Automatic Detection of New Vessels in Retinal Photographs using Machine Learning

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Abstract. Diabetic Retinopathy is a rare micro-vascular complication that leads to severe ocular disorder or visual impairment. This complication is unidentified due to the mild progression of its symptoms that is associated with Diabetic Mellitus. The disease is categorized by the development of abnormal new vessels developing the optical disc of the retina of the eye. In this paper, an automatic detection system for detecting new vessels in the optical disc region is detected by using image processing techniques in advance. Segmenting the vessels from the optic disc by extracting the desired region of interest. Based on this, the features are extracted and detected as the presence of new vessels in the optic disc by using a Support Vector Machine (SVM) classifier. This automatic system is trained and tested by using 65 normal images that are categorized as 33 normal images and 32 abnormal images. The discrimination performance of the system shows an accuracy of 95.38% in detecting the new vessels. It obtained sensitivity and specificity of 96.8% and 93.9% respectively.

Keywords: Diabetic Retinopathy, Optic disc, Image processing, Fundus image, SVM

1. Introduction

The extensive accessibility of the image processing approach in the medical field plays a vital role in screening human abnormalities by a frequent visual perception with transient and less workload. Thus, image processing in the medical field plays a significant role in planning procedures of diagnosis and surgical treatments performed within patients suffering from different health issues. Images have the greatest density of morphological information that helps to communicate with humans. The recent development in automatic medical imaging techniques helps to analyze quickly to understand about the life and diseases for accurate diagnosis and quality treatment. The process of the human and the machine's understanding of images involves the selection of images for extracting the desired features from the images by the pre-trained model. The automatic processing technique plays a major part in medical image processing. Recently, for better analysis, many innovations are taken over in computer-based techniques to screen the abnormalities in humans. Specifically, the huge complexity in medical imaging is based on a host of factors such as the knowledge bases, noise, incompleteness, redundancy, inconsistency in data and knowledge, imprecision, different paths of reasoning such as qualitative subjective reasoning and heuristic reasoning [1].

Diabetes Mellitus (DM) is a serious medical complication that occurs due to metabolic disorder of improper secretion of insulin results in increased blood glucose level or hyperglycemia. When diabetes reaches the uncontrolled level it results in coma or even death if not treated immediately [2]. This disease
is significantly related to microvascular and macro-vascular difficulties causing concurrent diseases like Diabetic Retinopathy, Diabetic Nephropathy, and Diabetic Neuropathy are conferred in 50% of type 1 and 30% of the type 2 diabetes mellitus patients [3]. The people affected by diabetes mellitus show an 80% chance of Diabetic Retinopathy after 10 years [4,13,14].

Diabetic retinopathy is characterized as microvascular complications that result in eye blurring or vision loss. An increase in the glucose level leads to damages in the blood vessels of the light-sensitive tissue at the back of the eye. The symptoms of this disease are silent and cause mild eye problems in the early stages eventually it results in blindness. Therefore, identifying patients at risk for subsequent vision blurring due to diabetes mellitus is considered to be a crucial part of the treatment of diabetic retinopathy. Regarding Diabetic retinopathy diagnosis, the eye fundus image is captured by using the dilated fundoscopy, it will reflect the present status of the eye. The eye of the DR patients is observed with improper growth of new blood vessels that niish the retina and bulges, cutting the blood supply. This difficulty is easily recognized by using the image processing technique. The growth of new vessels is easily identified in the fundus images by extracting them by using the required image processing technique. Consequently, this will help to identify diabetic retinopathy during the early stages of the disease.

In this paper, an automatic method for detecting retinal photographs which show the development of new vessels on the optic disc region is analyzed and evaluated. The features of proliferative retinopathy, the development of new vessels at the optic disc helps in the identification and prediction of DR at the earliest and most likely helps in adding value to an automated diagnostic system.

2. Background Studies:

Ramya [5], in this paper, explained a method to classify DR. The system recognized the normal eye image by the rate of 86% and the DR eye image by the rate of 82%. Goatman et.al [6] in this paper, designed a system to classify the growth of new blood vessels in the optic disc region by using fifteen features that are oriented with the blood vessel, and the features are classified as normal and abnormal by using SVM classifier. Aswale and Shaik [7] in this paper, described a system to classify DR by using an SVM classifier. Priorly the fundus image is pre-processed, segmented and the feature is extracted and classified as DR or normal eye image. This system produced an accuracy of 93.33% respectively.

Chandrakala and, Sindhu Madhuri [8], this is another method performed by pre-processing the retinal image by using geometric transformation technique, used point-based technique for segmentation and by using performance matrix based on Principal Component Analysis (PCA) and SVM the DR is determined. The accuracy of prediction by PCA and SVM are 89% and 95% respectively. Gandhimathi et al. [9] in this paper used two different classifiers - Multi-Layer Perceptron (MLP) and Support Vector Machine (SVM). The retinal image is pre-processed using a filter, segmented using the watershed algorithm, and required features are detected and required features are extracted based on shape, contrast, position, orientation, brightness, and line density. The proposed methodology produced an accuracy of 93.7%. Hosanna et. al [10] had presented a new automatic vessel segmentation technique by using an SVM classifier. In this, the optic disc from the retinal image is segmented by using the discrete anisotropic filter with a bee colony algorithm. The features of the blood vessels are extracted by using Gray Level Co-occurrence Matrix (GLCM) and trained by using an SVM classifier to predict true or false blood vessels.

Revathy et al. [11] proposed another machine learning approach to predict features of exudates, hemorrhages, and microaneurysms by designing Hybrid classification techniques by combining various machine learning methods that include a combination of support vector machine, k nearest neighbor, random forest, logistic regression, multilayer perceptron network. By this hybrid approach, the technique obtained the highest accuracy of 82%.
Enrique et al. [12] utilized 400 retinal images of non-proliferative diabetic retinopathy classified based on different grades. The process is carried out by detecting the features of blood vessels, microaneurysms, and hard exudates to train the SVM classifier based on the different grades of retinal images. The automatic system designed using an SVM classifier obtained an accuracy of 94%, maximum sensitivity, and predictive capacity of 94.6% and 93.8% respectively. The paper is outlined as followed, Section 3 discusses the proposed methodology, and Section 4 gives the experimental results and discussion, and finally concludes with Section 5.

3. Proposed Methodology:

This section depicts the methodology used to detect the new vessels in the optic disc region of the retinal image. Figure 1 shows the process in a form of the block diagram of the proposed technique.

![Figure 1. Block Diagram of the Proposed Method](image)

3.1. Image Acquisition

Initially, the technique starts by collecting the retinal images to pre-process, segment, extract features, train, and test the classifier. The features extracted will help classify the images based on the presence of new vessels in the optic disc region of the fundus image. For the images, the commonly available dataset is used for the detection of diabetic retinopathy. From the Kaggle dataset, only 65 images are used for this system. Among 65 images, 33 normal and 32 abnormal i.e., eyes with symptoms of diabetic retinopathy are collected.

3.2. Pre-processing

In the image, the pre-processing technique is carried to improve the features of the image to extract the desired features from the image.

3.2.1. Green Plane Extraction

The 3-order matrix is used to represent the colored image. The rows are expressed in first-order, columns expressed in second-order, and pixel color expresses the third order. In this study, the RGB color image format is used. Hence, the third order of the image takes the value of 3 colors that include Red, Green, and Blue respectively. The rows and columns values are assigned based on the size of the image. Among the other colors, the green color plane is used in the DR analysis as it shows the better contrast difference between the blood vasculatures in the optic disc region, and the background retina, and secondly it would reduce computational overhead if a single green channel is used for vessel detection instead of all the three red, green, and blue channels.
The Green channel produces high contrast and vessels are differentiable from the background while in the red and blue channels vessels are not much different and showing similar shades as the background.

### 3.2.2. Contrast Adjustment

The grey levels of the image were stabilized by stretching the contrast of the image to cover the whole dynamic range of the pixels, the surrounding pixels with dark borders and with any image labels are excluded. The contrast of any fundus image is normally very low due to many reasons, like insufficient or varying lighting conditions while capturing retinal images, low dynamic or nonlinear range of the imaging sensor such that non-uniform distribution of illumination within the image. So, it is important to make the contrast high to make the edges of vessels more visible and separable from the background. For this reason, many contrast enhancement methods are applied, i.e., methods based on spatial domain and histogram-based techniques like histogram equalization technique, Contrast limited adaptive histogram equalization technique, Adaptive histogram equalization technique, and local and global contrast stretching techniques, etc. However, the study is made use of the sigmoid function-based contrast enhancement technique which is a key and distinguishing part of this method. A sigmoid function is a mathematical function that has an "S" like shape, it is the logistic function's special case and having the formula:

\[
f(x) = \frac{1}{1+e^{g \cdot x}}
\]

Where "g" is the gain and it controls the actual contrast and "x" is the cutoff which denotes the normalized greyness factor and its value is varied around it. Its normal initial value is 0.5 which is mid of the greyscale. Different images may require a different value of g to be enhanced. This function has the property of the continuous function. Its output ranges between 0 and 1. It is differentiable and a real-valued function, bearing a first derivative that is either non-positive or non-negative.

### 3.3. Region of Interest

A Region of Interest is a particular sample from the dataset that is recognized for desired purposes. This concept can be applied to any area. For example, in medical image processing, the tumor boundaries are identified in the image or in a volume, to measure its size. Here, the Optic disc is considered as a region of interest. In this method, 15 and 0.5 values are used for gain and cutoff respectively. All the images for study are resized before locating the optic disc, as its diameter ranges up to 300 pixels approximately. The region of the optic disc region is then masked and extracted by using morphological operations.

### 3.4. Vessel Detection

#### 3.4.1 Detection of Thin Vessels

This process is carried out to segment thin vessels that are normal vasculatures present in the optic disc region. In the comparison of normal vessels with the abnormal ones, the abnormal vasculatures are found to be small and are more twisted than the normal vasculature. The lamina cribrosa provides a mesh-like structure that acts as a bright background for the detection of vessels with greater contrast. Hence the vessels forming dark ridges are identified by using the strength of ridges k is given by

\[
k = \frac{L_{xy}^2 + L_{xx}^2 + 2L_{x}L_{xy}}{(L_{x}^2 + L_{y}^2)^{3/2}}
\]

Where L provides the Gaussian filtered image that is used to determine the scale of the ridges. \(L_x\), the subscript indicates the partial derivative and \(L_{xx}\) is the second-order partial derivative concerning x. The k value becomes positive for vessel ridges and negative for the valley in between the vasculature. K value is unspecified when the slope reaches zero in both directions.
3.4.2 Removal of Bifurcation and Small segments

On Detecting the thin vessels from the ROI of the Optic disc. The filter is used to remove the bifurcated vessels. The undesired pixels in the image that includes dots or thin lines forming noises are identified by applying thresholding. Then the undesired pixels are removed by undergoing further processes that are to be performed to improve the image and maintain the undesired blood vessel pixels as a post pre-processing step. To accomplish this step, an image opening (morphological operation) is used to exclude the desired pixels that are limited to or less than 90 pixels. Now due to image opening, little gaps between vessels have appeared which is removed to some extent with image dilation.

3.5 Detection of New vessels

An SVM classifier shows a discriminative and better performance in classifying DR in comparison with other classifiers. It is a supervised learning technique that is used to map the input features in high-dimensional space. The classes are separated by constructing a margin of the hyperplane. The mapped points that lie closest to the decision of separation affect the position of the support vector. The probability of the classification error of the mapped points is minimized when it is non-separable. To separate two different classes linearly by using Optimal hyperplane (HO) is given as follows,

\[ y_i (w . x_i + b) \geq 1 \quad i = 1 \ldots m \]  

(3)

The extracted features are normalized by using the following formula,

\[ f = \frac{f - m}{s} \] 

(4)

Where \( f \) represents the feature and \( f' \) represents the normalized value, respectively. m and n values are the mean and standard deviation for the feature. The values are calculated to train the classifier by using the features. The abnormality in the vessels is detected by taking the probability of the highest abnormalities and comparing it with the threshold values. Different points are taken into consideration by varying the threshold values of the abnormal. The classifier is trained by using the images except for the test image. The feature values are normalized before the classification and it is calculated each time excluding the test image.

4. Experimental Results and Discussion:

In this paper, the results are discussed based on problem recognition. The SVM classifier technique is applied to extract the features from the input fundus images for the early prediction of diabetic retinopathy. The results are processed by using MATLAB software and the processed images are displayed by using Graphical User Interface (GUI). The below images in figure 2. show the output of each processing technique.

(a) Input Image

(b) Extracting Green Plane
Figure 2. New Blood Vessels Classification using SVM classifier

The performance of the SVM Classifier is analyzed by using False Positive (FP), False Negative (FN), True Negative (TN), and True Positive (TP) are given as follows:

- True Positive (TP): Normal Eye is correctly identified as a normal image.
- False Negative (FN): Normal Eye is incorrectly identified as Diabetic Retinopathy.
- True Negative (TN): Diabetic Retinopathy is correctly identified as Diabetic Retinopathy.
- False Positive (FP): Diabetic Retinopathy is incorrectly identified as normal.

From the above classes, the accuracy, sensitivity, and specificity of the classifier values are calculated by using the following formulae.

\[
\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \tag{5}
\]

\[
\text{Sensitivity} = \frac{TP}{TP+FN} \tag{6}
\]

\[
\text{Specificity} = \frac{TN}{TN+FP} \tag{7}
\]
Table 1. shows the confusion matrix to evaluate the performance of the classifier. The correct and incorrect predictions are classified into each class. This shows the way by which the classifier predicts the different labels with confusion. It is plotted along with Normal and abnormal blood vessels in the optic disc of the retinal image with respect to true or false labels.

### Table 1. Confusion Matrix for SVM Classifier

| Actual/Prediction | Positive | Negative |
|-------------------|----------|----------|
| Positive          | 31 (TP)  | 2 (FP)   |
| Negative          | 1 (FN)   | 31 (TN)  |

The Accuracy of the SVM classifier is calculated as 95.38% respectively. Then the sensitivity and specificity of the classifier are measured as 96.8% and 93.9% respectively. The comparison of the accuracy of the proposed system with existing works is analyzed and represented in Figure 3.

![Accuracy Comparison](image.png)

**Figure 3.** Comparison of Classification Accuracy

The proposed system showed a better performance in the classification of diabetic retinopathy and hence it can be used by the ophthalmologists to predict diabetic retinopathy in the patient at the earlier stage in an efficient way.

### 5. Conclusion and Future Scope:

The project deals with the development of an automated system for the detection of new vessels from the optic disc of retinal eye image by using a machine learning algorithm. The SVM Classification model gives an accuracy of 95.4%, specificity of 96.8%, and sensitivity of 93.94%. The SVM classifier shows better performance in the classification of the disease. To develop a user-friendly interface, this project has been designed with a Graphical User Interface. Image processing operation returns parameters that are necessary for the machine learning model. The output consists of the main window where the user input image is inserted in the main window that undergoes different phases of image processing operation output. This trained model delivers an efficient output. The accuracy of the machine learning model can be improvised by training the model with different machine learning algorithms. Training with various algorithms with different datasets will yield greater accuracy.
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