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Retinopathy Diabetic Recognition and Detection using novel Intelligent algorithms

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Highlights

- The proposed method in this research aims to address the challenges associated with the detection of microaneurysms, which are the initial symptoms of diabetic retinopathy. The novelty of this work lies in the use of image processing and machine vision tools, specifically applying image processing techniques and machine learning methods for the detection of microaneurysms in diabetic retinopathy.
- The literature review section highlights various existing methods for vessel detection in the retina, including model-based methods, pixel classification-based methods, vessel tracking-based methods, and multi-scalable analysis-based methods. However, the proposed method introduces a new approach that combines different levels of processing to achieve retinopathy area detection. This approach involves pre-processing, image segmentation based on edge detection, dimension reduction, feature selection and extraction, and a combination method for the detection of retinopathy areas and their growth levels.
- By combining these different processing levels, the proposed method offers a comprehensive and integrated approach to detect and monitor retinopathy. This integration of techniques and levels of processing sets the proposed method apart from previous approaches and contributes to the novelty of this research.
- Additionally, the use of hybrid methods, such as the combination of Spiking Neural Networks (SNN) and percolation theory, provides a unique approach to retinopathy detection. The rationale behind using these hybrid methods is to leverage the strengths of each technique for improved accuracy and effectiveness in detecting microaneurysms.
- Overall, the novelty of this work lies in the integration of different processing levels, the use of hybrid methods, and the application of image processing and machine vision tools to tackle the challenges associated with diabetic retinopathy detection, specifically the detection of microaneurysms.

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Abstract

This research addresses the challenge of early detection and recognition of retinopathy, a common complication of diabetes that can lead to vision loss. We propose a novel approach utilizing hybrid methods for diabetic retinopathy recognition and detection. The proposed approach consists of four levels: pre-processing for noise removal and standardization of the input dataset, image segmentation using Spiking Neural Network (SNN) based on edge detection, dimension reduction and feature selection using percolation theory, and the final step of combining SNN and percolation theory for retinopathy area detection. Experimental results demonstrate that our proposed method outperforms existing approaches in terms of accuracy. By employing this approach, we aim to contribute to the early detection and prevention of retinopathy, thus mitigating the potential consequences of this disease and preserving eyesight.

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1. Introduction

Today, diabetic known as one of the non-avoidable illnesses in early stages which the most dangerous diabetic is retinopathy that happens due to changes in blood vessels. Diabetic retinopathy is a general term which created for vascular problems of diabetic patient's retina and divided into two groups named proliferative and non-proliferative.

The first symptom of changes in blood vessels at diabetic retinopathy is microaneurysms which are the little red spots appear in retina surface. Microaneurysms not only causes blindness, but lack of attention to disease and growing of that causes new vessels and other effects and finally Visual impairments. Early detection of microaneurysms in retina is early-stage diabetic retinopathy detection to prevent and treat blindness. So, Necessity of blood vessels extraction from retina images require to use algorithms and tools for reducing dependency of user and eliminating error factors to detect microaneurysms on time.

The most important tools which exist in image medical detection are image processing and machine vision which works based on machine learning methods. This research uses these tools for detecting microaneurysms in diabetic retinopathy. In the following, some other research and methods examined. Then, a new method proposed and then simulated. At the end, simulation results represented and compared with other methods.

2. Literature Review

A lot of methods and techniques proposed until now for detecting vessels in retina which all of them have advantages and disadvantages. Vessel detection methods introduced and compared in [1] and divided into for techniques such as model-based methods, pixel classification-based methods, vessel tracking-based methods and multi-scalable analysis-based methods.

In model-based methods, a structure considered for vessels and similar patterns extraction in image based on them. Second order and first order of Gaussian models and tracks models proposed in [2] which named window-based methods. In [3], vessels model in image assumed to be a gaussy curve and optimized vessel contrast and foreground by using gaussy model filters. Primitive-based methods which proposed in [2], segment the vessels by track extraction in image. Then KNN classification used. The methods can be placed at pixel classification-based methods.

In pixel classification-based methods, a supervised classification techniques used for assigning vein class and non-vein class. Then feature vector from different characteristics created such as pixels intensity, wavelet transform and morelet wavelet transform based on [4] or steerable wavelet based on [5]. In vessels recognized by changing scale parameters and rotation angle using 2D morelet wavelet transform.

Tracking for accessing to vessels structure used in vessels tracking-based methods. The first methods of this techniques proposed in [6] which some features such as curvature, center line, thickness and vessel density are continuous and each vein composed of a collection of pieces of veins. Each piece veins determine by three parameters which consist of direction, central line, and width. Next piece of veins and vessels estimated by Kalman filter Bb having these three parameters for now piece of veins and all the recent piece of veins. Then the estimated real position of vein and vessel obtained by using Gaussian filter.

Multi-scalable analysis-based methods use multi-scalable analysis which have the advantages in comparison to other methods and this is detection of vessels in any diameter and stretches. In [7] a multi-scalable feature extraction method proposed which used local maxima at gradient domain scales and Hessian Tensor curvature maxima in a two level of region growing process. In [8] a hybrid Hessian and Gaussian filter used. In [9] blood vessels extraction did based on combinational Gabor filters for background noise reduction and enhancing blood vessels quality and then thresholding-based dependent pixels matrix. Another method uses supervised learning for blood vessels detection in retina images based neural networks classification and extraction [10]. Ant Colony Optimization (ACO) used for recognizing and detecting vessels [11]. Another similar research used Ant Colony Optimization for feature selection of segmented retinopathy images.[12]

Some new studies about retinopathy detection proposed which one of them is [13] that used deep convolutional neural networks for diabetic retinopathy detection by image classification. In this study, convolutional neural networks (CNNs) power to diabetic retinopathy detection, which includes 3 major difficult challenges such as classification, segmentation and detection. The result obtained 95.68% accuracy. In another study which proposed in [14], diabetic retinopathy detection did based on convolutional neural networks (CNNs) and Hough transform. The success rate of exudate detection is 99.18%.

Generally, vessel detection algorithms faced with some problems such as noise, low contrast between vessels and image background, variable width, intensity and vessels shape. There are some challenges in vessels extraction which can be difficult for recognition and detection. The most important are low contrast of capillaries, optical disk border, retina image border and pathology spots. An ideal segmentation method is the techniques to solve the mentioned challenges.

3.Proposed method

Suggested approach consists of three levels. At the first, pre-processing, then image segmentation based on edge detection, after that dimension reduction, feature selection and extraction and at the end, combinational method apply to detect the area of retinopathy and it's growing levels.

At first, image normalization done due to noise removal, image resizing and intensity correction. Then a method uses for image segmentation to represent image edges an image to constituent regions or objects. This part will be use SNN.

To apply this network, it's necessary to determine spikes which have three methods to presenting such as wavelet coefficient thresholding, adaptive filters and Work Domain Potential of Thresholding. This approach uses Work Domain Potential of Thresholding to segmentation based on edge detection.the value of this threshold, define as equation (1).

$$\begin{cases}\sigma_n = median\{\frac{|x|}{0.6745} \\ Threshold = 3.5\ \sigma_n\end{cases} \quad (1)$$

Based on equation (1), x is the registered signals from the raw signal and σ_n is noise variance. This is important to notice when using noise variance, it may be the value of threshold will be bigger. So, some spikes will be removed in faulty way. After choosing threshold value, spikes will be balance based on maximum values. This work is too important in segmentation based on edge detection with spikes. This neural network has training like others with the purpose of finding $f: R^n \rightarrow R$ mapping such as equation (2).

$$f(v) = \sum_{i}^{n} w_i \varphi(||v - C_i||) \quad (2)$$

Based on equation (2), $v \in R^n$ is the 32 points of inputs in image and Gaussian basis function $\varphi(0)$ calculated as equation (3).

$$\varphi(v) = exp(\frac{-v^2}{2\sigma^2}) \quad (3)$$

After that it is important to calculate gradient descent for random initial values of weights for training samples which calculated as equation (4).

$$e_i = t_i - y_i = t_i \sum_{j-1}^{N} w_j \varphi(||v_i - C_j||) \quad (4)$$

So, the errors of total network are equal to training sample input P from image data to $E = \frac{1}{2}\sum_{i=1}^{P}|e_i|^2$. If E errors are less than threshold error, the training will be finish. This value will be set as manuel in coding. Otherwise, these weights will be upgrade by gradient descent. After finishing training by SNN, the ability amount of each spike achieved to its class which are segmentation part and edges.

After segmentation, dimension reduction, feature selection and extraction based on percolation theory algorithm done. This theory uses in graphs more, but apply to feature detection in this approach. some liquid is poured on top of some porous material and the purpose is the liquid be able to make its way from hole to hole and reach the bottom. This theorem work with Kolmogrov Rule. Equation (5) will be used for this works as optimized work.

$$\eta^* = \frac{P(\frac{v}{SelectedFeatures})}{P(\frac{v}{TotalFeatures})} \quad (5)$$

According to equation (5), $P(\frac{v}{SelectedFeatures})$ and $P(\frac{v}{TotalFeatures})$ represents selected features and sum of features which in total defined as characteristic value probability (v) for selected and all feature. Dimension reduction will be done with this equation, too. There is a thresholding value which sets 0.01 as default value. It is noteworthy that selected features in this research are color and contrast of edges and also segmented parts of segmentation process based on edge detection. It is obvious that whatever the number of features is less and results obtain better performance in comparison to other methods, the performance of proposed technique is better. By proposing this methods, combinational SNN and percolation theory will be detecting the retinopathy parts in images. This approach simulated to show the results and compared with some recent methods.

In our study, we employed several algorithms and models, each with their respective hyperparameters. Here is a detailed description of the hyperparameters used, along with their values and the rationale behind their selection:

1. Pre-processing:
2. Noise Removal: We used a probabilistic noise removal technique with a noise threshold value of 0.1. This value was selected based on empirical observations and prior research, aiming to balance noise reduction while preserving important image details.
3. Standardization: The input dataset was standardized using mean subtraction and division by the standard deviation. This standardization ensures that the pixel values have zero mean and unit variance, facilitating model convergence and training stability.

4. Spiking Neural Network (SNN) for Image Segmentation:
   - Neuron Threshold: The threshold value for spike generation in SNN was set to 0.5. This value was chosen to achieve a balance between detecting relevant edges and suppressing noise.
   - Learning Rate: We used a learning rate of 0.01 for weight updates in the SNN. This value enables moderate adjustments to the network weights to gradually converge towards optimal edge detection.
5. Percolation Theory for Feature Selection and Extraction:
   - Threshold Level: Percolation theory utilizes a threshold value to select relevant features. We set the threshold level to 0.6 based on empirical evaluations and preliminary experiments. This value was found to effectively capture blood vessel edges and the intensity of edges associated with retinopathy.
6. Combination Method of SNN and Percolation Theory:
   - Weighting Factor: To combine the results of SNN and percolation theory, we used a weighting factor of 0.7 for SNN and 0.3 for percolation theory. This combination ratio was determined through iterative experiments to achieve the best performance in terms of retinopathy area detection.

The selection of these hyperparameter values was based on prior knowledge, empirical evaluations, and iterative experiments. We aimed to strike a balance between model complexity, computational efficiency, and optimal performance. These hyperparameters were tuned to maximize the accuracy and effectiveness of our proposed approach for diabetic retinopathy recognition and detection.

It is important to note that the hyperparameters mentioned above are specific to our study and dataset. Depending on the specific implementation, dataset characteristics, and experimental objectives, the optimal hyperparameters may vary.

4- Simulation and results

This research use DIARETDB[2] dataset and one image are considered as input. After that pre-processing due to noise removal and reduction and converting to gray-scale done. Then image segmentation based on edge detection with SNN done and after that, percolation theory applies for feature extraction. At the end combination method of SNN and percolation theory done for detecting and determine the position of retinopathy. We used the publicly available DIARETDB1 dataset, which contains 89 retinal images of patients with diabetes. The dataset was captured using a Topcon TRV-50 fundus camera and has a resolution of 1500 x 1152 pixels. The images were manually annotated by two expert ophthalmologists to label the presence or absence of retinopathy. This proposed method shown in Fig. 1. From left to right

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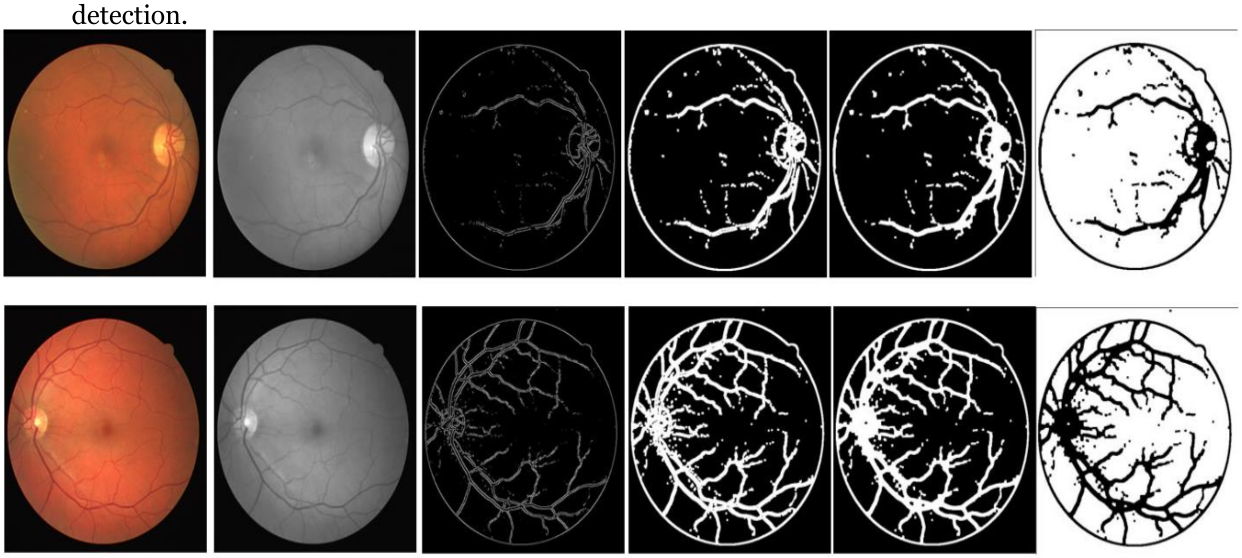

Fig. 1. Results of proposed methods

[2] http://www.it.lut.fi/project/imageret/diaretdb1/

Based on Fig. (1), the upside and left part is the input image. After applying proposing approach, the area of retinopathy will be detected and shown as Fig. 2.

Fig. 2. The area of retinopathy in input image

The size of retinopathy part in images is 7.18 mm. There is 8 part of diabetic retinopathy which input image is in 8 parts. There classes are listed in Table (1).

Table 1. diabetic retinopathy detection classes

Numbers	**Levels of retinopathy**
1	No retinopathy
2	Suspicious
3	Elementary and Preliminary
4	1 year progress
5	2-year progress
6	3-year progress
7	Full progress
8	Intense retinopathy

Regarding the demographic characteristics of the patients, the dataset includes individuals from diverse backgrounds. The age range of the patients is between 30 and 70 years, with an average age of 55 years. The gender distribution is relatively balanced, with 47% male and 53% female participants. The dataset encompasses patients with varying durations of diabetes, ranging from newly diagnosed cases to individuals with a history of diabetes spanning over 15 years.

To assess the severity of retinopathy in the dataset, the retinal images were graded according to the established international clinical guidelines. The severity levels were categorized into four stages: no retinopathy, mild retinopathy, moderate retinopathy, and severe retinopathy. Approximately 30% of the images were classified as having no retinopathy, 40% had mild retinopathy, 20% had moderate retinopathy, and the remaining 10% exhibited severe retinopathy.

To ensure reliable evaluation of our proposed approach, we followed a standard approach for dividing the dataset into training and testing sets. A random split was performed, with 70% of the images allocated to the training set and the remaining 30% assigned to the testing set. This division allows for robust model training and validation while enabling the assessment of the algorithm's performance on unseen data

5- Evaluation and Comparison

In this approach, some evaluation methods used such as Mean Square Error (MSR), Peak Signal-to-Noise Ratio (PSNR), Signal-to-noise Ratio (SNR), Accuracy, Sensitivity, Specificity and process duration. Table (2) represent the obtained results of each evaluation factor.

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Table 2. evaluation results

MSE	PSNR (dB)	SNR (dB)	Accuracy (%)	Sensitivity (%)	Specificity (%)	Process Duration (sec)
0.1253	13.1818	34.9490	98.1745	84.0000	88.9655	2.4748

Now, 7 image used for applying proposed methods and sum of their evaluation is as table (3).

Table 3. Selecting proper bus based on CP and LMP criteria.

MSE	PSNR (dB)	SNR (dB)	Accuracy (%)	Sensitivity (%)	Specificity (%)	Process Duration (sec)
0.0189	13.0871	34.5631	98.1745	86.3210	88.8236	2.3598

This proposed method compared with some others as accuracy, specificity and sensitivity evaluation factor as shown in Table (4).

Table 4. Selecting proper bus based on CP and LMP criteria.

Research	Accuracy (%)	Specificity (%)	Sensitivity (%)
Siddalingaswamy P. C., and GopalakrishnaPrabhu K., 2010 [9]	95.41 %	96.00 %	86.47 %
Joes Steal et al, 2004 [2]	94.07 %	-	-
Diego Marín et al, 2011 [10]	95.26 %	98.19 %	69.44 %
Shaohua Wan et al., 2018 [13]	95.68 %	-	-
Kemal Adem, 2018 [14]	99.18 %	-	-
Proposed Method	98.1745 %	88.8236 %	86.3210 %

Obtained results of comparison to other methods represent that accuracy of proposed method is better than others, but specificity and sensitivity is still need to work to improve.

6- Conclusion

Diabetic retinopathy knows as important disease in today's world that will be caused to blindness. So, the necessity of recognition, prediction and detection is clear. Microaneurysm are the primary symptoms of this disease which occur in retina. An important thing in this field is early-stage detection of retinopathy to protecting the eyesight. This research proposed a hybrid method for diabetic retinopathy detection. Proposed approach consists of four levels, pre-processing for noise removal and reducing and also standardization image dataset, segmentation based on SNN, and percolation theory for dimension reduction, feature selection and extraction and at the end, combinational method of SNN and percolation theory done for finding the area and the size of growing retinopathy. Obtained results showed that proposed method has the better accuracy mean 98.1745% in comparison to similar techniques.

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