Diagnosing Diabetic Retinopathy using Retinal Blood Vessel Examination Based on Convolution Neural Network

Mohammad Hosein Fatehi[1], Mehdi Taghizadeh[2], Mohammad Mahdi Moradi[3] , PedramRavanbakhsh[4]
[1,4]Department of Biomedical Engineering, Kazerun Branch, Islamic Azad University, Kazerun, Iran
[2,3]Department of Electrical Engineering, Kazerun Branch, Islamic Azad University, Kazerun, Iran
Email: mh.fatehi@iau.ac.ir, taghizadeh.azad@gmail.com, moradi.m.mahdi@gmail.com , pedi3474@gmail.com
Receive Date: 20 June 2022, Revise Date: 25 July 2022, Accept Date: 22 August 2022

Abstract

Retinal blood vessels include arteries and veins and are usually next to each other. Blood vessels are used to classify the severity of the disease and are also used for guidance during surgery, as retinopathy is one of the dangerous diseases.Diabetic retinopathy can cause the formation of new vessels (neoangiogenesis). This condition causes low vision and even blindness. Therefore, a reliable method for diagnosing and classifying the vessel is needed in order to avoid these complications. Retinopathy is one of the hidden diseases that is usually not known. prevent the next possibility.There are several methods for diagnosis, the most common of which is the use of traditional methods based on manual feature extraction, which requires a lot of feature geometry and expertise, and is usually dependent on data. From this method, neural convolution is a reliable, efficient and reliable method for extracting features without manual intervention, which requires a lot of expertise, which also reduces the dependence on data.In this article, using convolutional neural network, diabetic retinopathy has been diagnosed with accuracy and sensitivity of 98.8% and 97.5%, respectively.The obtained results indicate that the proposed method is suitable for locating blood vessels automatically.

Keywords: blood vessels, convolutional neural network, localization, retina.

1. Introduction

Retinal blood vessels usually include arteries and veins. Information about the structure of blood vessels can help to diagnose the severity of eye-related diseases and even non-eye-related diseases such as diabetes. Also, in many cases, they can be used as an aid for surgery. [1].

Blood vessels are used to locate and diagnose the optic nerve of the pit. Also, as a basic result for investigating and diagnosing local eye disease and irregularities in diameter and color. In some cases, they cause the blockage of the central retinal artery and occasionally cause the general contraction of the retinal arteries [2].Abnormal blood vessels may become hard tissue that separates the retina from the back of the eye and causes retinal detachment, which, if left untreated, can lead to severe vision loss and blindness. Abnormal blood vessels, the distribution of blood vessels in retinal images, is the basis of many medical analyzes in the diagnosis or prevention of diseases such as blood pressure or heart disease. [3].Therefore, identifying and diagnosing blood vessels is very important, and the simpler, more accurate and automatic these methods are, the more useful they are. For these reasons, in this article, we are looking for a simple and efficient method to separate blood vessels.

2. Related works

In today's world, the role of engineering in medicine has increased day by day, and

diagnosis of diseases has become faster, easier and more accurate by developing imaging technology and processing these images. Several researches have been conducted in these fields, which can be attributed to Akbari et al. in [4], who investigated the detection of blood vessels in human retina images using interconnected components and achieved 95% results.

Also, Joz et al. [5] proposed a method for automatic segmentation of blood vessels in two-dimensional color images of the retina. This method works based on the edges of the image and obtains an acceptable result.

Kolinder et al. [6], in a research proposed the segmentation of retinal blood vessels based on the neural network, and their proposed method recognized the segmentation of retinal blood vessels using supervised methods with an acceptable accuracy of 96%.

Hosseini et al. [7] investigated the image segmentation method for retinal image detection using Gabor filter. In this research, a new method using Gabor filters to extract feature vectors from eye images is presented. In the pre-processing stage of this method, after applying the Wiener adaptive filter, the desired area is selected from the normalization bar. Then the 2nd order wavelet is applied to this area twice and its dimensions are reduced. In the next step, Gabor filters are applied to the image in different directions and the feature vector of the image is extracted. Acceptable results were obtained, which calculated 98% accuracy of locating the area.

In [8], a segmentation identification method is proposed for the analysis of retinal color images. In this article, image processing methods such as morphological operators, local threshold, and two-dimensional Gaussian filters have been used for the segmentation of retinal depth digital images. .

In the articles stated based on manual and engineering characteristics, it is a characteristic that if the methods can be system-based and automated, it is very important and valuable and can help humans a lot in the diagnosis of diseases.

3. Materials and Methods

Detection of blood vessels is a major problem in automatic processing of retinal images, and on the other hand, vessels have certain characteristics such as thickness (which is a key indicator in diagnostic transformation).

Segmentation and zoning of blood vessels is the best method to find border lines in a photo. In this case, the boundary lines are related to the structure of the blood vessels, where it is not necessary to extract the entire network just to find the structure of the eye.

4. Database

Stare database is used in this article. The STARE (Structural Analysis of the Retina) database was designed and initiated in 1975 by Michael Goldbaum at the University of California and the University of San Diego. The database was funded by the US National Institutes of Health.

The dataset consists of 400 raw images of the retina, with specialized annotations in each image, the segmentation of blood vessels, including 400 manually labeled images, which include healthy labels, 200 images, and 200 retinopathy images, which are labeled by two face labeling experts has taken .

5. Preprocessing

The main step in this topic is pre-processing the extraction of blood vessels, in which the images are resized first, and then we perform the processing on the gray images to increase the processing speed. As a result, we first convert the received image into a gray image if it is colored.

6. Image Processing

First, the image has been balanced so that the retinal vessels can be separated as well as possible, which in this research will be applied from the contrast limited adaptive graph balancing (CLAHE) in order to adjust the contrast to the image. After performing the balancing operation, the Gaussian filter has been applied with the aim of reducing the amount of noise on the image, and its calculation formula is shown in Equation 1.

$$G(x,y) = \frac{1}{2\pi\sigma^2} exp\left(\frac{x^2+y^2}{\sigma}\right) \quad (1)$$

Using a combination of opening operation and Gaussian filter is an approach to reduce all the details of the vessels and some noises.

Then, to improve the results, image contrast improvement has been applied to the images. In a digital image, the values of pixels represent the characteristics of that image (such as image brightness and image resolution). The histogram of an image is actually a graphical expression of the brightness of the image. Brightness values (0-255) are expressed along the X axis and the frequency of each value is expressed along the Y axis. Figure 1 shows the histogram of a gray sample image.

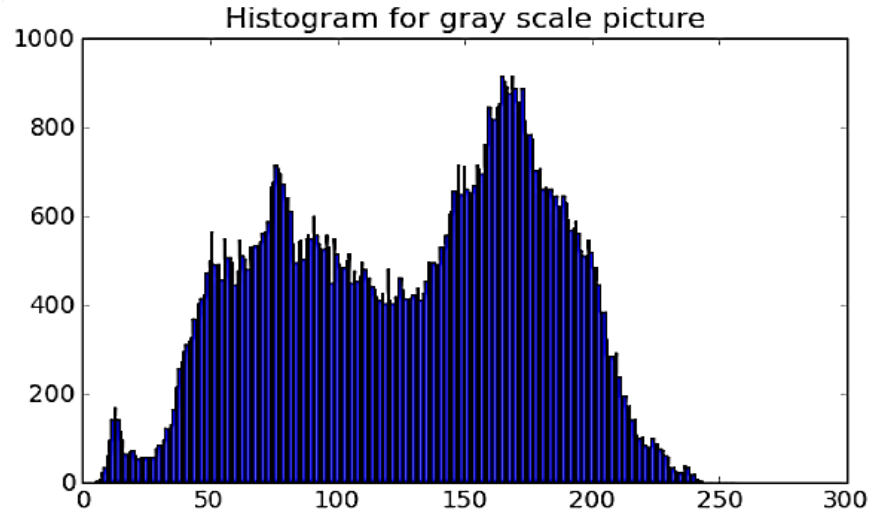

Fig.1. Histogram of a gray image

In the proposed method of the article, the contrast improvement limit value is considered to be 0.15. This value is selected according to experience and repetition and testing.

Then, the adaptive histogram equalization method calculates the new value of the histogram by calculating the cumulative distribution function. In this research, Rayleigh's probability function was used, which Rayleigh distribution usually provides better results in cases where the variable has two members and the two members have a normal distribution with

the same variance and are independent of each other [9].].

At this stage, the image is completely cleaned of noise and we are ready for the main stage, which is the diagnosis of retinopathy

7. Classifier

In this part, which is the main stage, the two groups of healthy and retinopathy are separated using convolutional neural network based on Alexnet architecture. Convolutional neural network is a reliable method in image processing, we used convolutional neural network in [11-13] to examine medical images from convolutional neural network, which has provided acceptable results.

8. Results

In this section, the proposed method of examining blood vessels for the diagnosis of retinopathy has been evaluated.

Reduce image noise

Figure 2 shows the contrast enhancement and denoised retinal image after grayscale.

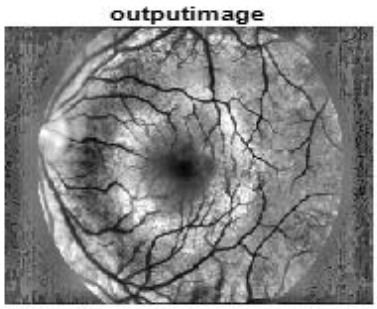

Fig.2 The reconstructed image with the proposed method

This step is applied to all the images so that the images can be entered into the convolutional neural network for recognition.

In Figure 3, you can see the convolutional neural network with the Alexnet architecture used

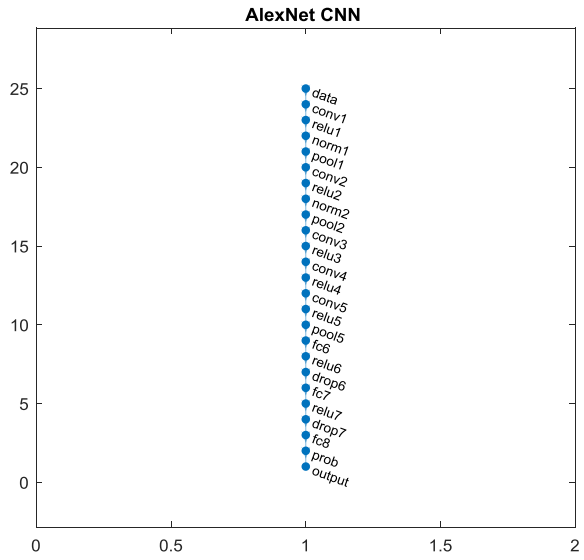

Fig.3. Convolutional neural network structure with Alexnet architecture

In Figure 3, you can see the structure of convolutional neural network with Alexnet architecture, which is used for classification in the proposed method.

Here, the confusion matrix has been used to calculate accuracy and sensitivity, whose relationships are given in equations 2 and 3. In this section, 1000 deep features were extracted and the features are entered as input to the convolutional neural network classifier, and the convolutional neural network separates two groups.

The classification results were calculated by 5-fold cross-validation, which was calculated and evaluated by the 5-fold method so that the results have higher validity.

The results are shown in Table 1 and Figure 4.

Sensitivity (Sen) and accuracy (Acc) are two metrics used to evaluate CNN classification performance. They are defined based on true positive (TP), true negative (TN), false positive (FP) and false negative (FN) values.

$$Sen = \frac{TP}{TP + FN} \quad (2)$$

$$ACC = \frac{TP + TN}{TP + TN + FP + FN} \quad (3)$$

In this work, cross-validation has been used, Kfold-5 has been used in this work, the results of which are shown in Table 1.

Table 1. Accuracy and sensitivity results of the proposed method

sensitivity	accuracy	K_fold
97.9	98	1
97.4	99	2
97.5	99.4	3
97.3	98.3	4
97.4	99.1	5
97.5	98.8	av

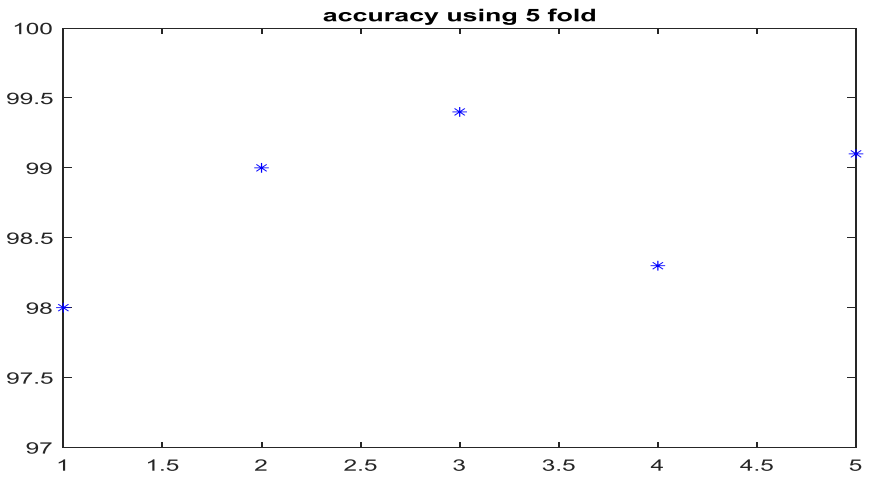

Fig.4. Accuracy results with 5-fold cross-validation

Discussion

Diabetes is a common disease that affects many people. This disease causes problems in body parts. One of these problems is diabetic retinopathy, which causes bleeding in the patient's retina. Because this complication occurs gradually, the patient often does not notice the problem. Therefore, timely diagnosis is very important.

In this article, first the possible and initial noise of the images were weakened, then two groups of healthy and retinopathy were distinguished by using convolutional neural network based on Alexnet architecture.

The accuracy results of one of the situations are shown in Figure 4 as a confusion matrix.

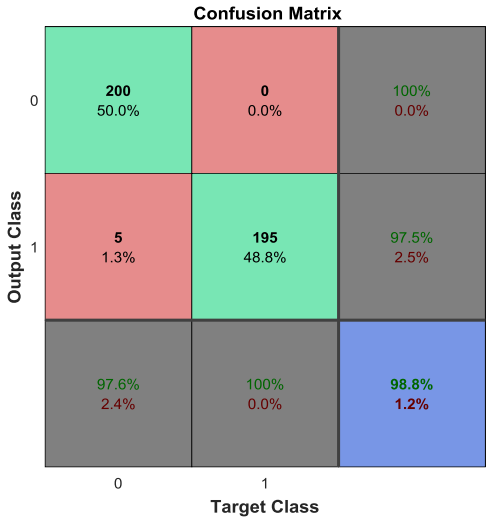

Fig.5. The confusion matrix of the proposed method

For better understanding, the ROC diagram is shown in Figure 6.

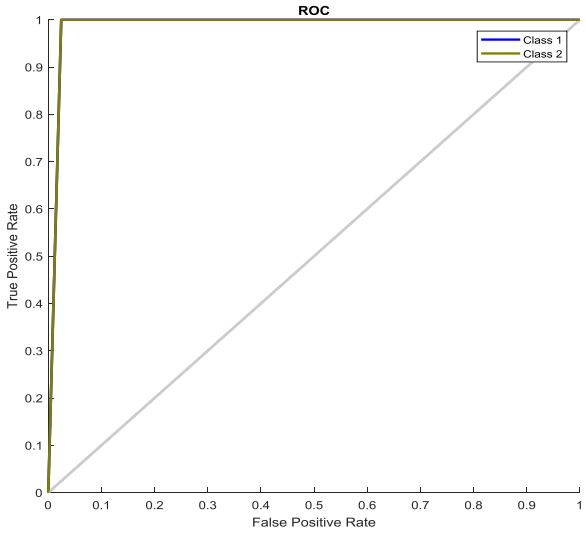

Fig.6.ROC diagram of the proposed method

To check the results of the proposed method with the results of other articles, it is shown in Table 2.

Table 2) Comparison of the proposed method with other methods

Ref.	accuracy
[4]	95
[6]	96
[7]	98
My method	98.8

According to the results of Table 1 and the comparison according to Table 2, it can be said that the proposed method has acceptable accuracy for diagnosing retinopathy and is also a suitable method compared to other methods.

References

[1] Classification of retinal vessels into arteries and veins for detection of hypertensive retinopathyو Biomedical Engineering Conference (CIBEC) (2014), pp. 133-136.

[2] P. SUN, X. ZHAO, M. TANG, Changes of retinal microcirculation in postnatal patients with pregmancy-induced hypertension based on OCTA,International Journal of Engineering Science, 22 (11) (2022), pp. 1861-1866.

[3] Q. ZHANG, W. WANG, Y. DU, Retinal optical coherence tomography and optical coherence tomography angiography in Alzheimer's disease,Chinese Journal of Behavioral Medicine and Brain Science, 31 (10) (2022), pp. 955-960.

[4] Asha Gowda Karegowda, Asfiya Nasiha, M.A.Jayaram, A.S. Manjunath, "Exudates Detection in Retinal Images using Back propagation Neural Network", vol. 25- No. 3, july 2011.

[5] Hindawi Publishing Corporation , Journal of Medical Engineering , Volume 2013, Article ID 408120, 21 pages .

[6] A. HATAMIZADEH, D. YANG, H. ROTH, UNETR: transformers for 3D medical image segmentation, Proceedings of IEEE/CVF Winter Conference on Application of Computer Vision (2022), pp. 574-584.

[7] Jyoti Patil, A.L.Chaudhari, "Development of Digital Image Processing using Fuzzy Gaussian Filter Tool for Diagnosis of Eye Infection", International Journal of Computer Applications (0975-8887), volume 51- No. 19, August 2012.

[8] A. Osareh, B. Shadgar, "Automatic Blood Vessel Segmentation In Color Images Of Retina", Iranian Journal of Science & Technology, Transaction B, Engineering, Vol. 33, No. B2, pp 191-206, 2009.

[9] K.K. BAHADAR, A. AKHALIQ, M. SHAHI DCorrection: a morphological hessian based approach for retinal blood vessels segmentation and denoising using region based Otsu thresholding,PLoS One, 11 (9) (2016).

[10] S.N. WANG, C.Z. ZHU, B.J. ZOU,Retinal blood vessel segmentation using extreme learning machine, Journal of Advanced Computational Intelligence and Intelligent Informatics, 21 (7) (2017), pp. 1280-1290.

[11] Moradi, M., Fatehi, M., Masoumi, H., Taghizadeh, M. Deep neural network method for classification of sleep stages using spectrogram of signal based on transfer learning with different domain data. *Scientia Iranica*, 2022; 29(4): 1898-1903.

[12] Moradi, M., Fatehi, M., Masoumi, H., Taghizadeh, M. Deep Learning Method for Sleep Stages Classification by Time-Frequency Image. *Signal Processing and Renewable Energy*, 2021; 5(3): 67-83.

[13] Moradi MM, Fatehi MH, Masoumi H, Taghizadeh M. Adaptive neuro-fuzzy method for sleep stages detection by PPG signal. Journal of Advanced Pharmacy Education & Research| Jan-Mar. 2020; 10(S1).