest arteries and six largest veins are considered. The arteriolar to venular ratio is defined as the ratio of CRAE and CRVE where CRAE is the Central Retinal Artery Equivalent and CRVE is the Central Retinal Vein Equivalent. We have applied our method for AVR computation on the publicly available INSPIRE-AVR dataset. We have reported the mean error and the correlation coefficient which is comparable to the reference AVR values.

Keywords: Retinal fundus image, Optic disc detection and segmentation, Fully convolutional neural network, Convolution neural network, Faster R-CNN, Computer-aided diagnosis of diabetic retinopathy, Ocular diseases, Arteries and veins discrimination, Attention mechanism, cardiovascular disorders.