Recognizing Diabetic Retinopathy Using IoT Enabled Nonmydriatic Fundus Camera Images with help of Morphological Functions and Transductive Support Vector Machines

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Abstract: ***Recognizing Diabetic Retinopathy (DR) at the early stage is the major difficulty faced nowadays and it can be efficiently done using Fundus Images with the help of Morphological functions and Machine learning so that it enables early detection and timely treatment with IoT enabled Smartphone portable Fundus Camera. At early stage it does not show any symptoms as it progresses to proliferative level it causes blindness. Major indications of DR are appearance of microaneuryms, haemorrhages, and hard exudates. In this paper, an algorithm automatic detection of DR has been proposed including Morphological Structural Elements, Contrast Limited Adaptive Histogram Equalization (CLAHE), Median filter, Circular Hough Transform (CHT) , thresholding and Wireless data transmission using Raspberry PI to Cloud Storage Services. Also in Machine learning, Support Vector Machines (SVM) classifier is used to classify fundus images to normal or presence of microaneurysm or haemorrhage or exudates. The image are captured through portable Nonmydriatic Fundus Camera connected to Raspberry Pi which uploads the image to Cloud Storage Services. The proposed algorithm has been tested for the images obtained from Cloud Storage database using MATLAB code. The sensitivity, specificity and accuracy of this approach are 93.33%, 90%, 95%.***

Keywords: Fundus image, haemorrhage, median filter, IoT, Raspberry Pi, Cloud Storage Services

1. Introduction

Diabetic Retinopathy is a major cause for vision blindness for many people who have diabetes for many years. The National Eye Institute estimates that 24,000 people become blind every year due to Diabetic Retinopathy. The retinal red blood vessel gets damaged for the diabetic people which leads to the cause of blindness [1]. Detection of diabetic retinopathy at one of the early stage will be a preventive measure against blindness.

An early detection of DR enables laser therapy to be performed to prevent or delay visual loss and may be used to encourage improvement in diabetic control. Fundus images obtained by the fundus camera are used to diagnose DR. Diabetic retinopathy has been classified into stages. The initial stage is the micro aneurysm. In this stage the retinal nerves will have small blob in the red blood vessels. The main reason is due to the high density of the blood in the blood vessel. The second stage is the outbreak of these blobs. The blood vessels burst open and release the blood into the vitreous chamber. In the third stage, the blood forms a translucent block in the vision, which can be observed by the diabetic person itself, known as soft exudates. The fourth stage is when this translucent block gets permanent place in the eye which causes partial blindness to the diabetic person. These blocks are known as hard exudates as they have high density. In fact, a patient with DR does not suffer any vision problems at the early stages. Therefore, they should undergo an annual eye exam because early diagnose is very important to prevent them from blindness.

Recent advancement in the Internet of Things (IoT) Technologies had made the data accessible in any part of the world with ease. As a support for IoT technologies Cloud Storage Service plays a huge role for accessing the data wherever the necessity occurs. The fundus is an essential component of an eye examination that provides valuable information to both ophthalmologists and nonopthalmologists. In physical examination, the fundus can also be photographed which can be documented in the Cloud storage services and share the images for telemedicine. The combined usage of handheld Smartphone and indirect lenses for mydriatic fundus photography is examined. This technique offers the advantage of being inexpensive and portable compared to most current methods of fundus photography.

The fundus image evaluations are used in diagnosing the eye which provides the valuable information for ophthalmologists [2]. In additional to physical examination the fundus image can be photographed and it can be documented as well as share the images for telemedicine. Pharmacologic dilation tends to be inconvenient for both the medical practitioner and the patient, with the dilating drops taking about twenty minutes to take effect and the patient experiencing blurred vision and light sensitivity for up to several hours after dilation. There is a small but real risk of inciting acute angle-closure glaucoma in susceptible eyes with the use of dilating eye drops [3]. Nonmydriatic fundus photography allows for imaging of the retina and optic nerve without pharmacologic dilation [4]. Unfortunately, the current available nonmydriatic cameras cost thousands of dollars and are either table-mounted or too bulky to carry around [4],[5].

Several image processing algorithms have been used to detect and classify DR.In [1] A.Biran et al. have developed a technique to classify and detect DR using Gabor filter and SVM classifier, which can also detect Microaneuryms, Haemorrhages and exudates. On other hand, another automatic algorithm have been developed by Malak T. Bantan et al. from umm al. Qura University for Auto-segmentation of Retinal Blood Vessels Using Image Processing [6]. In which, first the fundus images go through a MATLAB code in [6] for pre-processing steps of image acquisition, grayscale conversion and contrast enhancement, intensity adjustment, complement and adaptive histogram equalization. Filters such as median, Averaging and Wiener filters were used. Huiqi Li and Opas Chutatape focussed on Fundus Image Features Extraction by development of algorithms to detect exudates [7]which are the different colour components of the colour fundus image. Moreover, Atul Kumar et al. [8] proposed a unique method for Detecting Exudates from Retinal Fundus Image using technique based on feature Extraction. Sagar Adatrao et Mayank Mittat [9] presented An Analysis of Different Image Pre-processing Techniques for Determining the Centroids of Circular Marks Using Hough Transform.Umer Farooq et al focussed on Improved Automatic Localization [10] of Optic Disc in Retinal Fundus Using Image Enhancement Techniques and SVM classifier, whereas the features proposed in [10] play key role to train a classifier.

It is proposed to take advantage of current camera and Light-Emitting Diode (LED) technology to create a prototype of nonmydriatic fundus camera that was affordable and small enough to carry in a white coat pocket which can be connected to Cloud storage service by enabling Raspberry Pi in the fundus camera. The fundus images are retrieved from the Cloud storage and the images are processed to detect the type of retinopathy disease using Median filter and Support Vector Machine (SVM) classifier which makes ophthalmologist process easy in detecting (DR). Next sections of this paper are structured as: proposed method is given in section II, which is followed by experimental results in Section III and further discussion on results in Section IV.

2. Proposed Methodology

In this paper, an automated detection algorithm of DR and classification of various stages of DR with the help of Nonmydriatic fundus camera images from Cloud storage services has been proposed. The Nonmydriatic camera captures the fundus images and then the images are transferred to the Cloud storage services. The independent channels contributed of an RGB image are namely Red, Green and Blue. Among the three channels, the green channel contains the maximum information.

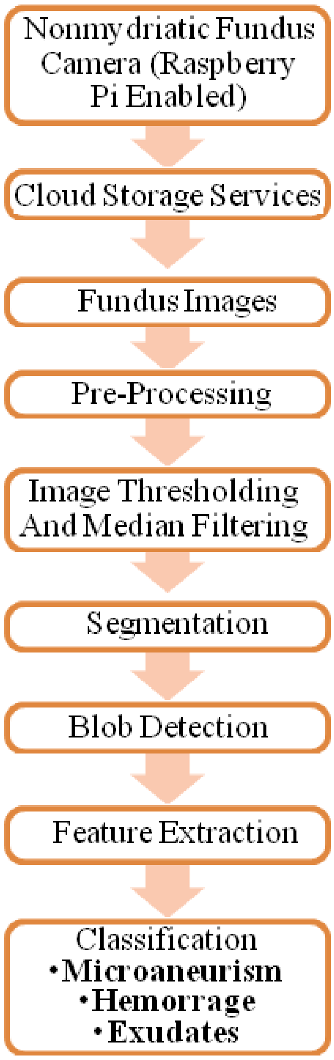


Figure 1: Block Diagram for DR Detection

Figure 1 shows the block diagram for DR detection , the algorithm starts with pre-processing stage which is based on several image processing techniques including green channel extraction, CLAHE, image thresholding, Circular Hough Transform (CHT) and median filtering in order to reduce the salt and pepper noise. Then the image is segmented using morphological functions by which blobs are detected, feature extracted and classified with the help of Support Vector Machine (SVM) classifier.

A. Nonmydriatic Fundus Camera:

Nonmydriatic fundus camera is based on the Raspberry Pi 2 Model and the NoIR camera (Raspberry Pi Foundation, Caldecote, Cambridgeshire, UK). Raspberry Pi is a card-sized computer board designed to easily interact with its environment. The NoIR camera board is sensitive to infrared light and is fixed-focus. The Raspberry Pi is attached to a lightweight lithium battery and LCD touch screen. The Raspberry Pi is also connected to the battery by micro-USB cable and to the LCD touch screen by a micro-USB cable and HDMI cable. The operating system used for the Raspberry Pi is Raspbian, which was preloaded on a micro-SD card (Raspberry Pi Foundation). Commands are typed into the Raspberry Pi through the LCD touch screen and the open-source Florence virtual keyboard program. A simple Python program, based on the picamera module written by Dave

Jones [10], is used for the fundus camera and is provided in the Supplementary Instructions.

B. Cloud Storage Services (ownCloud):

The ownCloud is used for storage of fundus images from the Raspberry Pi device can be seen in Figure 2. The ownCloud is a open source, self-hosted file sync and share app platform .The shell of Raspberry Pi is accessed through a remote computer connected to Raspberry Pi on a network through SSH login. The VNC server is installed on Raspberry Pi which uses remote frame buffer (RFB) protocol to GUI enabled desktop of Raspberry Pi. This eases the access than the command line text environment through SSH login using PuTTY. The Apache server and them Cloud service is installed in Raspberry Pi. The Raspberry Pi cloud service is behind the domestic ADSL/DSL router. The router connects the Pi server to internet. Request from users for server access is forwarded to Pi by the router only when the set up forwarding for the Apache server on port Nos. 80 and 443(http and https port numbers) are done. Weaved can be used for port-forwarding for secure access. Then the cloud service is setup on Raspberry Pi and users can login through ownCloud portal and store their data on Raspberry Pi from any corner of the world.

C. Fundus Images

Fundus images contain information about the internal structures of the human eye including the retina. In this project fundus images from the ownCloud storage are used. The best 40 images are selected. Each image has been JPEG compressed. In this, the best 20 images are selected.

D. Pre Processing

The RGB image is converted to grayscale image by extracting the green channel. Figure 4 (a) and (b) shows the original image and the green channel image. The contrast of the gray image is enhanced using Contrast Limited Adaptive Histogram Equalization (CLAHE) Method(c).Histogram equalization redistributes the histogram of each colour channel in the input image such that the output image contains a uniform pixel value distribution .It prevents the over amplification of noise. Moreover image pre-processing is used to clarify the image and to make the feature extraction process simple.

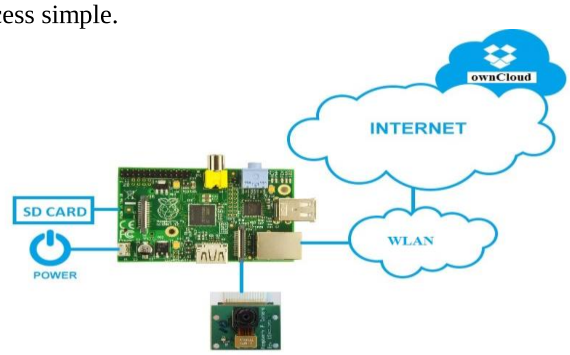


Figure 2: Raspberry Pi connected to the ownCloud

E.Image thresholding and Median filtering

The gray thresh function chooses the threshold to minimize the intraclass variance of the black and white pixels. Median filtering is an effective method that can remove impulse noise without blurring sharp edges of the image.

F.Segmentation

Morphological Functions are used to separate the blood vessels and exudates and they are applied to do the post-processing. In segmentation, Morphological open and close functions are used. The opening is a combination of dilation [12] and erosion operations. Mainly segmentation of blood vessels and blobs (lesions) are focussed during segmentation. Among various methods of segmentation like local threshold, adaptive seed region growing segmentation, morphological operations performed with best efficient output of segmented images.

G.Blob detection

Blob detection is done with the help of Circular Hough Transform (CHT) as shown in Figure 1.

H.Feature Extraction

The main abnormal features of diabetic retinopathy are exudates and blot haemorrhages [13]. The optic disc is also detected and eliminated using CHT. After detecting blobs with the help of CHT, using region props function the properties like radius, centroid, major axis length and minor axis length.

I.Classification:

SVM is a method used for data classification. It constructs a [11] hyper plane to separate the input data linearly into different classes. Transductive support vector machines extend SVMs in that they could also treat partially labelled data in semi-supervised learning by following the principles of transduction. In the cases of nonlinear data, the training data are mapped into high dimensional feature apace using a nonlinear kernel function. Then, the data can be classified linearly. The SVM classifier is trained with 30 fundus images which show different levels of DR. After extracting the features, they will go under classification part for identifying that whether the provided input image is normal or having DR. The input test image fed to the classifier appropriately classifies the level of DR based on the training of SVM Classifier. The test fundus image [11] is then applied as an input to SVM classifier which provides at the output the level of DR.

3. DietPi Software

The Fundus camera takes the advantage of latest advancement in LED technologies. The Raspberry Pi is connected to Cloud storage services (ownCloud) via Ethernet Cable. First install DietPi disk image in the Raspberry Pi through microSD card connected to it. DietPi gets bootup and shows the IP address. Login in with the username root and password dietpi shown in Figure 3. Dietpi enters after login and updates automatically. Then it asks for reboot. Then login DietPi again and install the ownCloud software. Navigate to Software Optimized to install the software.

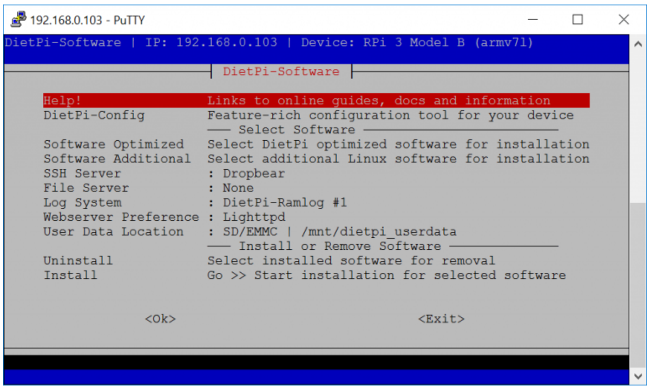


Figure 3: DietPi Software

After the software installation with the generate IP address login to ownCloud in browser between http:// IP address /owncloud. It prompts a setup for admin account creation. Then create username and password to access ownCloud. Now when an image is captured in Fundus camera it is uploaded to the ownCloud quickly and it can be accessed through internet anywhere in the world. We can setup port forwarding by assigning appropriate port and IP address. The obtained image is processed for recognizing the Diabetic Retinopathy.

4. Results

The performance of the proposed method is measured in terms of sensitivity, specificity and accuracy [14]. While sensitivity is the ratio of abnormal images classified correctly, specificity is the ratio of normal images classified correctly. Accuracy is the ratio of the total number of correctly classified images to the total number of images. Table 1 shows the results of the performance measurements with a comparison to the other methods.

The equations used for performance measurements are

$$\text{Accuracy} = (TA+TN) / (TA+FA+TN+FN) \quad (1)$$

$$\text{Sensitivity} = TA / (TA+FN) \quad (2)$$

$$\text{Specificity} = TN / (TN+FA) \quad (3)$$

TA→ Abnormal image is correctly classified as Abnormal
TN→Normal image is correctly classified as Normal
FA→ Normal image is incorrectly classified as Abnormal
FN→Abnormal image is incorrectly classified as Normal

Table 1: Results of the Performance Measurements

Method	*Sensitivity*	*Specificity*	*Accuracy*
A.Biran et al [1]	93.2%	87.5%	94.4%
Atul et al. [4]	92%	80%	90%
Proposed method	93.33%	90%	95%

The proposed results such as sensitivity, specificity and Accuracy are improved from the earlier methods [1], [4].

Figure 4 and 6 shows the input and output of detecting Microaneurysms, haemorrhages, exudates and normal eye. Figure 5 shows the vector classifications of the Support Vector Machine (SVM) classifier.

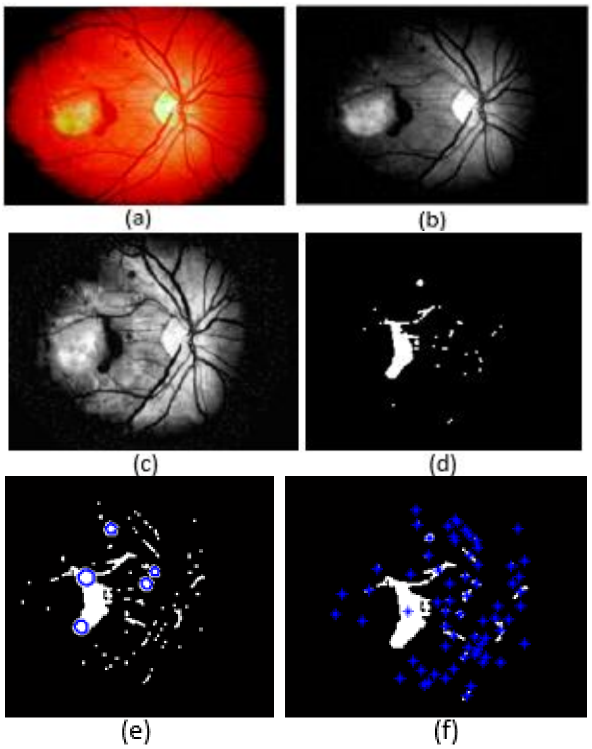


Figure 4: (a) RGB scale retinal image (b) Green scale image (c) CLAHE equalized image (d) Segmented Hemorrhage (e) Feature Extracted image (f) Region properties for classifier.

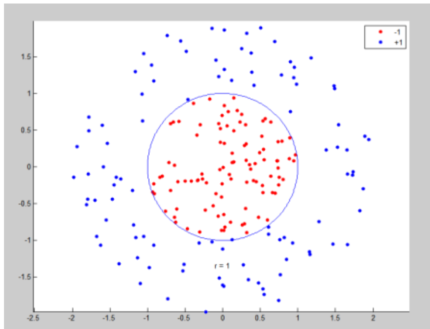
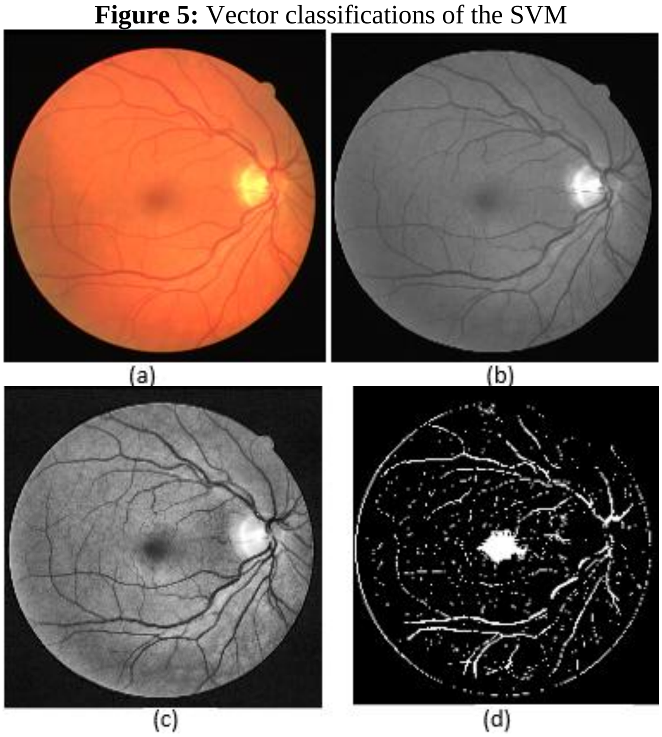
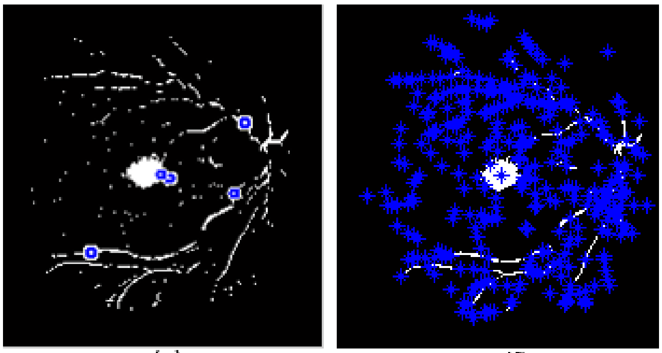


Figure 5: Vector classifications of the SVM





(e) (f)

Figure 6: (a) Normal RGB fundus image (b) Green scale image (c) CLAHE equalized image (d) Segmented Image (e)Feature Extracted image (f) region properties for classifier

5. Discussion and Conclusion

In this paper, Internet Of Things (IOT) enabled nonmydriatic fundus camera connected to cloud storage services and an automatic algorithm for recognizing Diabetic Retinopathy with the help of fundus images is proposed. It is a combination of efficient morphological functions, machine learning, and noise reduction techniques. The parameters are simulated and inferred better than previous methods.

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