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Classification of Diabetic Retinopathy Severity Levels of Transformed images using K-means and Thresholding method

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Abstract: ***Diabetic Retinopathy is one of the major eye complications which occurs because of diabetes. The main reason behind this disease is damage to the blood vessels and due to which lack of oxygen supply in retina. This paper is an extension work of the previously done This paper categorizes the severity levels of diabetic retinopathy by using clustering approach and thresholding method. Two approaches are implemented in this paper Spatial Domain and Frequency Domain for calculating Feature Vectors. Clustering is applied to these Feature Vectors and classification is done by using thresholding method. The classification with encouraging results is obtained i.e. Sensitivity, Specificity and Accuracy is 94%, 100% and 97% respectively.***

Index Terms: Clustering, Diabetic Retinopathy, Frequency Domain, Spatial Domain, Thresholding.

I. INTRODUCTION

Diabetes is a chronic disease that occurs either when the pancreas does not produce enough insulin or when the body not producing enough insulin effectively [1]. There are different complications arises due to diabetes, one of the complications is Diabetic retinopathy which is a leading cause of blindness. Retina is the area which mainly covers the back of the eye. Blood vessels within the retinal tissue is damaged which causes them to leak fluid distorting the vision. There are some cases when the blood vessels get swell up and leak fluid or abnormal blood vessels grow up on the retina's surface [2].

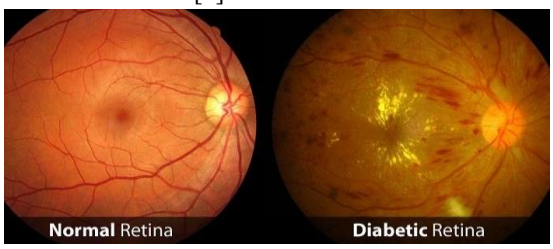

Figure 1 Normal retina vs Diabetic retina

Figure 1 presents the difference between the retina of a normal person and a diabetic person. In the normal person's retina, the image has a clear visibility of the blood vessels, macula and fovea (human eye parts), whereas in Diabetic Retina, distortions in image can be seen with various blood clots and yellow lipo-protein formation. Person with Diabetic Retinopathy usually does not experience any symptoms until the last stage. Figure 1 shows the difference between the normal and diabetic retina. In the normal retina, the image has a clear visibility of the blood vessels, macula and fovea (parts of a human eye), whereas in Diabetic Retina, there are distortions in the image with blood clots and yellow formation. The person with diabetic retinopathy may not experience any symptoms until the person reaches the severe stage [3]. The Early Treatment can reduce the blindness in people who are suffering from this condition.

II. LITERATURE REVIEW

As discussed in the previous section, Diabetic Retinopathy if not detected early can lead to blindness.

Terms which are associated with retina [8]

Micro-Aneurysms: Micro-Aneurysms is a tiny aneurysm or swelling, in the side of blood vessel. In people suffering from diabetes, micro-aneurysms are sometimes found in the retina of the eye.

Retinal Hemorrhage: Retinal Hemorrhage is a disorder of the eye where bleeding occurs on the back wall of the eye in light sensitive tissue.

Exudates: An Exudate is a fluid which gets filters from the circulatory system into areas of inflammation or lesions. This fluid can be clear or pus like.

Diabetic Retinopathy prevails through four stages [4-7]

1. Mild Non-Proliferative Retinopathy: This is the starting stage. In this stage, Micro-Aneurysms occurs, these are the swellings which are small areas of balloons in the retina's tiny blood vessels.
2. Moderate Non-Proliferative Retinopathy: This is the second stage of Non-Proliferative Diabetic Retinopathy. In this stage, there is a blockage of blood vessels which provides nutrition to the retina.
3. Severe Non-Proliferative Retinopathy: This is the final stage of non-proliferative diabetic retinopathy. In this stage, many blood vessels are blocked which leads to deprive of blood supply to the retina's several areas. These areas tend to send signals to the body for the growth of new blood vessels for the nourishment.

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4. Proliferative Retinopathy: This is the final and advanced stage of Diabetic Retinopathy, where the signals which are sent by the retina triggers the growth of new vessels which are fragile and abnormal, they tend to grow with the retina and on the surface of the clear vitreous gel which fills inside the eyes. The walls of the blood vessels are very thin and fragile and because of this, they leak blood and thus leads to severe vision loss which results into blindness.

From the Literature Review, the following methods were generally followed for the classification of diabetic retinopathy.

Pre-Processing

Pre-Processing are the methods which is applied to the images before the actual processing of the images to enhance the features and quality of the image. Median and Averaging Filter is widely used for smoothening of the image by reducing distortions in an image and suppressing the noise and preserves the sharp edges [9] [10] [11]. Contrast Limited Adaptive Histogram Equalization (CLAHE), Histogram Thresholding and Histogram Equalization are used for the improvising and enhancing the image contrast [10] [12] [13]. Region of Interest can be extracted by Resizing the image to get the Particular area [11] [14] [15] [16]. By Extracting Green Channel and Binarization by thresholding mask can be separated and removal of optic disk can be done [17].

Feature Vector Extraction

Prominent and Distinguished characteristics of an image constitutes Feature Vectors of an image. A gradient Based Technique Sobel Edge Detection is used to separate background from an image. In Diabetic Retinopathy, Sobel Edge detection is used for edge ball detection and optic disk detection respectively [18] [19]. K-Means Color Compression is used for Segmentation of Exudates [18]. Optic Edge Detection can be carried out by Histogram Thresholding followed by Smoothening and Edge Detection, division of image is done. For Classifying each pixel into blood vessel, detection of Exudates is done by using KNN [19]. Top Hat and Morphological Closing Operations I.e. Dilation and Erosion is used for detection of Exudates and Hemorrhages. Morphological Closing Operations such as Dilation and Erosion used for object's contour, eliminates small holes and fills gaps between objects [10]. Wavelet Features of the binarized DR image can be extracted by using DWT. The Output is HH, HL, LH and LL. Taking LL band for further processing and Extracting Grey Level Co-occurrence matrix features (texture features) from LL band [12]. Different Transforms such as Discrete Wavelet Transform (DWT) can be applied to get features such as Energy. While applying DWT, the image is divided to windows by applying segmentation by thresholding. Applying DWT to each window and calculating the energy and Standard Deviation. Window containing more energy will contain feature such as Optic disk [11]. Also, when comparison of different transforms is done such as Wavelet Transform, Curvelet Transform and Counterlet Transform, it is found that Best transform is Counterlet Transform as it saves time by doing Multiple Decomposition focus on improvising the texture and quality of contour of the original image [20]. Combined Approach of Haar Transform and First Order Statistical Feature can be used to detect non proliferative diabetic retinopathy [21] [17].

Classification

Classification is the process of classifying images into different categories. Fuzzy classifier with three classes normal, intermediate and severe for the classification of the images [18]. Data Mining methods such as Decision tree also provides better classification for accurately classifying the disease associated with retina [9]. By finding the Location of Haemorrhages, severity of the disease can be detected which also can be used for classification [10]. Convolutional neural network with Quadratic Kappa metric for classifying the normal and abnormal images [1]. To classify normal and abnormal images by calculating the Euclidian distance between the features, KNN Classifier is used [12] [21]. KNN with Gaussian Mixture Model can be done for classification for good results [22]. Comparison of accuracy of different classifiers can be done to check which classifier gives the best results, SVM classifier is found to be the best classifier [19]. For Classification of images, Different Neural Network such as Multi-Layer Perceptron Neural Network, Artificial Neural Network and Feed Forward Neural Network along with sigmoidal output can be used [5] [15] [16]. For Non-Proliferative Diabetic Retinopathy lesions, K-means can be used [17].

III PROPOSED METHODOLOGY

This section presents the implemented approaches of the research work. Following is the block diagram of the proposed work which is divided into two domain Spatial Domain and Frequency domain.

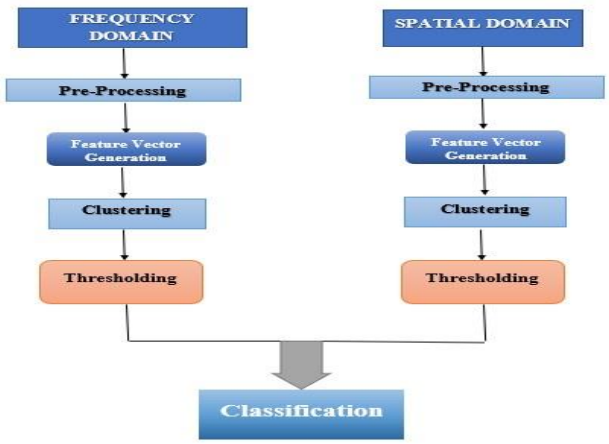

Figure 2 Block Diagram of Proposed Method

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Figure 2 shows the Block Diagram of the overall structure of the system is given which is detailed below.
The System is divided into two phases
A. Frequency Domain
B. Spatial Domain

A. Frequency Domain

a. Collection of Database and Pre-Processing

The Proposed Work is conducted using the DIARETDB1 database which is available online. This database is open source containing 89 fundus images and their respective ground truth images which have the findings of defects of each image by using some efficient algorithms. Of the 89 images, 5 images are normal, 84 are abnormal containing at least micro-aneurysms.
Pre-Processing
All the fundus images of size 1500*1152 are cropped to 1024*1024 pixels, only extracting the Region of Interest (ROI).

b. Feature Vector Generation

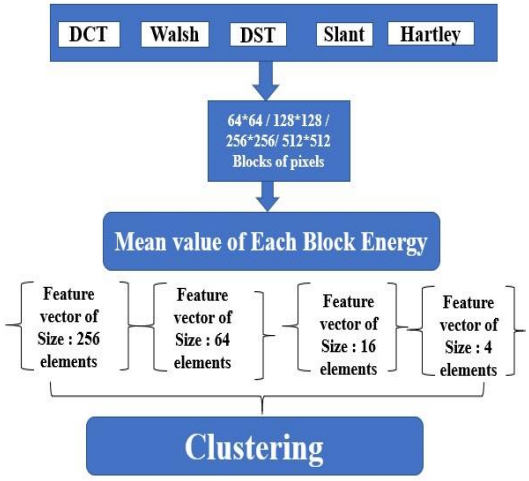

Figure 3 Steps followed for Feature Vector Generation for frequency domain

Figure 3 depicts the steps followed in frequency domain for feature vector generation. Dividing each image into 128*128 blocks of pixels. Thus, the image gets divided into 8 rows and 8 columns, thus in total 64 blocks of 128*128 pixels are generated. Similarly dividing the image into 64*64 blocks of pixels, 256*256 blocks of pixels and 512*512 blocks of pixels, thus 256 blocks, 16 blocks and 4 blocks are obtained respectively. Extracted a non-overlapping block from each block size and applying the transforms such as DCT, DST, Walsh-Hadamard, Slant and Hartley separately on a block and made all the negative values to zero, Calculating the energy by using the equation (1) and (2) given below.

- $E=\Sigma P^2$ ----------(1)
- Total $E=\sqrt{E}$ ------- (2)

where E=Energy
P=Value of the Pixels
Total E: Total Energy

The Total Energy obtained from each block is taken and mean of every block combines to form feature vector of an image of respective transforms. Similarly Feature Vector of every image with every block size and every transform is taken. The Feature Vector Database of each transform is given to the clustering step.

c. Clustering

Feature Vector Database is given to clustering methods of K-means and K-medoids clustering. All the Energy Level of same range is grouped under one cluster. Clustering is done for three clusters, for different block sizes of pixels such as 64*64, 256*256 and 512*512.

d. Performance Evaluation

Performance Evaluation is done in two ways

i. Subjective Analysis
ii. Objective Analysis

In Subjective Analysis, we have visually analyzed the ground truth images under same cluster and check for the concentration of the Energy Levels. These Energy levels are divided into three ranges i.e. Low, Medium and High based on the area and severity of concentration of white patches(defects) by manually looking into the image. In Each Cluster, the number of Low, Medium and High is counted to check which cluster have maximum Higher, Medium and Lower Concentration values.
In Objective Analysis, ground truth images are pre-processed by taking the region of interest and energy value is calculated of every image of each severity categorization.
Both the Analysis were compared to see if there is any cluster having a particular severity concentration.

e. Thresholding

From all the cluster, Low, Medium and High values of clusters is identified and taking the mean value of clusters group, threshold value is calculated of every range i.e. Low, Medium and High.

B. Spatial Domain

a. Collection of Database and Pre-Processing

The Image Acquisition and Pre-processing step is same as the Image Acquisition and Pre-processing step in frequency domain.

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b. Feature Vector Extraction

The Calculation of Feature Vector is different in Spatial domain which can be detailed in the diagram given below

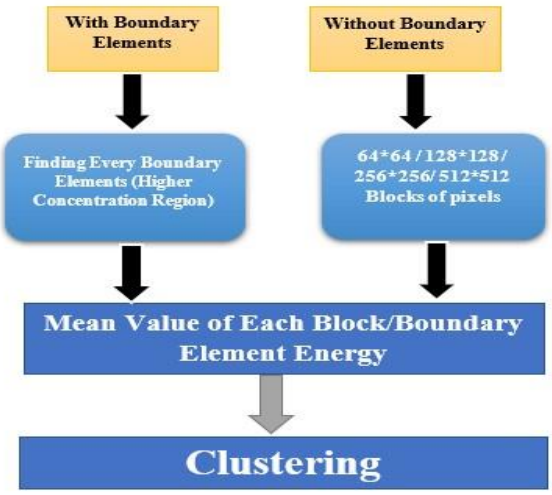

Figure 4 Steps followed for Feature Vector Generation for spatial domain

As shown in Figure 4, In Spatial Domain, we have implemented two approaches

i Spatial domain with boundary area of the high concentration region.

ii Spatial domain considering the whole image.

i. Spatial Domain with boundary area of the high concentration region:

In this step, Ground Truth Images are taken. The boundary of the patches (higher concentration area) in the ground truth images are used to get the Feature vector of the images. Energy of the Higher concentration area is taken by using the Previous equation (1) and (2) used in the Energy calculation of frequency domain. Average of Energy values are taken.

ii. Spatial Domain considering the whole image

Without considering only the boundary elements, the whole image is taken into consideration. The energy is calculated by using different block sizes and stored in feature vector database.

c. Clustering

After the calculation of Feature Vector Database of Spatial Domain, the values are then given to Clustering to form different clusters using K-means and K-medoids clustering. All the Energy Level of same range group under one cluster. Clustering is done for 10 Iterations.

d. Performance Evaluation

Performance Evaluation is the same steps followed in the frequency domain of subjective and objective analysis

e. Thresholding

From these clusters, Low Medium and High values of clusters can be identified and taking the mean values of those group of clusters we get the threshold values of Low, Medium and High.

Classification based on thresholding

Classification stage is common for both frequency domain and Spatial domain.

After the calculation of Feature Vector Database, of all the Frequency domain and Spatial domain methods, To Classify the image, we have done two Classification. Classification by calculating overall threshold values of particular severity and Classification by divided the thresholding into three ranges low, medium and high values to see how well the classification is done.

Classification is done based on the threshold values obtained from the clusters of Different Energy Values of Frequency and Spatial Domain.

Table 1 Table describing the threshold values of different transforms of different severity level.

	Microaneurysm	Hemorrhage	Hard exudate	Soft exudate
Spatial without boundary	5576.51	14635.73	14894.27	3362.69
DCT	4861.57	12749.55	13499.78	2765.39
DST	41597.41	110348	113703.9	25220.34
Walsh	430.22	1141.71	1217.8	248.764
Slant	5479.88	14504.61	14738.76	3163.03
Hartley	5479.88	14504.61	14738.76	3163.03
Spatial with boundary	4000	5570	5170	5811

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Table 2 Table describing the threshold values of Low, Medium and High of different transforms of different severity level.

		Threshold Values			
	Range	**Micro-aneurysms**	**Hemorrhage**	**Hard Exudates**	**Soft Exudates**
Spatial with boundary	Low	500	400	1000	7000
	Medium	11000	10000	11000	12500
	High	28000	27000	20000	25000
Spatial without boundary	Low	1230	2988	1490	590
	Medium	12150	34210	28170	6690
	High	21750	61867	65880	20040
DCT	Low	950	2980	2910	500
	Medium	9930	29970	31310	5580
	High	19380	55820	63910	17710
DST	Low	8440	20230	10810	4410
	Medium	85720	176300	212710	49565
	High	164020	382170	512310	107990
Walsh	Low	80	300	100	30
	Medium	890	2690	2300	1000
	High	1490	4220	5540	1670
Slant	Low	1100	2790	1250	180
	Medium	12563	34230	28160	6110
	High	22130	61870	65880	20030
Hartley	Low	1100	2790	1250	180
	Medium	12563	34230	28160	6110
	High	22130	61870	65880	20030

Table 1 and Table 2 shows the values of thresholds in different transforms. In Table 1, we have considered the average value of all the thresholds of different transforms whereas in Table 2, we have considered Individual threshold values for different transforms. Ground Truth Images are taken and checked for the thresholding values of different

severity levels i.e. Micro-Aneurysms, Hemorrhages, Hard Exudates and Soft Exudates. Comparing all the threshold values with the ground truth images, and training the system with all the Permutations and Combinations of the Low, Medium and High Values, Classification of Different images under different severity levels are done.

There are various conditions we have inferred from the literature survey for training an image to satisfy so that it can be grouped under a severity level. For example, If the image only contains Micro-Aneurysms as High and others Low then the image is classified as mild non-proliferative diabetic retinopathy. If the image contains Micro-Aneurysms and Hemorrhages High and else everything Low then that image can be classified as Moderate non-proliferative retinopathy. Similarly, if the hard exudates and the soft exudates are high then irrespective of any conditions the image can be classified to severe non-proliferative diabetic retinopathy.

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IV RESULTS AND DISCUSSIONS

Result is divided into two parts Frequency Domain and Spatial Domain. In Previous research paper [25], we have implemented a part of Frequency Domain, i.e. All Transforms except Slant and Hartley. There are two parts Subjective Analysis and Objective Analysis. In **Subjective Analysis**, by looking area of defects in the image manually and we have three different concentration or severity levels. Low, Medium and High. All transforms i.e. DCT, DST, Walsh-Hadamard, Slant and Hartley gives the same grouping of clusters in every transform, where Hard Exudates have the highest number of images under every clusters. The number of images is lowest under Soft Exudates and Highest in Hemorrhages. Soft Exudates < Micro-Aneurysms <Hemorrhage< Hard Exudates. In **Objective Analysis**, actual calculation of low, medium and high values is done based on the grouping by k-means clustering using Energy Values. It is Found that the maximum number of images are in Low value in every transform. After Classification by average threshold values, the results are given in table 3

Table 3 shows the overall classification of images with average thresholdinto different Severity Levels

No of images	Severity Level
45	Mild
13	Moderate
24	Severe
7	Normal

In Table 3, the classification by average thresholding is done. 45 images are classified as mild, 13 images were classified as moderate and 24 images are severe and 7 images are normal. To check which Transform gives better classification, further threshold values are divided into three ranges.

Table 4 Classification of images in each approach

	Mild	Moderate	Severe	Misclassified	Normal
Spatial with Boundary	41	16	21	7	7
Spatial without Boundary	37	11	18	7	16
DCT	46	12	11	13	7
DST	0	13	0	7	69
Walsh-Hadamard	0	5	24	7	53
Slant	46	12	12	9	10
Hartley	46	12	12	9	10

Table 3 and 4 shows the classification of images with the thresholding methods. In Table 3, Since average threshold values are taken In Table 4, the classification of images along with individual transforms with three ranges are shown where DST and Walsh-Hadamard are giving the worst results of misclassified image as 69 and 53 respectively. Table 4 shows all the values of the classification of images with different approaches implemented individually. DST and Walsh are giving the minimum results, whereas Spatial with Boundary, Slant, Walsh are giving best results.

Performance Evaluation Parameters

Sensitivity of an algorithm specifies its ability in classifying.

$$Sensitivity = \frac{TP}{TP + TN} \times 100$$

Specificity is a measure of the ability of a test to give a negative result in classifying

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$$Specificity = \frac{TN}{TN + FP} \times 100$$

Efficiency is the ability of the algorithm to classify.

$$Efficiency = \frac{TN + TP}{TP + TN + FP + FN} \times 100$$

After calculating the Performance evaluation parameters, with all the transforms of both the thresholding methods, we get the following tables.

Table 5 Table of Performance Evaluation Parameter of each approach

	Spatial Domain		Frequency Domain				
	Spatial with Boundary	Spatial without Boundary	DCT	DST	Walsh-Hadamard	Slant	Hartley
Sensitivity	93.39%	92.90%	93%	72%	85%	93.33%	93.33%
Specificity	100%	100%	100%	100%	100%	100%	100%
Efficiency	93.25%	79%	83%	20%	40%	84%	84%

Table 5 shows the Performance Evaluation Parameters of each Transforms individually, where we can see that Sensitivity is Higher in Spatial with Boundary method which comes out to be 93.39% and Worst sensitivity is 72% which is in DST. Since all the normal images were classified correctly, sensitivity comes out to be 100%. Efficiency is higher in spatial with boundary method which comes out to be 93.25% and lower in DST which is 20%.

Table 6 Performance Evaluation Parameters of System when Average Threshold is taken

Sensitivity	94%
Specificity	100%
Efficiency	97.7%

Table 6 shows performance evaluation parameter of the system if overall thresholding is considered i.e. by taking the average of all threshold values and classifying with the average threshold

Since DST and Walsh are not giving good results, we have neglected them for this result.

We have compared our results with a previous implemented research paper [22] which is detailed in Table 7. Where KNN method is used for classification. The Database they are using is DIARETDB0 and DIARETDB1. Since they have used two database combinedly the efficiency of the classification is better. They have used Spatial domain methods for getting the Segmentation and then applied Haar wavelet to get the features. While in our proposed system, we have implemented frequency as well as Spatial domain for getting feature vector to compare which method is getting good results

Table 7 Comparison of Performance Evaluation Parameters of System

	Our Method	Existing Method
Sensitivity	94%	80%
Specificity	100%	75%
Efficiency	97.7%	75%

V CONCLUSION

Diabetic Retinopathy is a main cause of blindness. This paper presents methods based on two domains Frequency and Spatial Domain. In the previous work, we have implemented Frequency Domain partly. Feature Vector is calculated by applying different transforms to the pre-processed image, K-Means Clustering and K-Medoids Clustering is applied to the Feature vectors of the images. Algorithmic Performance is calculated by subjective and objective analysis. K-means Clustering and K-Medoids Clustering were giving the same results. Different block sizes of 64*64, 128*128, 256*256 and 512*512 were taken which were giving the almost same results under a transform. Micro-Aneurysms have the maximum number of images in the clusters in all the three transforms i.e. DCT, DST, Walsh-Hadamard, Slant and Hartley where all the transforms are giving the same maximum concentration severity of 73%. A Certain Pattern can be seen in the severity levels in DCT, DST, Spatial without Boundary i.e. Soft Exudates < Micro-Aneurysms < Hard Exudates < Hemorrhage which is the same pattern followed by the number of images in frequency domain. DST, Walsh and Spatial with boundary are giving slightly different result. DST is giving too high Energy values, Walsh is giving too low energy values and Spatial with boundary is not matching the threshold value .

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Threshold values are taken for different severity levels, and the images are tried to train according to the threshold values.

Further improvement is done by taking the threshold values under clustering and further dividing the threshold values in three ranges Low, Medium and High. By taking these ranges further training is done to the system with the three ranges. The images are classified according to the training of the threshold values to the images.

Average thresholding of all the approaches and Individual Threshold of each approach is taken separately to check the performance evaluation parameters. In Individual Thresholding Method, DST and Walsh are not giving encouraging results. Spatial with boundary elements and Slant and Hartley are giving the best results of 93.24%, 84% and 84% respectively. When comparing between Spatial and Frequency domain, Spatial Domain gives high efficiency results with less misclassification

Sensitivity, Specificity and Efficiency of the thresholding method is calculated which are 94%, 100% and 97%.

VI . LIMITATIONS AND FUTURE SCOPE

2 mild images were classified as normal images since the threshold values of mild and normal images have only a small difference.

Validation from the doctor is required so as to divide the fundus image into different severity levels.

The Ground Truth Images are the images which have certain algorithms applied which if found out. Then the System can be applied to different database and the efficiency can be increased.

Different Block Size can be applied with various clustering methods for checking the clustering efficiency and the threshold values.

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