A Novel Advanced Approach Using Morphological Image Processing Technique for Early Detection of Diabetes Retinopathy

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Abstract

Diabetic retinopathy (DR) is a common complication of diabetes mellitus and can lead to irreversible blindness. To date, DR is the leading cause of blindness and visual impairment among working adults globally. However, this blindness can be prevented if DR is detected early. Diabetes mellitus slowly affects the retina by damaging retinal blood vessels and leading to microaneurysms. The retinal images give detailed information about the health status of the visual system. Analysis of retinal image is important for an understanding of the stages of Diabetic retinopathy. Microaneurysms observed that appear in retina images, usually, the initial visible sign of DR, if detected early and properly treated can prevent DR complications, including blindness. In this research work, an advanced image modal enhancement comprises of a Contrast Limited Adaptive Histogram Equalization (CLAHE), through morphological image, processing technique with final extraction algorithm is proposed. CLAHE is responsible for the detection, and removal of the retinal optical disk. While the microaneurysm initial indicators are detected by using morphological image processing techniques. The extensive evaluation of the proposed advanced model conducted for microaneurysm detection depicts all stages of DR with an increase in the number of data set related to noise in the image. The microaneurysms noise is associated with stage of retina diseases as well as its early possible diagnosis. Evaluation is also conducted against the proposed model to measure its performance in terms of accuracy, sensitivity as well as specificity in real-time. The results show the test image attained 99.7% accuracy for a real-time database that is better compared with anty colony-based method. A sensitivity of 81% with a specificity of 90% was achieved for the detection of microaneurysms for the e-optha database. The detection of several microaneurysms correlates with stages of DR that prove an analysis of detecting its different stages. This study aimed at early detection of DR with high performance in accuracy.

Keywords: Retina Image, CLAHE, Retina Optic Disc, Mathematical Morphological Operation, Diabetic Retinopathy, Microaneurysms.

1. INTRODUCTION

Diabetic retinopathy (DR) is a complication of diabetes mellitus that causes damage to the blood vessels in the retina [1][2]. The retina is the nerve layer that lines the back of the eye, senses light, and creates impulses that travel through the optic nerve to the brain and thereafter facilitates vision. Retinal image analysis plays an important role in detecting DR in early stages [1][2]. DR is the leading cause of blindness and visual impairment among working adults globally [3] According to the statistical data of the International Diabetes Federation, the number of adults living with diabetes is going to increase gradually to an estimated 629 million by 2045 throughout the world. Henceforth, diabetic retinopathy has the probability to become a major health issue throughout the world.

It is important to understand that DR progress slowly over time. The occurrence of DR can be prevented, if detected early by conducting health check-ups with a systematic treatment of diabetes [4][5].Therefore, detection of early symptoms, for example microaneurysm that appear in retinal image mutual treatment proves advantageous to prevent further complications. It reduces the risk of loss of visual acuity [6].

Research has proposed the use of a fundus camera, used by an ophthalmologist to capture retinal images. There are various camera settings to diagnose numerous eye-related diseases. Analysis of retinal images includes the identification and extraction of many retinal anatomical structures. It is directly related to the disease like Retinal optic disc. There are several examples of retinal anatomical structures that show the target features for different segmentation techniques [7-10]. DR has four stages: specifically, normal, mild, moderate, severe as well PDR (Proliferative Diabetic Retinopathy) as shown in Figure 2. This clinical manual diagnosis of this disease is error-prone. Routinely detecting DR in its different stages from retina images is proposed in various computer vision-based techniques[11]. This technology can help reduce the manual burden on ophthalmologists and overcome the barriers and challenges of early detection of DR.

In this research work, efforts are made on the outcome of diabetes in the human eye retinal optic disc. The retina optic disc is the brightest part of a retinal image. It has a large number of blood vessels. The Optic disc identification is used to identify the blood vessels as well as the fovea. Moreover, an optic disc of the retina contains most of the retina information used for other analyses of a human being.

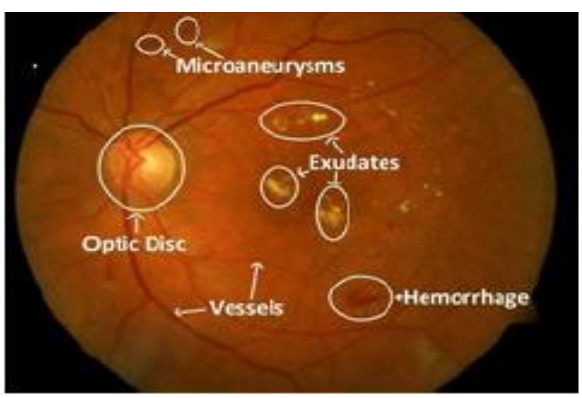


FIGURE 1: Different features of retinal images of human being eye correlated to diabetics [12].

Diabetic retinopathy is divided into numerous stages such as mild, moderate, severe, and proliferative retinopathy.

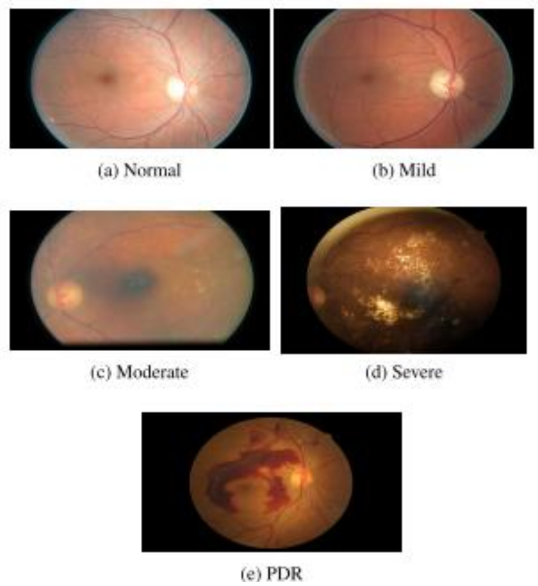


FIGURE 2: Different stages of DR [13].

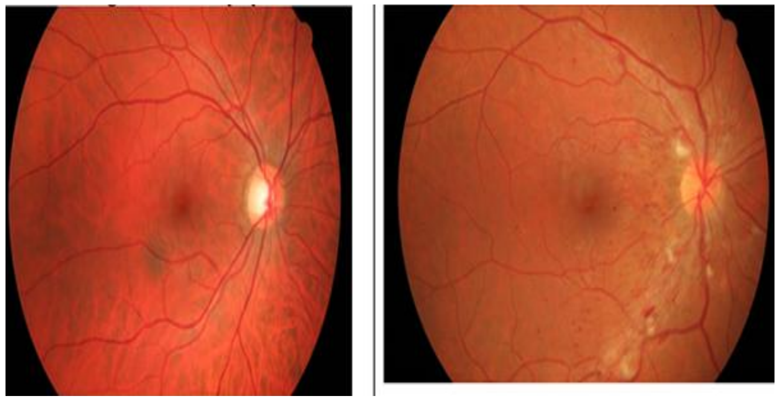
DR stage	Diagnosis	Description	Findings observed in clinics
0	No DR	Normal retina	No abnormalities
1	Mild non-proliferative retinopathy	Micro aneurysms, i.e., small bumps in the tiny blood vessels of the retina made in this stage.	Microaneurysms (MA) only.
2	Moderate non-proliferative retinopathy:	As the disease grows, some blood vessels that promote the retina are blocked.	Two or more of the following features: Microaneurysms (MA), Hard exudates (HE), Haemorrhages (H),
3	Severe non-proliferative retinopathy:	Many more blood vessels are blocked, miserly several areas of the retina of their blood supply.	20 H in for each of the four quadrants or IRMA in one quadrant or Venous beading in two quadrants.
4	Proliferative retinopathy	At this advanced stage, the vasoproliferative factors produced by the retina begin to start the growth of new blood vessels. These fresh blood vessels are fragile and abnormal.	Vitreous hemorrhage or/and Neovascularization.

TABLE 1: A short brief classification of DR based on clinical findings of the retina [14, 23].

DR types	No of MA
Normal	0
Mild	> 0 and < 5
Moderate	> 5 and < 15
Severe	> 15

TABLE 2: Table is shown below microaneurysms numbers (MA) according to their DR types [24].

(1) Proliferative retinopathy:



(a) (b)

FIGURE 3 :(a) health eye units and study area (E-ophtha database); (b) an eye with diabetic retinopathy (E-ophtha database).

In this research work, an advanced model of image enhancement comprises a Contrast Limited Adaptive Histogram Equalization (CLAHE) through morphological image processing technique. Finally, an extraction algorithm is proposed. The CLAHE is responsible for the detection and removal of the retinal optical disk. The microaneurysm initial indicators are detected by using morphological image processing techniques.

1.1. Research Question

To reach the goal of early detection of DR the following research question must be answered. The primary research question in this research paper is:

RQM. Can a mathematical morphology algorithm detect early symptoms of DR with high performance in accuracy?

1.2. Practical Implications of the research

The benefit is a contribution to the field of computer science a new algorithm proposed a new approach for having a mathematical morphology model. The target audience that can benefit from this study is medical expertise as well as patients. It will make a diagnosis of the disease in early stages as well as help the patients to understand their current diabetic situation in accuracy by using the emerging technologies.

The proposed algorithm evaluates microaneurysm detection. It shows all the stages of diabetic retinopathy with an increase in number dataset of noise in the image. An algorithm that comprises three modules will detect the noise of microaneurysms associates with stages of the retina diseases for its early diagnosis.

Experimental evaluation shows proposed algorithm is computationally fast in processing, forceful variation in image contrast and illumination. It is equivalent to the state-of-the-art methodologies in terms of measurable performance metrics. Section 2 introduces the material and method. Section 3 presents the experimental results. Finally, Section 4 highlights the conclusion.

2. THE MATERIAL AND METHOD

2.1 Related Works

The classification of DR is comprehensively studied in the literature review. The literature identified different algorithms deployed for detecting DR that achieved various results and performances. Lately, plentiful state-of-the-art research significant to the identification of DR reported [25]. This section analyses other existing works that this research intently related, several gaps, as well as strengths of the reviewed works, shown below:

Five deep Convolution Neural networks (CNN) were employed to build a model for the referable Diabetic Retinopathy (RDR) [26]. The proposed model used Kaggle, DiaretDBI, and DiarectDB1 for training and testing, respectively. The binary classification was made as normal and mild stages for non-referable while the rest of the three-stage used as referable DR. The evaluation of the model made using binary classification. The performance of CNN attained 93.6% sensitivity and 97.6% specificity based on DiaretBD1 [27]. A novel architecture classifies the images as normal or abnormal, referable or non-referable DR proposed. The proposed architecture achieves a high AUC of normal versus abnormal and referable versus non-referable in DR task 0.978 and 0.960 respectively, and specificity is 0.5.

Three CNN models for binary classification as well as detection of DR lesions is another proposal [28]. They used Kaggle and DIaretD1 datasets for training and testing, respectively. Another research introduced a CNN model with a dropout regularization technique that trained on the Kaggle dataset and tested [29] on the DRIVE and STARE dataset while attained an accuracy of 94%. Furthermore, the CNN architecture was proposed and applied to the Kaggle dataset [30]. They added a delta value to get an equal level of brightness of the image the accuracy of the model was 74%. The CNN architecture was used for classifying five stages but could not classify the mild stage accurately, due to the nature of architecture [31]. A Method of using left and right eye images separately and applied them to different CNN models [32]. The pre-processing and augmentation phases were performed on the dataset to improve the contrast of images. The results attained 83.68% accuracy. However, in their work, they did not classify the DR stages.

A deep convolution neural network (DCNN) for just two stages of DR (normal and Non proliferative DR (NPDR)) was proposed without consideration of PDR stage [33].

They applied many pre-processing steps [34] like (median, mean, Standard deviation, etc.) after they trained the model on the training dataset. The model was able to achieve an accuracy of 89.6% by using DNN.

Hough transform as well as feature extraction method proceeded by a decision tree. [35]. The algorithm proposed [36] mainly consists of region extraction inclusive morphology, contrast normalization as well as Multimodal based modeling and classification. Their results in terms of accuracy, sensitivity as well as sensitivity 99.4%, 98.64%, and 99.69% respectively. Multiple image scales designed [37], as well as classification, provided using multiple kernel learning methods to minimize false positives of the blood vessels in the retina.

A digital image with morphological processing that consists of mathematical morphology by applying some structure element (SE) [38]; in both images, that is binary images as well as gray-level images. An automated enhancement method as well as a segmentation method for blood vessels; their method decreases the optic disk and underlines the vessels by applying morphological that rotated structuring elements to the retinal image[40]. This method has an average accuracy, sensitivity, and specificity on the DRIVE database of approximately 0.942, 0.735, 0.969, respectively. They require a combination of image processing techniques as well as data mining techniques [41] that are used to extract the required information to build a feature set for prediction in medical image analysis. A proposed network obtained complex classification rates under area accuracy of 0.984, the sensitivity of 0.958 as well as specificity of 0.974 E-optha database [42]. The tracing of exudates presence in the retinal image is been done by, blood vessels segmentation method, with the help of using morphological bottom hat transfer [47]. There is an integration of methodologies that have been proposed, for the fame as well as a decision of DR, specifically two features have been used, the sum as well as the space of MA are settled [48]. There is an intelligent system that is used to detect DR with support of a vector machine, detect DR [49]. Other studies also identify presence of DR with SVM classification method[50]. A neural network technique has been applied to detect diabetic retinopathy [51]. Human Vision is an important feature in part of image processing [52].

After seen different researchers, that have proven their worth of using Mathematical morphology as brilliant techniques applied on blood vessels gray-scale images [39] prove that and conclude on the method has an average of 0.943,0715,0.977, accuracy, sensitivity as well as specificity respectively.

To date, many scholars have used machine learning, deep learning algorithms, to improve the performance of their works. According to [42] fifty-one (51) scholars used machine learning and deep learning-based early DR diagnosis with eighteen (18) scholars of image processing-based MA detection algorithms.

Most of these approaches in benchmark are having their advantages and disadvantages that distinguish them from others. Nevertheless, little research is based on image processing techniques. Therefore, in this paper, an advanced system with enhancement capability of the retina optical disk using morphological image processing technique and a connected component extraction algorithm is proposed. The proposed model manages to remove connected vessels by taking into account various structural elements and morphological properties. We observe many approaches lower the performance, this mainly caused of noise, to resolve those noise we perform enhancement operation. This model will add value to the MA detection and is different from the former models.

2.2 Contribution of the paper

1) The proposed algorithm enhances the Retinal image that involves background standardization by improving the contrast of an image.
2) The proposed algorithm detects and removal of retina optic disk.
3) The proposed algorithm implements morphological image processing techniques as well as a connected component extraction algorithm by removing blood vessels in operation.

3. METHODOLOGY

The proposed methodology consists of three main phases; image enhancement phase, detection as well as extraction of the optical disk phase, and morphological techniques phase. Fig 4 shows the methodology flowchart of this research. In this research image enhancement and morphology, techniques are used to conduct retinal analysis. The image enhancement process is used to enhance the contrast of the image. Afterward, mathematical morphology techniques were deployed in the optic disk of the enhancement image. This is to identify an anatomical structure such as a microaneurysm. Figure 4 depicts the following of our proposed model design in the work. First, the input image has to be transformed from RGB form into a grayscale form by using the following equation [46].

$$GRAY=(R+G+B)/3 \qquad (1)$$

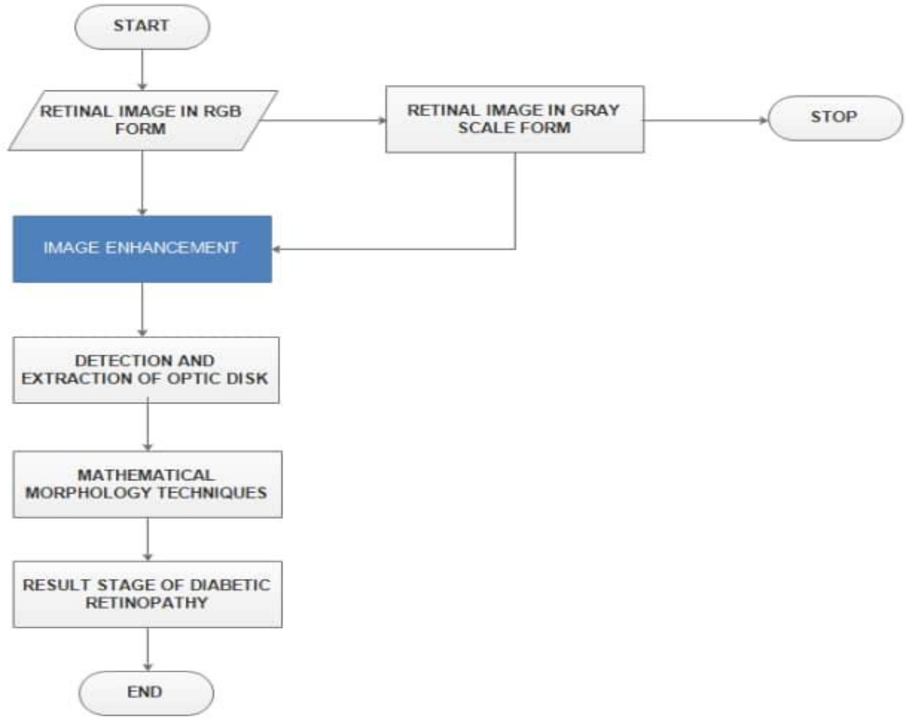


FIGURE 4: Methodology flowchart of this research.

3.1 Image Enhancement

The CLAHE is one of the enhancement techniques that improve the quality of the images. This increases the contrast in a low contrast image.

It usually operates on the small regions in the image. It uses the contrast amplification limiting procedure that happens in neighbouring pixels. Especially in the homogeneous areas to avoid any kind of noise that might happen in the image.

Detection of Optical disk

This is the process of detecting the optic disk.

Algorithm steps:

Step 1: Start

Step 2: Declare variables radius, grayimage, minlocation, maxlocation

Step 3: Read value radius

Step 4: Set radius == 100

if (radius%2==0)

r←--r

else

display ("its ok")

Step 5: Load(image, maxinlocation ,radius)

Step 6: circle (image)

Step 7: display "image"

Step 8: stop

Extraction of the Optical disk

This is the process of extracting the optic disk after detection.

Algorithm steps:

Step 1: Start

Step 2: Declare variables radius, grayimage, minlocation, maxlocation, destination

Step 3: Read value r

Step 4: if (radius%2==0)

r←--r

else

display ("its ok")

Step 5: Load (image, maxinlocation, radius)

Step 6: circle (image)

Step 7: original image copy to (destination, image)

Step 8: display "destination"

Step 9: stop

3.2 Morphological Techniques

This stage details the implementation of morphological image processing techniques.
In this case enhanced grayscale image, Dilation operation with linear structure element. It is used through the help of mathematical morphology algorithms that are connected component extraction algorithm.

Algorithm: Removing a connected component.
This is the process of removing connected components (connected blood vessels) in the optic disk after detection.

Algorithm steps:

Step 1: Start

Step 2: Declare variable Point A, Y, B

Step 3: Read Set at Point A.

Step 4: Assuming Y= connected components in set A

Step 5: Extract all connected point in set A belongs to Y

$$X_k = (X_{k-1}B) \oplus \cap A. \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

i. *Has to be computed in various steps*

ii. *Where B is the structuring element*

Step 6: The algorithm will terminate when we nd out Xk = Xk−1

Step 7: Y = Xk

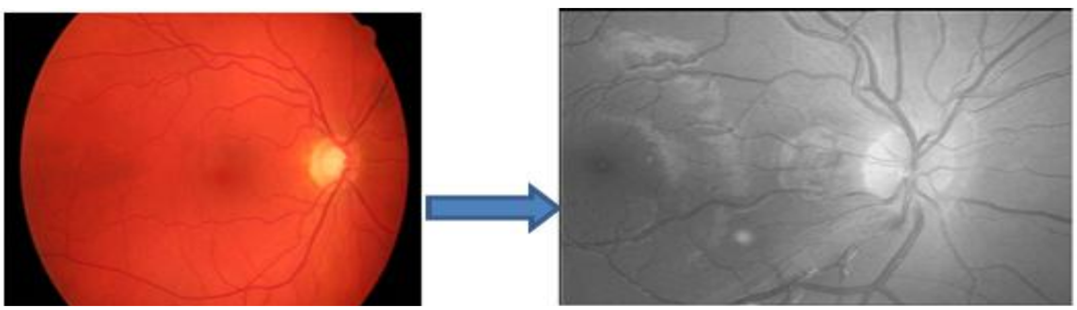
Step 8: Stop

4. EXPERIMENTAL RESULTS

4.1 Healthy Eye and Diabetic Retinopathy Eye

Figure 5 depicts the model to read both normal and abnormal retina observed. The input retinal image in RGB forms has converted into a grayscale image. An image converted to the red channel, green channel as well as blue channel.

To extract red channels and blue channels then the background plane, as well as retinal blood vessels, get brighter. This becomes too dark for the retinal images. Then the green channel s used only to increase the contrast between the background planes with the retinal blood vessels.

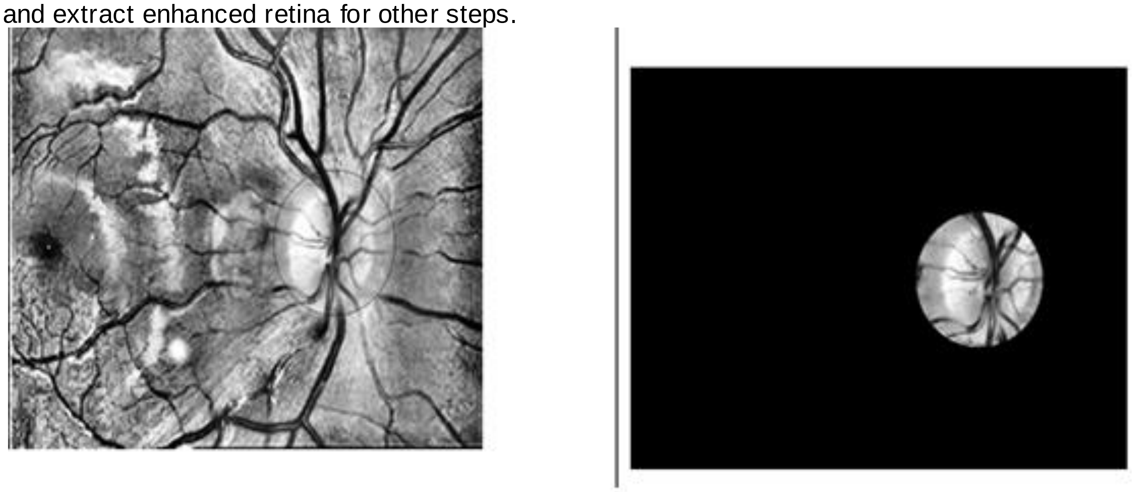


(a) (b)

FIGURE 5: (a) Showing Retinal image in RGB form (E-ophtha database); (b) Showing a Retinal image in Grayscale form (paper).

4.2 Enhancement by using CLAHE

A diagnosed image is enhanced using CLAHE so that can get clear blood vessels after to detect and extract enhanced retina for other steps.

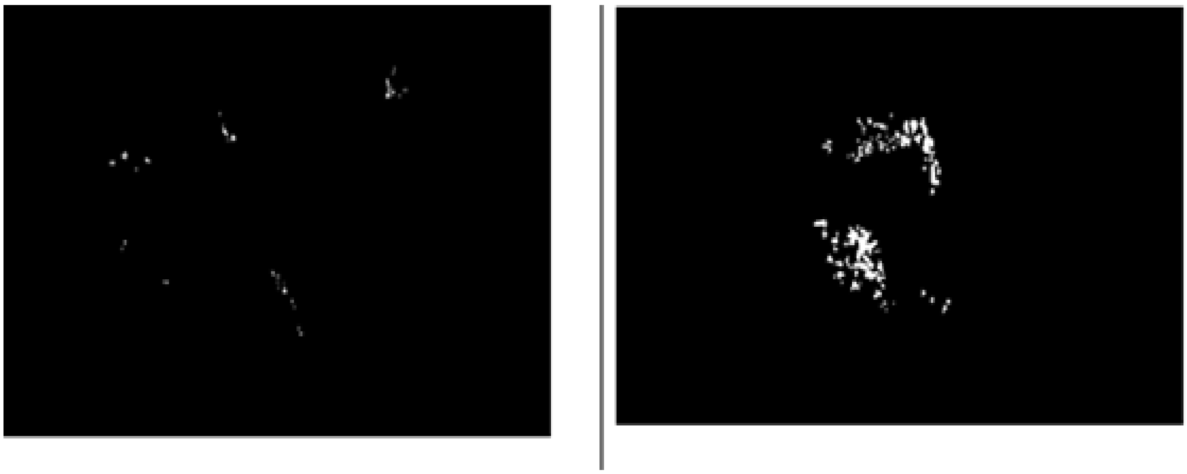


(a) (b)

FIGURE 6 :(a) Showing Enhancement of retina as well as to detect its optic disk; (b) Showing an extract optic disk in enhancement retina.

4.3 Morphological Operations

Figure 7 shows the Mathematical Morphology operations used. The structural elements are determined using prior heuristic knowledge of enhancement retina images. The enhanced image undergoes several morphological openings by using structuring elements to eliminate the vessels. Different structural as well as morphological properties of vessels occupied into account for successfully extracting the retinal vessels skeleton in this stated approach. The performance of the morphological operation is contingent greatly on the size as well as shape of the SE. Mathematical morphology is a method for extracting geometrical structures from signals based on set theory [45].



(a) (b)

FIGURE 7: Image obtained after Mathematical morphology operations (a) Showing mild stage of diabetic retinopathy; (b) Showing moderate stage of diabetic retinopathy.

The performance of this approach on the E-ophtha database compared to different approaches. Table 3 illustrates the performance of our approach against the above approaches on the E-ophtha dataset.

Approach	Accuracy
Memon, et al [27]	74%
Dutta ,et al [31]	89.6%
Akram M U et al [36]	99.4%
M.S. Miri and A. Mahloojifar [39]	94.3%
Y. Hou [40]	94.2%
Shilpa Joshi & P. T. Karule [42]	92%
Selçuk T, Alkan[43]	93%
Our approach	99.7%

TABLE 3: Area Accuracy performance of proposed algorithm with benchmark algorithm in detecting microaneurysms (MAs) by using E-ophtha database.

The specific graph for detecting micronrurms for E-optha database, the graphs shows the area accuracy of different images that are used in terms of sensitivity as well as specificity.

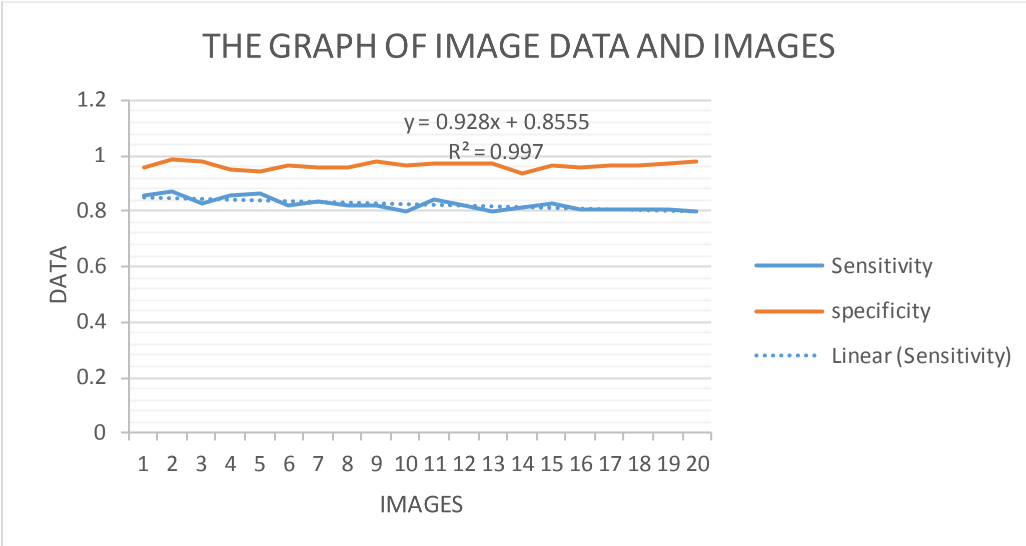


FIGURE 8: Accuracy graph of different images used concerning sensitivity as well as specificity.

The accuracy depends significantly on the sensitivity as well as specificity of an experiment. An experiment that has high specificity and sensitivity with a low rate of false positives and false negatives has higher accuracy.

The proposed approach reaches better accuracy equating with the approaches that implement morphological processing. Based on the results above prove that this method produces as good results and very effective.

5. CONCLUSION

An advanced model of image enhancement comprised of a CLAHE through morphological image processing technique for early detection of DR presented shows accurate results for the data used in our model. An enhancement of the retinal image involves background standardization by improving the contrast of an image. Precise detection and removal of retina optic disk of a retina for both normal and abnormal were successfully determined. Abnormal retina images, the microaneurysms were detected and shown in different stages with the help of structure morphology techniques, and blood vessels removed in the optic disk image by morphological opening by reform using multi-structure elements. The high ability of CLAHE for retinal image contrast improved and make it better for other essential steps.

The structure morphology of using multi-structure elements scratches increases the accuracy of this model by 99.7% in terms of sensitivity as well as specificity. Since microaneurysms (MA) are one of the main symptoms of diabetic retinopathy then through Mathematical Morphology within retinal images an early detection was observed.

6. ACKNOWLEDGMENTS

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