Retinal Vessel Segmentation Using an Entropy-Based Optimization Algorithm

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ABSTRACT

This article presents an algorithm for the segmentation of retinal blood vessels for the detection of diabetic retinopathy eye diseases. This disease occurs in patients with untreated diabetes for a long time. Since this disease is related to the retina, it can eventually lead to vision impairment. The proposed algorithm is a supervised learning method of blood vessels segmentation in which the classification system is trained with the features that are extracted from the images. The proposed system is implemented on the images of DRIVE, STARE and CHASE_DB1 databases. The segmentation is done by forming clusters with the features of patterns. The features were extracted using independent component analysis and the classification is performed by support vector machines (SVM). The results of the parameters are grouped by accuracy, sensitivity, specificity, positive predictive value, false positive rate and are compared with particle swarm optimization (PSO), the firefly optimization algorithm (FA) and the lion optimization algorithm (LOA).

KEYWORDS

Diabetic Retinopathy, Feature Extraction, Optimization, Retinal Vessels

INTRODUCTION

The structure of blood vessels in retina helps in detection of number of eye diseases which includes arteriosclerosis, diabetes, retinal vein occlusion, retinal artery occlusion, hypertension, cataract, glaucoma and most importantly diabetic retinopathy. These all diseases can be detected by monitoring the changes in the structure of an eye. A human eye consists of iris, lens, blood vessels, pupil, retina etc. Eye helps in sensing and visualizing different objects. All the different parts of an eye help in visualizing in one or another way. Each and every part can lead to different disease if affected by diabetes. The patients having prolonged and untreated diabetes suffered from eye disease named as diabetic retinopathy (DR). DR is the leading cause of blindness as the retina of the eye is directly affected by this disease. According to the latest figures issued by World Health Organization (WHO), the patients suffering from diabetes will reach to 300 million by 2025 (Zimmet, 2016). Currently, the number of diabetics are 69.2 million from which 7 million people suffer from vision loss (Joshi, 2016).

Diabetes can affect any body part like eyes, kidneys, the liver, the heart, and bones. Eye became the significant part of the human organ system needs special care. The impact of untreated blindness

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is shown on blood vessels, nerves and the vision of the patient. DR is caused when the blood vessels of the human retina are damaged, and they leaked blood and lipids. The symptoms of DR is same as that of changes that occur in eyes due to age, so there is a need of fine procedures which can differentiate between DR and age related eye degradation.

DR can be detected easily by segmenting retina and its blood vessels. The segmented images of the retina help in studying the blood circulation of human eye at the micro level. As it is the part of central nervous system, so it is easy for researchers as well as for the ophthalmologists to study the retina for different pathologies (Fraz, 2012). It is highly sensitive to light and consists of optic disc, blood vessels and macula. The various pathologies in the retina of an eye can be detected by monitoring the variations in the various components of retina. The blood vessels can be easily visible to the human eye. So, the pathologies in blood vessels can be checked easily by the clinicians. All the different eye diseases that occur due to pathologies in retina can be detected by segmentation of retina. The retinal images are captured using special camera named as Fundus Camera as well as by using ophthalmoscopes. Fundus camera is a camera of high resolution especially used for retinal imaging. Other techniques used for acquiring retinal images include laser screening, optics screening and angiography. Fundus imaging is prominently used for retinal imaging by dilating the pupil of retina using some eye drops. Then the fundus of the image which is the region opposite to lens of eye and includes optic disc and macula is focused for imaging.

The various diseases in eye cause different types of changes in the vasculature of human retina. The various disorders of an eye can be checked by studying the segmentation of retina and its various parts. The clinicians also study the changes in the retinal vasculature for evaluating the severity of eye diseases and to decide whether the disease can be curable or not. The various changes in the retinal eye can be categorized into neovascularization, collateralization and origination of retinal vascular shunt (Paul, 1974). If the new blood vessels are originated in either retina or in the area adjacent to it, then it leads to neovascularization. In this the blood vessels grows in irregular fashion generally near larger arteries and veins in any direction. They are appeared in the areas where there are no blood vessels present. Collateralization relates to the growth of blood vessels in between the existing blood vessels by joining new arteries and veins to the existing new arteries and veins respectively. The blood flow in the vessels is hampered if there is cross connection between them. The last case of formation of shunt occurred when the blood flows without using capillary bed at a very high speed.

DR is disorder of human eye which is caused by untreated diabetes. In this the blood vessels are damaged and they leak blood and in some cases they lead to growth of new blood vessels. Due to which, the vision deteriorates and it leads to blindness. DR leads to formation of microaneurysms, exudates, hemorrhages, cotton wool spots, and lesions. Microaneurysms are small red dots which are formed when the walls of capillary blood cells are weakened. When the weakened blood cells leak, they become hemorrhages which are flame-shaped. After that, when the proteins and lipids from the blood are leaked, then they lead to formation of exudates. Hard exudates are of yellow or white color in eye retina. When the severity of DR advances, the blood vessels get obstructed and leads to soft exudates or cotton wool spots and they are white in color.

DR is classified broadly into two stages: Proliferative DR (PDR) and Non-Proliferative DR (NPDR). NPDR is the initial stage of DR in which the damage of retinal blood vessels has just started. The three stages of NPDR are mild, moderate and severe (You, 2011). The mild stage of NPDR is the initial stage of NPDR and requires no treatment but the progression of the disease needs to be monitored strongly by the clinicians. In mild NPDR only microaneurysms occur or in some other cases hemorrhages can also occur. In moderate NPDR, cotton wool spots start appearing due to blockage of blood vessels that nourish the retina. In the case of severe NPDR, the growth of new blood vessels starts in an irregular fashion in the eye retina. Finally, vision loss or blindness occurs due to formation of new blood vessels and due to weakness of existing blood vessels in the retina.

DR can be detected by the segmentation of blood vessels of the retina. The variations in width, length, branching angle, vascular pattern, and tortuosity of the blood vessels can be helpful in detecting
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