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DESIGN AND DEVELOP A COMPUTER AIDED DESIGN FOR AUTOMATIC EXUDATES DETECTION FOR DIABETIC RETINOPATHY SCREENING

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Abstract

Diabetic Retinopathy is a severe and widely spread eye disease which can lead to blindness. One of the main symptoms for vision loss is Exudates and it could be prevented by applying an early screening process. In the Existing systems, a Fuzzy C-Means Clustering technique is used for detecting the exudates for analyzation. The main objective of this paper is, to improve the efficiency of the Exudates detection in diabetic retinopathy images. To do this, a three Stage – [TS] approach is introduced for detecting and extracting the exudates automatically from the retinal images for screening the Diabetic retinopathy. TS functions on the image in three levels such as Pre-processing the image, enhancing the image and detecting the Exudates accurately. After successful detection, the detected exudates are classified using GLCM method for finding the accuracy. The TS approach is experimented using MATLAB software and the performance evaluation can be proved by comparing the results with the existing approach's result and with the hand-drawn ground truths images from the expert ophthalmologist.

Keywords: Exudates, Diabetic Retinopathy, Pre-processing, Image processing, Classification, Three Stage.

1. Introduction

Two words, Diabetes and Retinopathy combine and deliver the term Diabetic Retinopathy. Diabetes is a disease, in a person who has high blood sugar due to the production of low insulin and Retinopathy exactly means the damages on the

Nomenclatures

H	Hue
S	Saturation
V	value
I	Intensity
DD	Disc diameter, mm
R	Red
G	Green
B	Blue

Abbreviations

DR	Diabetic Retinopathy
DRFI	Diabetic Retinopathy Fundus Images
TS	Three Stage
FCM	Fuzzy C Means
CLAHE	Contrast level adaptive threshold based Histogram Equalization
PDR	Proliferative Diabetic Retinopathy
NPDR	Non Proliferative Diabetic Retinopathy
CHT	Circular Hough Transform Method
GLCM	Gray-Level Co-occurrence Matrix

retinal images. DR-[Diabetic Retinopathy] is an eye disease spread to the eye, which is regarded as the manifestation of diabetes on the retina. There are two types of DR, one is PDR and the other one is NPDR. In PDR, the condition of the capillaries of retina got shut down and in NPDR retinal capillaries gets damaged and microscopic leaks occur on the vessels, also the leakage causes the retina to swell and it interferes with normal vision and all this is because of new retinal blood vessel growth on the retina [1]. In the earlier researches, the main objective is to determine the severity of the diabetic retinopathy by analyzing the various components such as Optic Disk, Blood Vessels, exudates, hemorrhages etc., by screening the DR [2]. A sequence of image processing steps was applied to the diabetic retinal images by detecting and analyzing the vascular network [3]. Arturo et al. [4], segment the OD, using a three different image segmentation algorithms [CHT, Morphological operation, Location detection] and the presented a comparable result.

In order to analyze the eye diseases like DR, the ophthalmologists compare and study multiple retinal images, usually called as fundus images and various components in the image such as Microaneurysms, Optic Disc, Blood Vessels, Soft-Hard exudates, and Fovea, Macula edema. The following Fig.1 shows the various components [Features] in the DRFI-[Diabetic Retinopathy Fundus Images].

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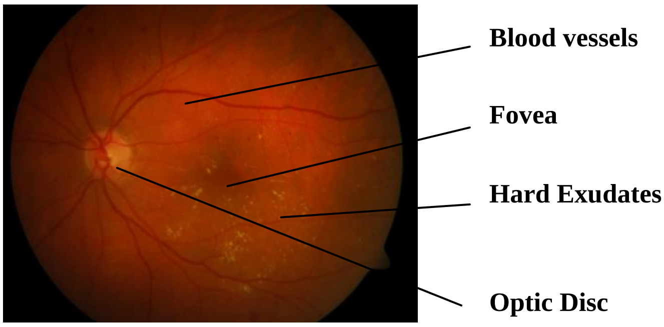


Fig. 1. Various Components of Typical Retinopathy.

In the existing systems, the various components in the retinal images are detected, extracted, analyzed separately and the conditions of the DR is classified as mild, moderate or severe. One of the common abnormalities in the DR patients is Exudates which are bright lipids leakage of blood vessels. The exudates are small yellow regions with well-defined edges on the surface of DRFI. This paper mainly focuses on analyzing the exudates by detecting the DRFI in order to understand the information about the early DR. The proteins and lipids leaked from blood streams due to DR through damaged blood vessels delivers the exudates.

The chief cause of exudates is leakage of proteins and lipids from the bloodstream into the retina through damaged blood vessels [9]. In retinal images, exudates exhibit a hard white or yellowish localized region with varying sizes, shapes and locations. Generally, they materialize near the leaking capillaries within the retina. The hard exudates are formations of lipid that get leaked from these weakened blood vessels. This kind of the retinopathy is termed as non-proliferative diabetic retinopathy.

Anitha Soma Sundaram [1] introduced an automated algorithm to detect and locate the exudates even in low-contrast images in a DRFI. The preprocessed input image is applied to mask technique, followed by score computation technique for segmenting the exudates in the input image and it helped the ophthalmologists to find the proper disease. Dr. Kekre and Dr. Tanuja Sarode [5] used mathematical morphology based operations in the initial stage and hybrid approach for detecting the soft, hard exudates. Sidra Rashid and Shagufta discussed and used Fuzzy-C-means clustering technique combined with morphology techniques and improved the robustness for accurately detecting the exudates [6] and the classification compared with ground-truths given by expert ophthalmologists. Nidhal K. El Abbadi [7] presents an automated method for detection of bright lesions [exudates] in retinal images. This algorithm used Specific color channels and the image features are extracted from physiological features in the DRFI. R.SriRanjini, M and Devaki [8], discussed about the computational intelligence approach and it is used to identify the exudates. The color images are segmented by Fuzzy-C means clustering approach.

T. Vandarkuzhali [9] gave a detailed manual analysis, among the test images and trained images from ophthalmologists. Also the author mainly used fuzzy logic and neural network to identify the abnormalities in fovea. G.Ferdic Mashak Ponnaiah, discussed and applied GA – [Genetic Algorithm] to find the OD location with the size [10] Kittipol Wisaeng [11] presented a fuzzy c means clustering combined morphological approach with key-processing step. Ranamuka, N.G. Meegama proposed morphological based image processing with fuzzy logic to detect the hard exudates form the diabetic retinal images [12]. The blood vessels and optic disc are eliminated initially and then, the exudates are detected. According to the output the area, pixel information will be compared with hand-drawn ground truth's images.

P.C. Siddalingaswamy and K. Gopalakrishna Prabhu [13] proposed line operator combined fuzzy c means clustering technique to detect the OD and Exudates. Using K-Means clustering the OD and the exudates are classified using SVM. Ramasubramanian and G.Mahsendran [14] proposed an automated algorithm applied mathematical modeling's which detects exudates, corrects classification and it is applicable for various appearance changes of retinal fundus images used in clinical environments. Morium Akter, Atiqur Rahman Xiangqian and A.K.M.Kamrul Islam [15], presented a novel method which automatically detect histogram equalization in color retinal images. This automatic approach does the entire functionality in level by level like preprocessing, detection, classification using SVM method.

Mehdi Ghafourian Fakhar Eadgahi and Hamidreza Pourreza [16] proposed a segmentation method for exudates detection with the help of histogram equalization followed by mixture-morphological operations. Soju George and Bahilal Limbasiya [17] designed an automatic method which extracts important features from both normal, abnormal images and compare them to find the abnormal images. In this paper, Brightness Preserving Dynamic Fuzzy Histogram Equalization method for image preprocessing, De-correlation stretching method to enhance the image in terms of pixel intensities are used. S. vasanth and R.S.D Wahida Banu [18] checks the macula by extracting the AM-FM features. This AM-FM features extracts the texture information in various frequency scales and gives complete details about the exudates shape, color. Also the macula is detected using candidate lesions with supervised classification with PLS – [partial least square] method.

2. Datasets and Methods

The digital retinal images are taken from the diabetic patients with diabetic retinal camera with a 45º field of view, taken at the Arvind Eye Hospital. The images are stored in JPEG image format with lower compression rates. The image size is 700 x 500 pixels at 24 bits per pixel. Out of 2150 images comprising of 1024 images with exudates and 1126 images without exudates are tested on a core i5 systems using MATLAB software. The complete functionality for detecting exudates is depicted clearly in Fig.1. The functionality following in the TS (Three Stage) method is preprocessing, image enhancement and exudate detection. It makes us to assess the accuracy more accurately and it differs from other approaches comparatively.

2.1. Existing Approach

In earlier research there were so many approaches were applied for detecting and analyzing the exudates, Microaneurysms, hemorrhages and fovea-macula. An automatic method is proposed to detect exudates from low-contrast digital images of retinopathy patients with non-dilated pupils using an FCM (fuzzy c-means) clustering technique. Preprocessing of contrast enhancement was applied in order to enhance the quality of the input image before four features, namely, intensity, standard deviation of intensity, hue, and the number of edge pixels, were selected to supply to the FCM method. The number of required clusters was optimally selected from a quantitative experiment where it was varied from two to eight clusters.

2.2. Problem Statement

Diabetic Retinopathy (DR) is globally the primary cause of visual impairment and blindness in diabetic patients. Retinal image is essential and crucial for ophthalmologists to diagnose diseases. Many of the techniques can achieve good performance on retinal feature which are clearly visible. Unfortunately, it is a normal situation that the retinal images are low-quality images. The existing algorithm cannot detect low-quality image. Therefore, this study is part of a larger effort to develop a new method for detection of exudates in the low quality retinal image.

2.3. Three-stage Approach

According to the problem statement, the TS method is used to detect Exudates for screening the DRFI. TS approach follows a three step process for detecting the exudates. Fig.2 shows the three stage functionality flow diagram.

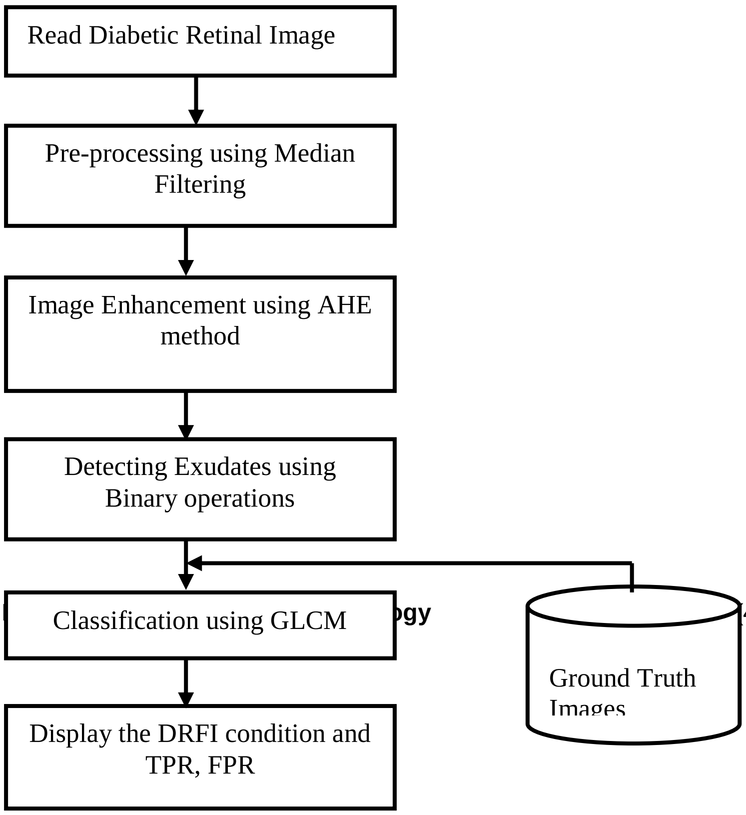


Fig. 2. Three Stage Functionality Flow Diagram.

2.3.1. Preprocessing

The input image is transformed from *RGB* color space into *HIS* color space and median filter is applied for removing the noise in the image to deliver a clear image. The *HSV* color space model can be obtained using the following Mathematical Model as:

$$H_1 = \cos^{-1}\frac{0.5\left[(R-G)+(R-B)\right]}{\sqrt{(R-G)^2+(R-B)(G-B)}} \tag{1}$$

$$H = H_1 \text{ if } B \le G, H = 360° - H_1 \text{ if } B > G \tag{2}$$

$$\mathrm{S} = \frac{\mathrm{Max}(R,G,B) - \mathrm{Min}(R,G,B)}{\mathrm{Max}(R,G,B)} \tag{3}$$

$$V = \frac{(R,G,B)}{255} \tag{4}$$

According to the values of *H, S, V* (1) (2) (3) the image will be converted and it shows the objects contained in the image separately. Once the image has been converted into relevant color space, the image will be filtered by a median filter which removes the noise and gives a clear image for further processing.

2.3.2. Median Filtering

Median filtering follows this basic prescription. The median filter is normally used to reduce noise in an image, somewhat like the mean filter. However, it often does a better job than the mean filter, of preserving useful detail in the image. This class of filter belongs to the class of edge preserving smoothing filters which are non-linear filters. This means that for two images A(x) and B(x) are

$$\mathrm{median}\left[A(x)+B(x)\right] \neq \mathrm{median}\left[A(x)\right]+\mathrm{median}\left[B(x)\right]$$

This filter smoothes the data while keeping the small and sharp details. The median is just the middle value of all the values of the pixels in the neighborhood. It is to be noted that this is not the same as the average (or mean); instead, the median has half the values in the neighborhood larger and half smaller. The median is a stronger "central indicator" than the average. In particular, the median is hardly affected by a small number of discrepant values among the pixels in the neighborhood.

2.3.3. Adaptive histogram equation (AHE)

Adaptive histogram equation (AHE) is information processing system semblance procedure technique utility to reform a tithe size in semblance. It dispute from usual histogram equation in the venerate that the adaptable process calculates several histograms, each agreeing to a conspicuous portion of the semblance, and uses them to redistribute the levity utility of the semblance. It is therefore compatible for improving the sectional compare of a semblance and cause out more detail. However, AHE has a prone to over expand report in relatively uniform provinces of a semblance.

2.3.4. Thresholding

Image thresholding is the simplest system used for effective image partitioning, which separates the foreground from the background. Image thresholding is more effective in images with high levels of contrast and it can approximate the threshold value for the appropriate image portions [collection of pixels] and set the foreground and background. The functionality of the Thresholding process is shown in Fig-3. The perception of the ocular disc on the man retina is a very essential work. It is essential for advances to discover of exudates, for the ocular disc has such characteristic in the condition of clearness, bleed and antithesis, and we must require usage of these characteristics for the discovery of exudates. Image is binarized by the gate so that ocular disc is accused.

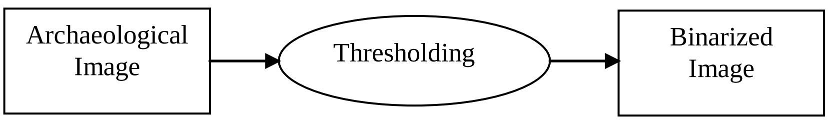


Fig.3: Image Thresholding

There are two kinds of Thresholding algorithms are used as local or adaptive Thresholding and global Thresholding. The simplest formula used for image Thresholding is:

$$\boldsymbol{If}\ \boldsymbol{f(x,y)} > T\ \ then\ \ f(\boldsymbol{x},\boldsymbol{y}) = \boldsymbol{0}\ \boldsymbol{else}\ \boldsymbol{f(x,y)} = \boldsymbol{255}$$

Threshold value lies between 120-170.This value is adjusted while experiment with different datasets.

2.3.5. Exudates Detection

Exudates are of two types, namely hard exudates and soft exudates. Hard exudates are short, sensational or pale soft, glossy field with distinct security. When difficult exudates invade on the spot sight is beloved. In the cause of satirical hypertensive retinopathy succeeds woolen exudates or impressible exudates are immediate. Exudates are the original type of diabetic retinopathy and appear when lipid or oily hold from disposition vessels or aneurysms.

A regional alteration speculator was then appropriate to the foregoing proceeded to get a criterion offense semblance which reveals the strength characterization of the secretly diversified group of exudates. The terminate semblance is threshold to get destroy of all provinces with light regional deviation. To betroth that all the adjacent pixels of the threshold issue are also included in the licentiate vicinity, a Boolean delay speculator was also appropriate. Resulting semblance will discover the exudates.

2.3.6. Classification of Diabetic Retinopathy

The macular district is exposed from the intenseness semblance by the darkest place on the retinal semblance [10]. Early Treatment of Diabetic Retinopathy Study (ETDRS) assortment of diabetic retinopathy has been planted to appoint an intensity direct supported on valuation of stereo retinal semblance of community endures from diabetic retinopathy, and is characterized as the riches authoritative for forward discovery and management. After the discovery of difficult exudates, the spot is placed supported on its relation attitude from the eyeglass disc. The macular district is then parted into three marker pen provinces worn three in closure with radii 1/3 of eyeglass Disc Diameter (*DD*), 1 *DD* and 2 *DD* centralized at spot. In any granted semblance if the exudates are withdrawn, then it is categorized as ordinary. The air of exudates external the 1*DD* province is condition as meek. The sparing cause is one with a personality of exudates within the 1*DD* province.

2.4. Texture Analysis of Retinal Images

(a) Exudates Area: Exudates area can easily be calculated from output binary image Containing exudates only. Exudates area is expressed in terms of number of pixels.

(b) Entropy: Concept of image entropy is inspired by Shannon’s information theory. Entropy is a statistical measure of randomness that can be used to characterize the texture of the retinal image.

(c) Kurtosis: Kurtosis is a descriptor of the shape of a probability distribution. Normally datasets with high kurtosis show tendency to have distinct peak near the mean and decline rapidly having heavy tails.

(d) Gray -Level Co-Occurrence Matrix (GLCM): A statistical process of examining structure that estimates the spatial relationship of pixels is the gray-level co-occurrence matrix (GLCM), also understood as the gray-headed-flat spatial concatenation table. The GLCM performance describes the structure of a semblance by scheming how often suit of pixel with specifying import and in a mention spatial relationship appear in a semblance, produce a GLCM, and then an extraction statistical degree from this grid.

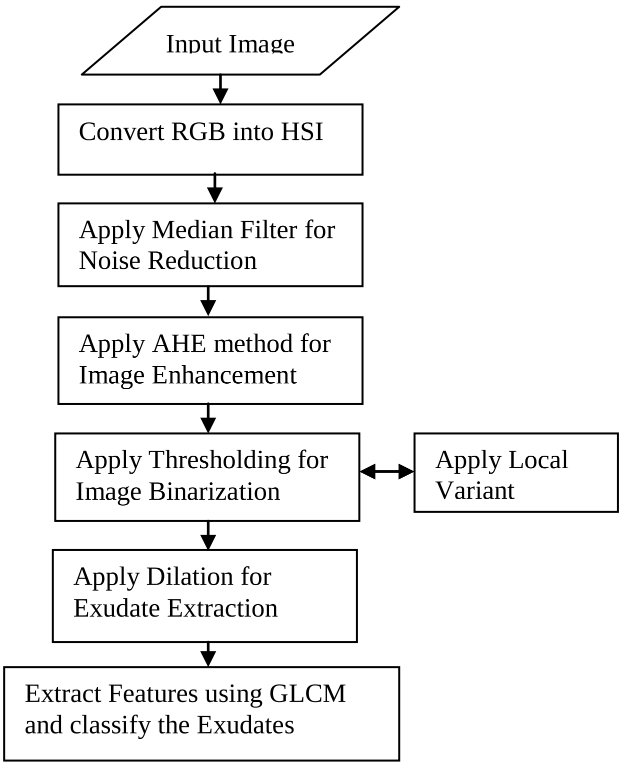


Fig.4: Flowchart for Exudate Detection and Analysis

The input image is converted into an HSI image from RGB, then remove the noise using median filter in order to improve the quality of the image. To separate the image contrasts AHE algorithm is applied to the image and separate the foreground and background using Thresholding method. Then the morphological dilation operation is performed on the image to extract the exudates [high contrast portion] and finally using GLCM the features of the exudates are extracted for classification. The reason for using GLCM method is, inter processed image is in the form of gray level. The feature extraction from a gray scaled image can be obtained in an efficient way is using GLCM. This entire operation is depicted in Fig.4 and in Exudates_Detection_Algorithm given below.

Exudates_Detection_Algorithm ()

{

1. Read the image.
2. Convert RGB image to HSI image.
3. Apply median filtering on intensity image to reduce noise.
4. For contrast enhancement, adaptive histogram equalization is applied.
5. Resulting image is binarized by thresholding.
6. Morphological reconstruction by dilation.
7. A local variation operator is applied
8. Again thresholding is applied.
9. Dilation is applied, which detects the exudates.

}

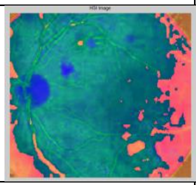
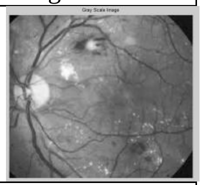
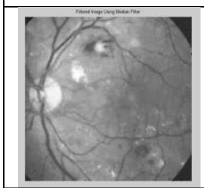
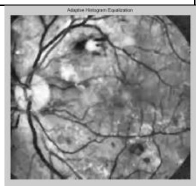
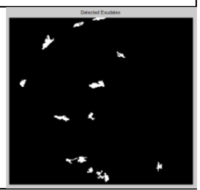
3. Results and Discussions

This system can support the ophthalmologists to expose the mark of diabetic retinopathy in the forward station, in supervising the progress of the complaint and for a larger usage scheme. Sensitivity and specificity of the converse rule are 95% and 98% relative. The process is properly analyzed in the structural form likely region, entropy and kurtosis of the semblance.

The results using AHE image enhancement are used as input to the binary thresholding method to cluster the different thresholding portions in the retinal image. Using morphological operations the different [exudates] texture based portion is segmented and feed as input to GLCM method. The GLCM successfully extracts the features from segmented image. According to the feature, the values of the normal and abnormal images are compared with data base images. From the comparison the TP, TN, FP, FN and sensitivity, Specificity values are calculated to check the performance of the automatic exudates detection method. All the stage wise results for the flow diagram [Fig.2] is shown in the following Table-1.

From Table-1, it is clear and can understand that the level by level experiment result is obtained using the proposed approach is given. The following Table-1 consists of three columns and four rows where the first row and the third row denotes the label of the image and the second and the fourth row shows the obtained output. In the second row, first column shows the input image, the second column shows the color space conversion from RGB to HIS, and the third column denotes the gray scale image whereas the image processing results are more accurate in gray color space. Similarly, in the fourth row, the first column denotes the noise removed image using median filter, second column denotes the enhanced image using AHE algorithm and the third column denotes the detected exudates. In this paper, the approach says that the detected exudate is hard exudates.

Table-1: Results Obtained by the proposed approach

Input Image	HIS Image	Gray Scale Image
		
Noise Removed Image Using Medial Filter	Enhanced Image uses AHE	Detected Exudates
		

The exudates are detected from diabetic retinal images using TS approach is shown as images in Table-1. To evaluate the performance of the proposed approach a test data set and a training data set were taken from MESSIDOR.

Data set

To verify the performance of the proposed approach, there are two data sets are taken to experiment and they are DIARETDB-Version-1 and MESSIDOR. The initial experiment is done on DIARETDB database and the results are given below. There are 200 images taken in the database, out of that 150 images are abnormal images having exudates and 50 images are normal images. According to this data collection, the proposed approach is experimented and the relevant result is given in Table-2.

From the Table-2 it, can understand that out of 50 normal images there are 48 images are identified as normal and out of 150, there are 147 images are correctly identified as abnormal images. Similarly, there are 2 images are incorrectly identified in normal and 3 images are in-identified in abnormal database.

Table-2: Experiment Results of DIARETDB Database

Data Base Image		Correctly Identified		In Correctly Identified	
Normal	**Abnormal**	**Normal**	**Abnormal**	**Normal**	**Abnormal**
50	150	48	147	2	3

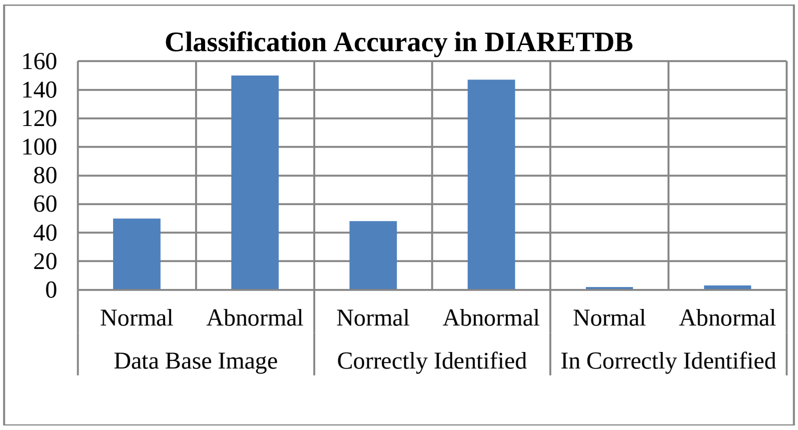


Fig.5: Classification Accuracy in DIARETDB

The performance evaluation of the proposed approach is also represented in graph form and it is depicted in Figure-5. The performance of the proposed approach can also be measured in metrics like TPR, FPR – [True Positive Rate, False Positive Rate].

$$\boldsymbol{TPR = \frac{Number\ of\ images\ detected\ and\ classified\ correctly}{Total\ Number\ of\ Images\ in\ particualr\ class}}$$

$$\boldsymbol{FPR = \frac{Number\ of\ images\ detected\ and\ classified\ Not\ Correctly}{Total\ number\ of\ Images\ in\ particular\ class}}$$

$$\boldsymbol{TPR = \frac{150+50}{48+147} = \frac{200}{195} = 97.5\%}$$

$$\boldsymbol{FPR = \frac{2+3}{200} = \frac{5}{200} = 2.5\%}$$

MESSIDOR database is taken to experiment the proposed approach and it is having four sets of images. Totally 400 images are available in the four sets, were 230 images exhibited DR condition. This database contains images occupied with both dilated and un-dilated pupils. This paper initially concentrates on developing and testing a detection procedure on the database. And the performance of the proposed approach is evaluated.

Table-3.Distribution of Training and Testing Data.

DR-Set	Number of images available in each data set	Testing of the probe Image
Set 0	70	70
Set 1	18	9
Set 2	30	39
Set 3	70	70

Table-3.Shows the distribution of images used in the training and testing sets and Table-4. Shows the percentage of images correctly classified using the best sensitivity/specificity.

Table-4. Abnormal Images Correctly Classified in Each Set

Set	Number of images available in each set	Number of images correctly classified	Correctly classified images in percentage
Set 3	70	68	97%
Set 2	18	15	83%
Set 1	30	26	86%
Total	118	109	92%

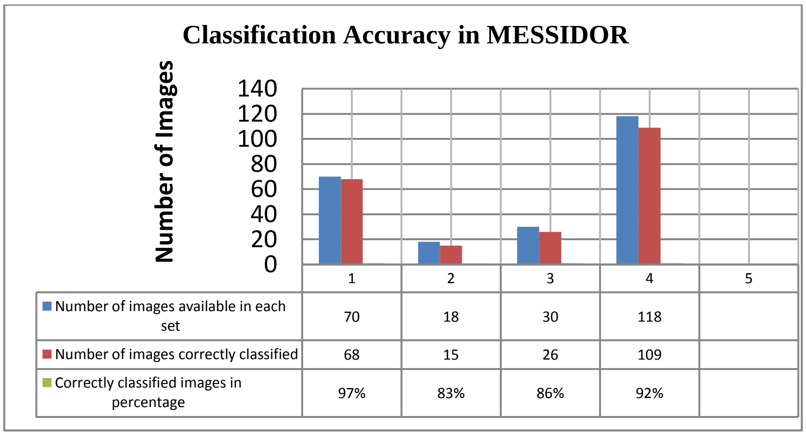


Fig.6: Classification Accuracy in MESSIDOR Database

From table-3, Table-4 and Fig.6, the performance of the proposed approach can understand that 97% of the images are classified correctly in set-1, 83% of the images are classified correctly in set-2, 86% of the images are classified correctly in set-3 and finally 92% of the images are classified correctly in set-4. From this overall performance of the proposed approach can be calculated as 89.5% in MESSIDOR database. Similarly, in DIARETDB, the performance of the proposed approach 97.5%. Hence the proposed approach is better.
The advantage of this proposed approach is easily usable, and it is applicable for low as well as high contrast based image. Also the time taken for the proposed approach execution is less.

The limitation of this approach is, only the exudates are detected from the retinal image. The abnormality of the retinal images can also obtained by verifying the optic disc, blood vessels, hemorrhages, and Microaneurysms. In future, this proposed extended and is applied to detect and verify the other causes in the retinal image.

4. Conclusion

Overall, the simulation outputs show that preprocessing, Image enhancement, Tumor segmentation, Feature extraction and classification together provide automatic exudate detection on any image. This proposed approach basically motivates to help ophthalmologists in DRFI screening process to detect and decide the conditions faster and more easily. This result can also be extended with checking other DR, causes like hemorrhages, etc. This paper provides more accuracy in exudate detection and classification than the existing approaches.

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