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Detection of Diabetic Retinopathy using Machine Learning Algorithm

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***Abstract*—Diabetic Retinopathy (DR) is an ocular abnormality caused due to diabetes. In this disease there is a progressive damage to the retina if the high blood glucose levels are not controlled. DR has mainly two stages Non Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR). In this paper, we propose a robust automated system which detects and classifies the different stages of DR. The optic disc and retinal nerves are being segmented, and using Gray Level Co-occurrence Matrix (GLCM) method the features are being extracted. The classification is done using Fuzzy classifier and Convolutional Neural Network, for detecting different stages of DR. The databases used are STARE, DIARETDB0 and DIARETDB1.**

Keywords—Diabetic Retinopathy, NPDR, PDR, NLM, GLCM, CNN classifier, Fuzzy classifier.

I. INTRODUCTION

Diabetes Mellitus is ordinarily known as diabetes, is a group of chronic diseases that are caused due to high glucose level in the blood of a person affected by it. Diabetic Retinopathy (DR) is a rare disease caused by high blood sugar levels which results in the damage of the retinal nerves and inflammation of the blood vessels which eventually results in loss of vision or complete blindness in the patient.[1] It is an incurable disease but can be prevented by keeping the blood glucose levels in check. Diabetic Retinopathy is detected by Ophthalmologists using various eye tests. DR can be kept in check by monitoring the blood glucose levels and by regular eye check-ups. Hence the proposed system is a machine learning algorithm designed to detect Diabetic Retinopathy in the most effective and reliable manner.

Classification of Diabetic retinopathy can be done by classifying it into two types that are as follows:

A. Non-proliferative diabetic retinopathy (NPDR):

The word Proliferative refers to abnormal swelling or growth of blood vessels. NPDR being the earliest stage of DR has minor or nonexistent symptoms. The retinal blood vessels weaken and may leak fluid to cause retinal swelling and hence causing blurriness of vision.

B. Proliferative diabetic retinopathy (PDR):

The advance stage in which fragile blood vessel starts growing known as the neovascularization. Due to poor blood circulation at this stage, the retina is oxygen deprived. Vessels bleed and leak fluid into the vitreous causing cotton wool like structures called soft exudates (EX). The lipid deposits which appear smooth and waxy in appearance are known as hard exudates. Serious complications of PDR include, clouding of vision, retinal detachment due to scar tissue formation, damaged optic nerve due to elevated eye pressure and the development of glaucoma. Glaucoma rapidly deteriorates the optic nerve. PDR can cause severe vision loss and blindness if blood glucose levels are kept unchecked and untreated. [2]

II. LITERATURE SURVEY

For classification of DR several approaches have been proposed by researchers which involves the basic steps of image processing like pre-processing of the raw images, image enhancement, post processing. Feature extraction and classification is done after training. Different features are extracted and taken as inputs for training algorithm. Previous researches are done by detecting lesions on the retina especially blood vessels, exudates and microaneurysms. Area, perimeter and exudates count is taken as features to classify the stages of the disease and classification is done by applying artificial neural network (ANN). [3]

Another system uses Non local means (NLM) filter for filtering out the noise and smoothening of the images. Whereas, contrast limited adaptive histogram equalization (CLAHE) is used to enhance the image. Microaneurysms (MAs) are segmented and positioned using Forstner Corner Detection theory. [4]

As proposed in one of the earlier system the area of blood vessels, microaneurysms count, area of the exudates, contrast and homogeneity are extracted as the features which are used in Fuzzy classifier for classification. Images from STARE, DIARETDB0 [5] and DIARETDB1 [6] databases are used. The classified images give accuracy up to 95.63%. [7]. Hence for our proposed system fuzzy classifier is used for classification of different stages of DR.

III. PROPOSED METHODOLOGY

The proposed methodology is explained using the flow diagram in Fig.1. The raw FUNDUS images are processed for noise removal and converted into gray images using the preprocessing steps to ensure easier postprocessing. The optic disc and retinal nerves are then segmented. The features that are extracted are used for classification using Convolutional Neural Network and Fuzzy Classifier to identify whether the eye image is Normal or of NPDR or PDR stage.

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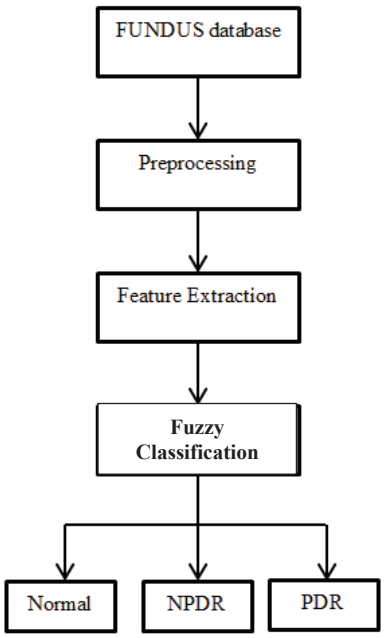


Fig. 1. Flow Diagram of the proposed model

A. Preprocessing

In preprocessing steps the raw image is converted into a grayscale image. The RGB image to grayscale conversion is done for ease of processing, grayscale images are then filtered using Non Local Means Filter (NLM). NLM filter is used to remove any noise present and to obtain a smooth image since even good quality images may have some noise present in it [8]. To reduce any error that the noise may cause during the processing and classification of images the preprocessing of the images are done. Fig 2 below is a raw FUNDUS image taken from the database as an input for the algorithm.

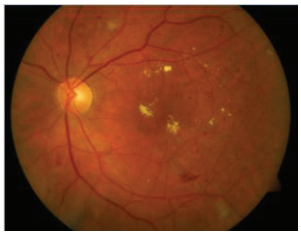
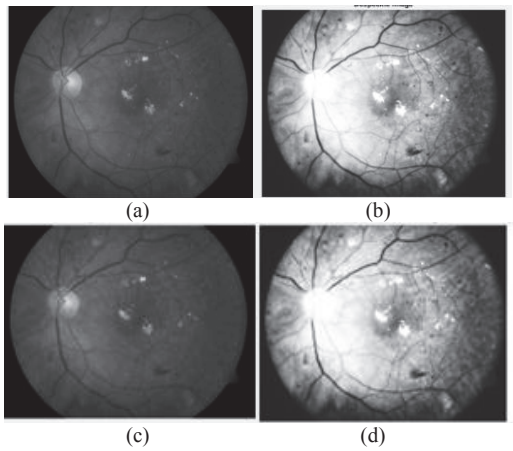


Fig. 2. Raw FUNDUS image taken as input in both the classifiers



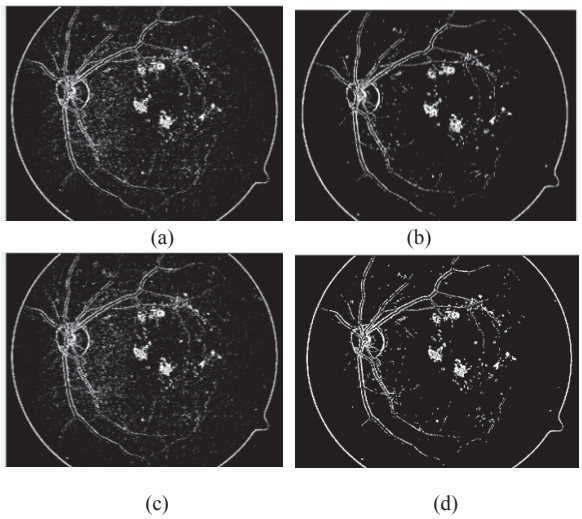
(a) (b) (c) (d)

Fig. 3. The resulting images of preprocessing :
(a) Grayscale image used in Fuzzy Classifier.
(b) Filtered image using NLM filter used in Fuzzy Classifier.
(c) Grayscale image used in CNN Classifier.
(d) Filtered image using NLM filter used in CNN Classifier.

All the images in Fig 3 are the resultant images after the first step i.e. the preprocessing step. Fig. 3 (a) and Fig. 3 (c) are the grayscale images where the input RGB image is converted into different intensities of gray according to the RGB intensities for easy postprocessing. Fig. 3 (b) and Fig. 3 (d) are the filtered images using NLM Filter which removes all the unwanted noise particles using the averaging of the neighbouring pixels and hence the output obtained is a smooth image which is to be used as an input in the further steps. The above images are used for the Fuzzy Classifier and the CNN Classifier respectively.

B. Post Processing

In Post processing of the filtered image the retinal nerves, hard exudates and optical disc is segmented. Blood vessels are the dark coloured nerves in the filtered images. Morphological operations are applied to segment the blood vessels. This technique involves erosion and dilation using structuring element on the preprocessed images. As a result the region of interest i.e. the nerves are segmented and smoothened. All the disconnected pixels which are not required are discarded.



(a) (b) (c) (d)

Fig. 4. The outputs of retinal blood vessel segmentation:
(a) Segmented image of blood vessels used in Fuzzy Classification.
(b) Enhanced image used in Fuzzy Classification.
(c) Segmented image of blood vessels used in CNN Classification.
(d) Enhanced image used in CNN Classification.

All the images in Fig 4 are the resultant images after the second step i.e. the postprocessing step. In this step basically the segmentation of the various parts of an eye in the FUNDUS images are done. Fig. 4 (a) and Fig. 4 (c) are the Segmented images of the blood vessels before enhancement. It still contains few unwanted particles which are removed while enhancing the images. Fig. 4 (b) and Fig. 4 (d) are the enhanced images in which all the disconnected unwanted particles other than the blood vessels are removed and a clear images of the blood vessels are obtained. This is the first step of segmentation i.e. the segmentation of the retinal nerves next step is the segmentation of the optic disc. The above images are used for the Fuzzy Classifier and the CNN Classifier respectively.

Optical Disc is the bright slightly elliptical or circular structure appearing in the retinal images. For optical disc segmentation morphological structuring element to find the flat disk shaped structure is used. The extracted images are diffrentiated from the exudates as the size of the optical disc is larger as compared to the exudates. The extracted image obtained is a binary image which is obtained by applying a threshold value to create a mask. The mask is used to segment the optical disc from the retinal image.

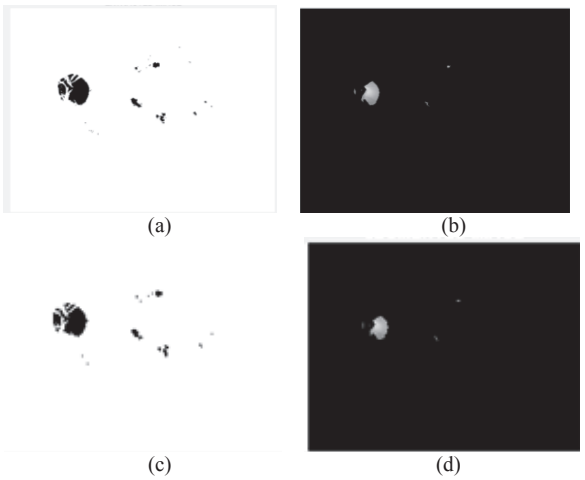


Fig. 5. The outputs of optical disc segmentation:
(a) Extracted binary image to be used as a mask in Fuzzy Classifier.
(b) Segmented Optical Disc to be used in Fuzzy Classifier.
(c) Extracted binary image to be used as a mask in CNN Classifier.
(d) Segmented Optical Disc to be used in CNN Classifier.

All the images in Fig 5 are the resultant images after the second step of segmentation i.e. the optic disc segmentation. In this step basically the segmentation of the optic disc of an eye in the FUNDUS images are done. Fig. 5 (a) and Fig. 5 (c) are the Segmented images of optical disc of the FUNDUS images. A binary of the images is created which helps in masking of the other parts which are not required and only the optic disc is segmented out of the entire image. Fig. 5 (b) and Fig. 5 (d) are the final segmented images of the optical disc segmentation. This is the last step of segmentation i.e. the segmentation of the optical disc.

The segmentd images are used in the feature extraction for the classification of images.

C. Feature Extraction

For feature extraction Gray Level Co-occurrence Matrix (GLCM) method is used to do the textural feature analysis.Textural analysis involves calculation of the pixel of interest of any image by finding their spatial variations of the pixel intensities.[9] We have considered contrast and homogeneity as our features from retinal images which are derived from the GLCM matrix. GLCM

- Contrast

Contrast measures the local variations in the grey level of the pixels in the co-occurrence matrix. The intensity of the grey image pixels are calculated using the following equation:

$$\sum_{i,j=0}^{N-1} (\mathrm{i}-\mathrm{j})^2 p_d(i,j)$$

where, $p_d(i,j)$ is the probability of obtaining adjacent occurring pixel pairs in a GLCM matrix.

- Homogeneity

Homogeneity is the distribution of the pixels which measures and gives the value of the closeness of the elements of GLCM to the elements in the diagonal of a GLCM matrix. Homogeneous images have very less grey pixel values, which produces high measurement for probability of i,j resulting in high values of sum of square. Value of Homogeneity is 1 for a diagonal. It is calculated by the following equation:

$$\sum_{i,j=0}^{N-1} \frac{1}{1+(i-j)^2} p_d\,(i,j)$$

D. Classification

Fuzzy classifier and Convolutional Neural Network are used for classification of the processed images. The extracted features are taken as input parameters for the classification model for classifying the Normal and stages of Diabetic Retinopathy. Fuzzy classification system is based on fuzzy logic or rules which are defined as if-then statements and the decision making is based on the specified rules. [10]

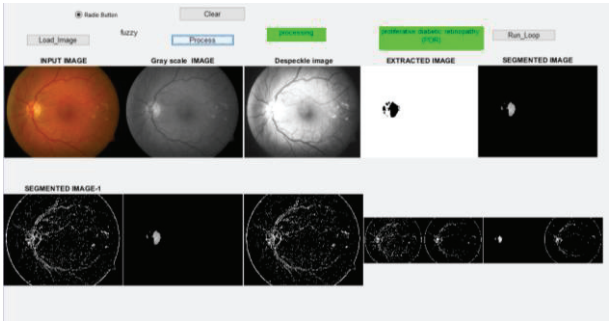
CNN classifier is a class of deep learning method mostly used in image processing. It consists of neurons in convolutional layer. The results that are subsampled from the convolutional layer are stored in the pooling layer. [11]

The features that are given as input to the classifiers are the retinal blood vessel area, optic disc, homogeneity and contrast for the different stages of the disease i.e. Normal eye image, NPDR and PDR. If no microaneurysms or exudates are detected, it is a normal eye image without DR. Or else the image is assigned as NPDR or PDR based on the severity of the disease.

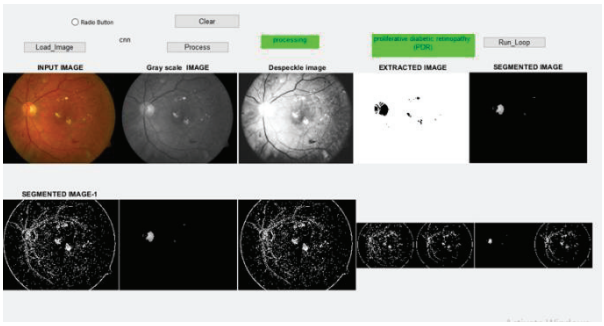
IV. RESULTS AND DISCUSSION

The standard images of resolution 1500 × 1152 pixel from the available datasets - STARE, DIARETDB0 and DIARETDB1. These images are taken for evaluating the proposed system. These images are captured using digital FUNDUS camera of 50^o field-of-view (FOV). The stages detected after classification for the images. The accuracy of the system is compared between fuzzy classifier and CNN Classifier. The formula used for accuracy is as follows:

$$Accuracy = \frac{True\ Positive + True\ Negative}{Total\ Samples}$$



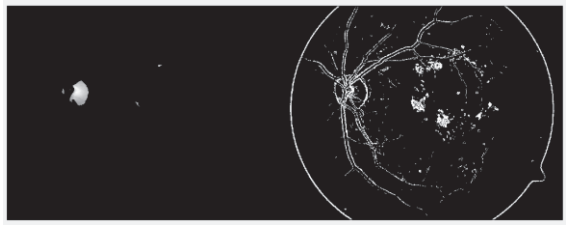
(a)



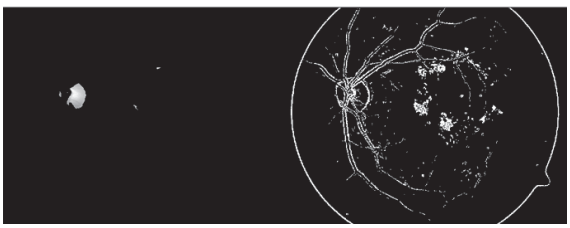
(b)

Fig. 6. Application:
(a) For Fuzzy Classifier
(b) For CNN Classifiet

All the images are processed step by step and the final segmented and extracted images are shown using the above application in Fig. 6. shows the UI application used for processing and showing all the resulting images in step by step format. The UI contains a load image push button which is used to load the input image then by using the radio button present the classifier is to be chosen by the user for the classification process as shown in Fig 6 (a) for the Fuzzy Classifier and Fig 6 (b) for the CNN Classifier. After the classifier is chosen the processing button is pressed which will process and show all the processed images with the result of the classification as the stage of the Diabetic Retinopathy predicted.



(a)



(b)

Fig. 7. Final Output:
(a) Final Segmented images of optic disc (left) and Retinal Nerves (right) for Fuzzy Classification.
(b) Final Segmented images of optic disc (left) and Retinal Nerves (right) for CNN Classification.

The above images in Fig. 7. are the Finals Segmented images of the the original FUNDUS eye image. The image in Fig 7 (a) shows the output i.e the optic disc and retinal blood vessels for the Fuzzy Classifier. The image in Fig 7 (b) shows the output i.e the optic disc and retinal blood vessels for the CNN Classifier.

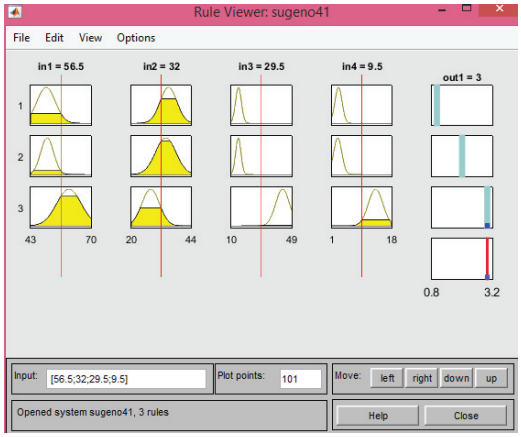


Fig. 8. Rule Viewer output of the Fuzzy Classifier

The above Fig.8. is a rule viewer shown as the output of the Fuzzy Classifier for each image which allows the interpretation of the fuzzy inference process in a single window. The Rule Viewer also shows how the shape of certain membership functions influences the overall results of the classification.

The rule viewer has columns and rows which shows the number of inputs taken as the number of columns and the rows explains the number of rules i.e the stages of the Diabetic Retinopathy that are Normal, Non Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR).

CNN classifier accuracy is 90% and for Fuzzy classifier it is 85% as described in Table 1 below. The classification for the Normal, NPDR and PDR stages are detected correctly with some false positive cases by both the classifiers the reason being the distinct features obtained for those image dataset.

TABLE I. ACCURACY RESULTS FOR THE CLASSIFIERS

Classification type	Accuracy (%)
Fuzzy Classifier	85 %
CNN Classifier	90%

This proposed system have simulated classified the different stages of the diabetic retinopathy. The classifications of the images are done using the Fuzzy Classifier and Convolutional Neural Network Classifier. The classifiers successfully classify the images into the different stages of DR that are the NPDR and PDR and also as the normal eye images. After comparison CNN classifier is better in classifying as compared to Fuzzy Classifier for the database taken.

As the future work the hardware can be used to for the identification of the diabetic retinopathy and implemented into a real time system.

REFERENCES

[1] “Grading Diabetic Retinopathy from Stereoscopic Color Fundus Photographs—An Extension of the Modified Airlie House Classification,” doi.org/10.1016/S0161-6420(13)38012-9 (1991).

[2] “Retinal Imaging and Image Analysis ” Michael D. Abràmoff et al, IEEE Reviews in Biomedical Engineering doi: 10.1109/RBME.2010.2084567 (2010)..

[3] "Detection of lesions and classification of diabetic retinopathy using fundus images," M. P. Paing, S. Choomchuay and M. D. Rapeeporn Yodprom, 9th Biomedical Engineering International Conference (BMEiCON), Laung Prabang, doi: 10.1109/BMEiCON.2016.7859642. (2016)

[4] “Region Growing Based Segmentation Using Forstner Corner Detection Theory for Accurate Microaneurysms Detection in Retinal Fundus Images," R. D. Badgujar and P. J. Deore, 2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBEA), Pune, India, 2018, pp. 1-5, doi: 10.1109/ICCUBEA.2018.8697671. (2018)

[5] “DIARETDB0 : Evaluation Database and Methodology for Diabetic Retinopathy Algorithms,” Kauppi, Tomi, Valentina Kalesnykiene, Joni-Kristian Kämäräinen, Lasse Lensu, Iiris Sorri, Hannu Uusitalo, Heikki Kälviäinen and Juhani Pietilä (2007).

[6] “DIARETDB1: diabetic retinopathy database and evaluation protocol,” Kauppi, Tomi & Kalesnykiene, Valentina & Kamarainen, Joni-Kristian & Lensu, Lasse & Sorri, Iiris & Raninen, A. & Voutilainen, R. & Uusitalo, Hannu & Kälviäinen, Heikki & Pietilä, Juhani. (2007). DIARETDB1 diabetic retinopathy database and evaluation protocol. Proc. Medical Image Understanding and Analysis (MIUA). 2007. 10.5244/C.21.15.

[7] “Automatic Lesions Detection and Classification of Diabetic Retinopathy Using Fuzzy Logic” Afrin, R., & Shill, P. C. International Conference on Robotics,Electrical and Signal Processing Techniques (ICREST). doi:10.1109/icrest.2019.8644123 (2019).

[8] "A non-local algorithm for image denoising," A. Buades, B. Coll and J. -. Morel, 2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'05), San Diego, CA, USA, 2005, pp. 60-65 vol. 2, doi: 10.1109/CVPR.2005.38. (2005)

[9] “Image Texture Feature Extraction Using GLCM Approach” P. Mohanaiah , P. Sathyanarayana , L. GuruKumarInternational Journal of Scientific and Research Publications, Volume 3, Issue 5, May 2013 1 ISSN 2250-3153 (2013)

[10] “Enhancement of exudates for the diagnosis of diabetic retinopathy using Fuzzy Morphology," A. B. Mansoor, Z. Khan, A. Khan and S. A. Khan, " 2008 IEEE International Multitopic Conference, Karachi, 2008, pp. 128-131, doi: 10.1109/INMIC.2008.4777722.

[11] "Detection of Retinal Lesions Based on Deep Learning for Diabetic Retinopathy," K. V. Maya and K. S. Adarsh, 2019 Fifth International Conference on Electrical Energy Systems (ICEES), Chennai, India, 2019, pp. 1-5, doi: 10.1109/ICEES.2019.8719242.