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Diabetic Retinopathy Detection using Non-Mydriatic Fundus Images

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Abstract: *In recent years diabetic retinal disease, also known as Diabetic Retinopathy (DR), has become a new global challenge in the area of ophthalmology. It is the injury caused to the blood vessels in retina due to complications of diabetes mellitus, which can develop complete blindness if it progresses to proliferative level. Hence there is a need to detect this condition as early as possible, more specifically in rural areas where there are limited resources for timely screening. Fundus images, obtained from fundus camera, have gained interest in this background as they serve a key role in detection of DR with latest technological development in the thrust region of image processing. This paper is aimed to highlight the algorithm for detection of DR using fundus images which are pre-processed with the help of image processing techniques using Python which is a highlevel programming language. Also, some of the features necessary to detect the disease are extracted. The analysis gives the specificity and sensitivity of one method which tells the probability of classifying the severity of the disease in patients, helpful for the clinical experts in diagnosing of the disease.*

Keywords: Circular Hough Transform (CHT), diabetic retinopathy, fundus images, pre-processing, Support Vector Machine (SVM).

I. INTRODUCTION

Diabetes is a disease in which the quantities of blood glucose rise which can also affect patients sight causing diseases like cataracts, glaucoma, and most importantly diabetic retinopathy. It is the condition where damage is caused to the blood vessels inside the eye [1]. In recent years, Diabetic Retinopathy (DR) has become the common causes of low vision provoking blindness, categorizing it as one of the most chronic diseases. The World Health Organization (WHO) recently analysed that there are approximately 130 million people all over the world having diabetes, showing regular increase in the number of patients every year [2]. Whereas, the National Eye Institute estimates that 24,000 people become blind every year due to DR [3]. The disease classifies itself as Non-proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR). NPDR shows early stage of the disease which can be cured using laser therapies and surgeries preventing vision loss. While PDR is advanced level of the disease where an abnormal new blood vessels (neovascularization) is formed at the back i.e. at the posterior pole of the eye [4].The presence of this disease can be diagnosed by examining the retina for its characteristic features, also known as fundus images which are obtained by capturing the retina of the eye by fundus camera. Over a period of last decade, there is a lot of research conducted where detection of DR is based on extraction of features of retinal images [2]. This approach consists of a study of retinal images with an aim of providing ways in diagnosing and identifying the severity of the disease. It broadly includes application of image processing and its algorithms on captured retinal images [1]. This area has been achieved a great progress in recent times which proved an improved medical care for the patients.

In this paper, a detection algorithm is propounded for DR with the help of captured fundus camera images taken from diaretdb0_v_1_1 database available on internet [5]. Section 2 provides the summary and flow diagram of the proposed system. The overall approach performed in the algorithm using python language, is discussed in sub-section 3 with the help of python code. Also, results are shown in section 3.4 by analysing performance parameters using SVM classifiers, concluding the overall methodology in the final section 4.

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II. PROPOSED METHODOLOGY

An automatic detection of DR with the help of fundus camera images taken from diaretdb0_v_1_1 database has been proposed in this algorithm. The flow diagram for DR detection is shown in Fig. 1. The fundus camera diagnoses the patient's eye and captures the image of interior surface and posterior pole of the eye, which comprises of retina, macula, optic discs and blood vessels. These images are already captured and available as standard DR database with calibration level 0 available as a public database for DR detection. By using this database, the disease can be detected [5].

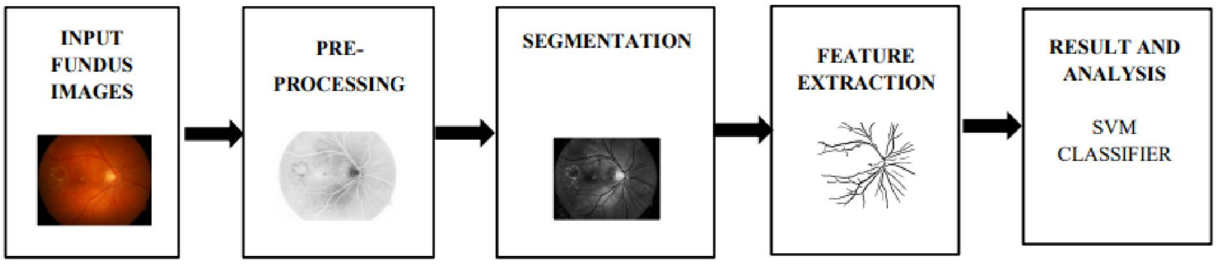

Fig. 1: Block diagram for DR detection

The algorithm starts with pre-processing stage which is based on green channel extraction. Among the three independent channels- Red, Green and Blue (RGB), green channel contains the maximum information and high contrast. Hence the captured image is converted to green plane [3]. Further several image processing techniques are implemented including adaptive histogram equalization CLAHE, thresholding and filtering so as to remove noise [4]. Then the image is segmented using morphological functions where features are extracted and classified using Support Vector Machine (SVM) classifier, demonstrating its outcome as specificity and sensitivity of the images.

III. OVERALL APPROACH

The proposed algorithm consists of different modules and following sub points depicts the detailed explanation of each step included in block diagram.

Input Fundus Images

DIARETDB0 is a copyrighted database which can be used for scientific research purpose [5]. The database contains 130 colour retinal images out of which 20 images are of normal healthy eye. Rest 110 images contains characteristics and abnormalities found in DR disease.These images in database are captured with a 50-degree field of view angle using fundus camera. Also, the images contain imaging noise and optical aberrations whose amount is undefined. The data is helpful for evaluating the performance of diagnosis methods in general. Fig. 2 shows some of the abnormalities found in DR detected retina. Some of them to name are exudates, micro aneurysms, haemorrhages and blobs.

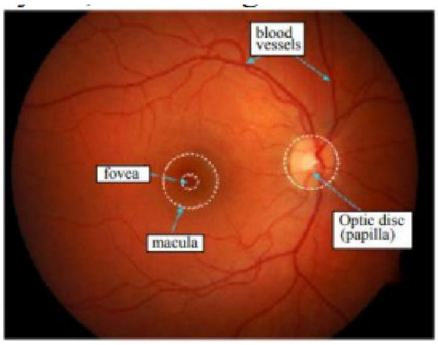

Fig. 2: Abnormalities in retina

Pre-processing

Captured colour fundus or retinal images show poor contrast and contains noise abbreviations, hence pre-processing stage has to be performed on these images, which is the initial stage in detection process. This algorithm is applied to improve the contrast, image enhancement and removal of noise. Green channel is mainly extracted in pre-processing as it showcases the best background contrast. In red channel the abnormalities are visible but it shows less contrast than the green one whereas blue channel contains noise and minimal information [6]. The original colour image is first read using OpenCV (cv2), which is an open-source machine learning library and then the green channel 2D array is extracted from the image array. Fig. 3(a) shows original fundus image and Fig. 3(b) shows its extracted green plane image.

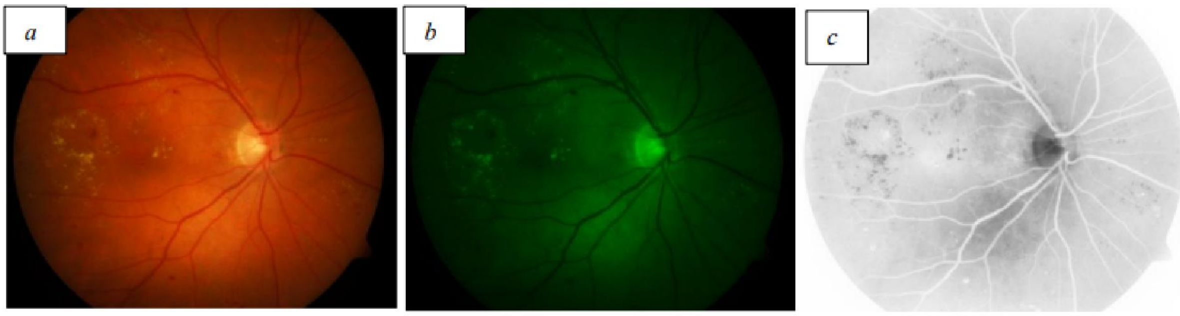

Fig.3: (a) Original image, (b) Green plane image, (c) CLAHE image

Adaptive histogram equalization (ADHE) is performed for enhancing contrast. It is used to improve regional contrast and edge enhancement in each area of image [6]. The input here is divided into tiles, by default 8x8 in OpenCV, and then these tiles are histogram equalized. If possibly noise is present, it will be amplified. The contrast of the grayscale image is enhanced using Contrast Limited Adaptive Histogram Equalization (CLAHE). It is an alternative of adaptive histogram equalization in which there is limited contrast amplification, so as to reduce this issue of noise amplification [3]. If any histogram is above the contrast limit which is already specified, by default 40 in OpenCV, then those pixels are clipped off and equalization is performed. Fig. 3 (c) shows the CLAHE equalized image.

Segmentation

Binary image can be created by image thresholding method using grayscale image. The gray threshold function chooses the threshold to limit the intraclass variance of the black and white pixels [3]. One of the thresholding methods is Otsu's binarization in which automatic calculation of a threshold value from image histogram for an image having two histogram peaks is performed. Otsu's algorithm finds a threshold value (t) [9] which reduces the weighted within-class variance given by Equation 1.

$$\sigma_w^2(t) = q_1(t)\sigma_1^2(t) + q_2(t)\sigma_2^2(t)$$ *Equation 1*

For improving image quality further, for example by edge detection or noise reduction, canny edge detection is used which detects wide range of edges. Canny edge detection is an approach to extract useful information from different objects. In this algorithm, the first step is to remove noise by 5x5 Gaussian filters. To calculate first derivative in horizontal direction (Gx) and vertical direction (Gy), sobel kernel is used [7]. From these, edge gradient and pixel direction is obtained using Equation 2.

$$Edge\_Gradient\ (G) = \sqrt{G_x^2 + G_y^2}$$
$$Angle\ (\theta) = \tan^{-1}\left(\frac{G_y}{G_x}\right)$$ *Equation 2*

At every stage, pixel is checked if it is a local maximum in its neighbourhood in the direction of gradient so as to remove unwanted pixel. All these algorithms are obtained using a single function in OpenCV. Fig. 4(a) shows edge detected image.

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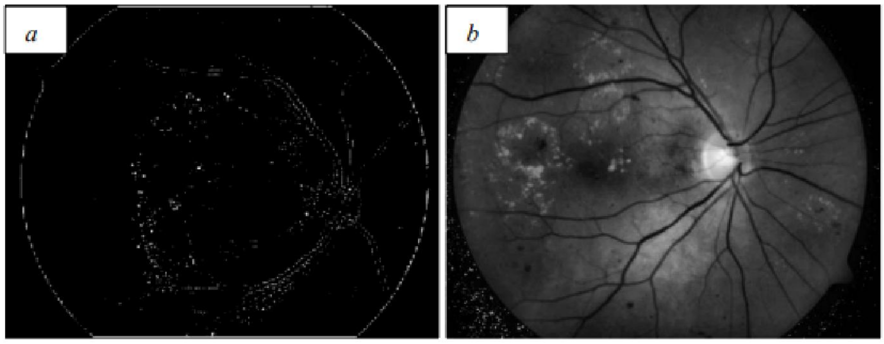

Fig.4: (a) Edge detected image, (b) Segmented image

Image segmentation includes partitioning the digital image into multiple segments. Here, mathematical morphology is used to extract useful image components in post processing steps. Morphological functions include dilation and erosion operation. Dilation is the function to add the pixels to the boundaries of the object in an image, whereas erosion is the method to remove the pixels in the boundaries of the object [3]. The size and shape of the image to process defines the number of pixels added or removed from the objects in an image. Equation 3 shows morphological operations used,

$$\text{Dilation: } (f + B)(x, y) = \max\{f(x - s, -y - t)|(s, t) \in B\}$$

$$\text{Erosion: } (f\theta B)(x, y) = \min\{f(x + s, y + t)|(s, t) \in B\} \qquad \textit{Equation 3}$$

Where f(x,y) is a defined finite grayscale image function and B is a binary structuring element. Fig. 4(b) shows the segmented image.

Feature Extraction

This approach is an important part of image processing as it is useful for detecting the abnormalities in DR [8]. Here, two abnormalities in retina are mainly focussed which are blob (lesions) or blot haemorrhages and exudates. Blob detection is done with the help of Circular Hough Transform (CHT) [3] as shown in Fig. 5 (a). It is the best method that allows the circular objects to be extracted from an image where three parameters are needed to define a circle shown in Equation 4.

$$C : (x_{center}, y_{center}, r) \qquad \textit{Equation 4}$$

Exudate is another abnormality which leaks out of blood vessels. There are two categories of exudates namely hard and soft exudates. The blood vessel starts to weaken and leak blood and fluid in retina which is a condition called macular edema. Blood vessels are detected and are shown in Fig. 5 (b).

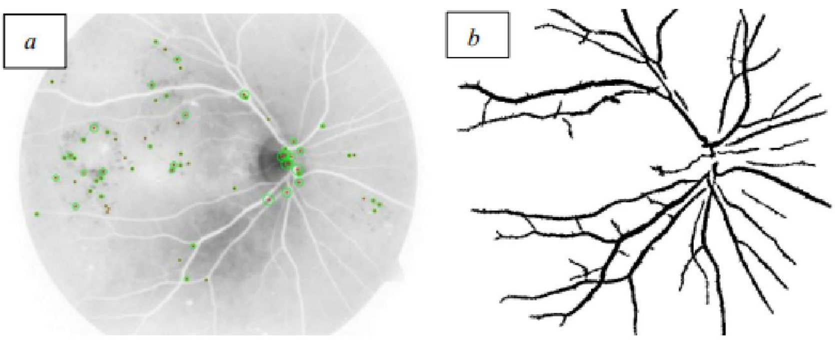

Fig.5: (a) Blob detected, (b) Blood vessels detected

IV. RESULT AND ANALYSIS

Support Vector Machine (SVM) is used as a classifier for DR detection. SVM are supervised learning algorithms that analyse data used for classification and regression analysis. A fixed number of randomly selected images are taken to form the training set and the rest of the images compose the test set [6]. Results for analysis have been evaluated by calculating sensitivity and specificity per image for two diabetic retinopathy findings. Equation 5 shows the formulae to compute sensitivity and specificity [5].

$$sensitivity = \frac{T_P}{T_P + F_N}$$

Equation 5

$$specificity = \frac{T_N}{T_N + F_P}$$

Where, True positive (TP) is the number of images identified as DR correctly;
False positive (FP) is the number of images identified as DR incorrectly; True negative (TN) is the number of images identified as normal correctly; False negative (FN) is the number of images identified as normal incorrectly. Sensitivity is the calculation of abnormal fundus classified as abnormal and specificity is the calculation of normal fundus classified as normal, both computed as percentage (%). The result can be analysed based on these two parameters, which is if the sensitivity and specificity values are higher, the method used is appropriate. Table 1 shows the performance parameter using SVM classifier.

DR abnormality	Sensitivity %	Specificity %
Blob detected	73	70
Blood vessel detected	77	80

Table 1: Results achieved

V. CONCLUSION

In past years from the research field of ophthalmology, many methodologies have been developed for automatic detecting and classifying DR. This paper also showcases one of the methodologies where input non-mydriatic images are directly taken and several image processing techniques are implemented using python language code. The features which are extracted are blobs and blood vessels, which are two of the important parameters for detecting DR. The methodology can be analysed using sensitivity and specificity of these parameters for SVM classifiers. The result demonstrated indicates acceptable performance measurements so that the algorithm can help the ophthalmologist to detect diabetic retinopathy at the early stage, which is necessary to prevent patient from blindness. All these combinations of the discussed algorithm in image processing provide a base from which a screening test can potentially be designed.

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