Artificial Intelligence In Medicine xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Artificial Intelligence In Medicine

journal homepage: www.elsevier.com/locate/artmed

Decision support system for detection of hypertensive retinopathy using arteriovenous ratio

Shahzad Akbar[a,*], Muhammad Usman Akram[b], Muhammad Sharif[a], Anam Tariq[b], Shoab A. Khan[b]

[a] Department of Computer Science, COMSATS University Islamabad, Wah Campus, Pakistan
[b] Department of Computer & Software Engineering, College of E&ME, National University of Sciences and Technology, Islamabad, Pakistan

ARTICLE INFO

Keywords:
Hypertension
Hypertensive retinopathy
A/V classification
Arteriovenous ratio
Grading of HR

ABSTRACT

Hypertensive Retinopathy (HR) caused by hypertension is a retinal disease which may leads to vision loss and blindness. Computer aided diagnostic systems for various diseases are being used in clinics but there is a need to develop an automated system that detects and grades HR disease. In this paper, an automated system is presented that detects and grades HR disease using Arteriovenous Ratio (AVR).The presented system includes three modules i.e. main component extraction, artery/vein (A/V) classification and finally AVR calculation and grading of HR. Proposed system uses vascular map and a set of hybrid features for A/V classification. The evaluation of proposed system is carried out using three datasets. The proposed system shows average accuracies of 95.14% for images of INSPIRE-AVR database, 96.82% for images of VICAVR database and 98.76% for local dataset AVRDB. These results support that the proposed system is trustworthy for clinical use in detection and grading of HR disease. Main contribution of proposed system is that it utilizes complete blood vessel map for A/V classification. These arteries and veins are then used to calculate AVR and grade HR cases based on AVR values. Another contribution of this article is that it presents a new dataset AVRDB for A/V classification and HR detection.

1. Introduction

Retina is an interior and important part of human eye whose function is to capture and send images to brain. It consists of different structures along with two types of blood vessels; veins and arteries. These retinal blood vessels are affected by number of eyes diseases such as HR, DR (diabetic retinopathy), etc. HR is caused due to constant high blood pressure in retinal blood vessels. A lot of peoples in the world are suffering HR disease; however, in most of cases, HR patients are unaware of it. The existence of HR and its severity can be detected by patient's eye ophthalmologic examination. Most of the time, HR is diagnosed at the last stage which led the patient to blindness or vision loss; therefore, it is necessary for HR patient to make sure the regular examination of their eyes.

Health care industry has made great use of computer aided diagnostic systems. The automated diagnostic systems are very useful for both ophthalmologists and patients to diagnose different retinal diseases. With the help of automated systems, the ophthalmologists can monitor and make treatment plan of retinal diseases. So, it is a need to establish an automated system for HR detection and grading through retinal images. Fig. 1 shows the normal fundus retinal image and HR affected abnormal images.

HR is considered as an indicator for damage of target organ and its signs may lead to guess the threats of cardiovascular disease, stroke, and mortality [1,2]. HR symptoms and signs frequently get mature in later stages, and these symptoms may help the ophthalmologists in clinical supervision and treatment [3,4].

The paper contains five sections in which Section 1 presents the introduction of HR disease and Section 2 describes the related work of A/V classification and computation of AVR. Section 3 presents the proposed model, color and intensity based features for A/V classifications, width computation of artery and vein segments, and finally calculation of AVR for HR detection and grading. Section 4 describes the experimental results on different datasets and Section 5 provides the discussion and conclusion along with future work.

* Corresponding author.
E-mail addresses: shahzadakbarbzu@gmail.com (S. Akbar), usmakram@gmail.com (M.U. Akram), muhammadsharifmalik@yahoo.com (M. Sharif), anam.tariq86@gmail.com (A. Tariq), kshoab@yahoo.com (S.A. Khan).

https://doi.org/10.1016/j.artmed.2018.06.004
Received 18 August 2017; Received in revised form 23 April 2018; Accepted 25 June 2018

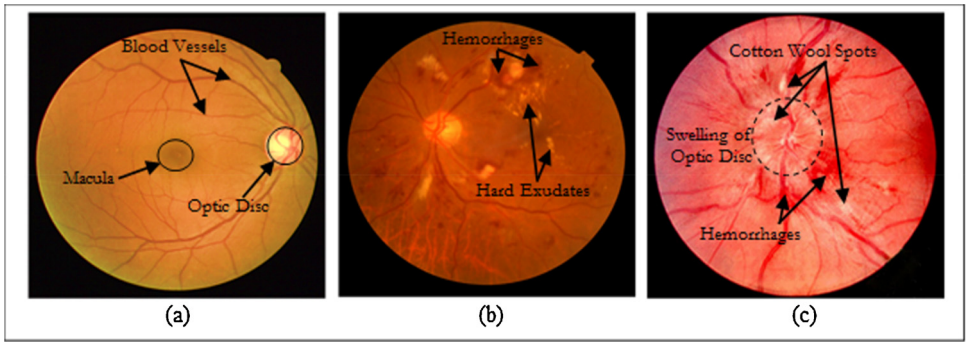

Fig. 1. (a) normal fundus image, whereas (b) and (c) are HR affected fundus images.

2. Related work

In the literature review, various methods were proposed for A/V classification and AVR computation that can be categorized into graph based vascular segmented network methods and features based methods. The graph based vascular segmented network methods classified the vascular network into two sub-graph network i.e. artery-graph network and vein-graph network, such type of methods was proposed by [5–8]. The drawbacks of these methods are manual analysis of graphs and high computational time due to complexity in graph. The feature based methods depend upon arteries and veins in fundus colored retinal image that contain several variations in color and geometric features [9], such type of methods were proposed by [10–14]. The drawback of these methods is manually taking region of interest (usually optic disc) for color and intensity features extraction.

Manikis et al. [15] presented a technique founded on region based classification and multi scale filtering for AVR computation and showed 93.70% accuracy on DRIVE and 93.10% accuracy on STARE databases, respectively. Noronha et al. [16] presented a system based on Radon transform for vessels segmentation and Hough transform for optic disc detection. The width of vessel segments was calculated for AVR computation and showed 92% accuracy on DRIVE database. Niemeijer et al. [17] presented a technique in which 27 features were extracted for A/V classification in region of interest (optic disc). To compute AVR, widths of vessels were calculated. This technique was a combination of vessel pixel classification and tobogganing. In A/V classification, it showed ROC (receiver operator characteristic) curve value 0.88 for DRIVE images. Narasimhan et al. [18] presented a technique to diagnose hypertensive retinopathy in which retinal blood vessels segmentation was done by gray level features and the moment based features. For A/V classification, intensity based features colors based features from retinal images were used for SVM (Support vector machine) classifier. AVR and retinal vessels width were measured for detection of HR. The proposed technique showed 93.0% accurate results on database VICAVR. Akbar et al. [19] proposed a hybrid system which detect HR along with Papilledema. To detect HR, It showed accuracies of 95.10%, 95.64% and 98.09% on INSPIRE-AVR, VICAVR, and local dataset, respectively. To detect Papilledema, it showed accuracies of 95.93% and 97.50% on STARE and local dataset, respectively. Mirsharif et al. [20] proposed A/V classification in order to calculate AVR in which color based features and intensity based feature were used in SVM and LDA (Linear Discriminant Analysis) for A/V classification. This technique showed 96% accurate results on DRIVE database. Muramatsu Chisako et al. [21] presented a technique in which retinal vessel segmentation was performed through top hat transformation along with double ring filter. The extracted features in region of interest (optic disc) were used in LDA classifier for A/V classification and showed 75% accuracy on DRIVE database.

For A/V classification, few graphs based automated methods were also proposed by [7,22]. CAIAR [23] automated system was presented to calculate vessel width and vessel tortuosity in children's retinal image. Few techniques were also developed for retinal images of adults such as Sirius [24] which is an internet based application used for analysis of retinal images, VAMPIRE [25] which is used to diagnose landmarks in retinal images and SIVA [26] is used for the morphological analysis of retinal images. Some automated systems such as RIVERS [27], ARIAS [28] and QUARTZ [29] were also developed to calculate vessel properties for analysis of retinal image.

In this related work, all methods were calculated on publicly standard databases that are designed for the diabetic retinopathy rather than publicly available HR database, still not available. These methods were evaluated on other than HR databases and showed a slightly higher accuracy just because of that the databases consist of such images in which arteries and veins are much clear and visible. Local databases were used by few researches; therefore, they achieved low accuracy results. In this paper, we evaluated the presented technique on local dataset of patients acquired from AFIO (Armed Forces Institute of Ophthalmology), Pakistan and two publicly databases i.e. INSPIRE-AVR and VICAVR for detection and grading of HR with good results than previous methods.

According to existing literature, most of the methods focused on A/V classification for blood vessels in optic disc region only. Another short fall is that there is no such database available which provides ground truth against A/V classification for complete fundus image along with annotated AVR and HR grading. In the presented paper, we proposed a novel method for A/V classification of complete fundus image. A new dataset AVRDB is also developed containing ground truths for blood vessels, arteries, veins, AVR and also HR grading. The proposed system not only detects HR but it also grades HR into moderated HR and severe HR.

3. Proposed methodology

The proposed method performs HR detection and grading through fundus retinal images and it contains three major modules i.e. preprocessing and main component extraction (blood vessels and optic disc (OD)), A/V classification and finally AVR computation and HR grading. Fig. 2 illustrates the flow diagram of proposed system along with all sub modules.

3.1. Preprocessing and main component extraction

First module of proposed system is main component extraction. It includes preprocessing to perform contrast enhancement, blood vessel enhancement and segmentation and OD localization and segmentation. Blood vessels are important for HR detection and grading due to the structural changes which appear in vessels at different stages of HR [30]. Blood vessels are enhanced through 2D Gabor wavelets [31] and vessel segmentation is performed using [32]. Fig. 3 describes the vessel segmentation results of normal and abnormal fundus retinal images.

The blood vessels enter retina through OD which is yellowish circular bright shaped in colored fundus retinal image and OD detection is