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Categorization of Diabetic Retinopathy Severity Levels of transformed images using clustering approach

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***Abstract*:** Diabetic Retinopathy is a diabetic complication that affects the eyes and can lead to blindness. The main cause of this condition is the damage to the blood vessels of the light sensitive tissue at the back of the retina. This paper attempts to categorize diabetic retinopathy with its various severity levels using clustering approach. Different Transforms such as Walsh-Hadamard, DCT and DST have been applied to the pre-processed image to extract the features of the image. These extracted features are used for Clustering of those images. The algorithmic performances are measured subjectively and objectively. The normal images were very well classified and distinguishable from the database using the proposed approach.

***Keywords*—**Diabetic Retinopathy, Severity, DCT, DST, Walsh-Hadamard, Performance Evaluation.

I. INTRODUCTION

Diabetes is a chronic disease that occurs either when the pancreas does not produce enough insulin or when the body cannot effectively use the insulin it produces [1].

There are various complications of diabetes in a person's body suffering from diabetes, Diabetic Retinopathy is a complication occurring to the people suffering from diabetes and it is a leading cause of blindness. Diabetic Retinopathy occurs when there is lack of blood supply to the retina. Retina is the area which covers the back of the eye. Diabetic Retinopathy damages the blood vessels within the retinal tissue causing them to leak fluid which distorts the vision. There are cases when these blood vessels swell up which causes fluid leakage or abnormal blood vessels grow on the surface of the retina [2].

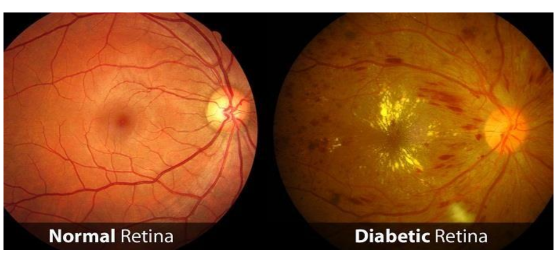

Figure 1 Normal retina vs Diabetic retina

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.

The paper is organized as follows: In Section II, the Literature Survey is done, all the methods and approaches of previous research papers are mentioned in this section. In Section III, proposed methodology of the paper is discussed, where III A explains the fundus image collection, III B explains the pre-processing methods applied to the fundus images, III C, III D and III E explains the generation of Feature Vector Database, Clustering approach and the Performance Evaluation respectively. Section IV discusses about the results of the proposed work and Section V concludes the paper.

II. LITERATURE REVIEW

As discussed in early section, Early Detection and the categorisation of the severity levels of diabetic retinopathy will help the patients to identify the seriousness of the disease.

Diabetic Retinopathy has four stages [4-7]:

1. Mild Non-proliferative Retinopathy: This is the starting stage. In this Stage, Micro aneurysms occur, they are swellings which are like small areas of balloon in the retina's tiny blood vessels.
2. Moderate Non-proliferative Retinopathy: In this stage, the blood vessels are blocked which provides nourishment to the retina.

3. Severe Non-proliferative Retinopathy: In this Stage, there are many blood vessels blocked, depriving blood supply to the several areas of retina. These areas of retina send signals to the body for the growth of new blood vessels for the nourishment.
4. Proliferative Retinopathy: The Advanced Stage where the signals which are sent by the retina for nourishment triggers the new vessels are fragile and abnormal and they grow with the retina and on the surface of the clear vitreous gel which gets filled inside eye. Usually these blood vessels do not cause any damage or vision loss. The walls of the blood vessels are very thin and fragile and due to which they leak blood and thus, there is severe vision loss which may result into blindness.

Terms associated with Retina [8]:

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

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

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

Following are the general methods which are found in the literature survey.

Pre-processing

Pre-processing are the methods which are applied to the images before actual processing of the images to enhance the features of the image.

Median filter [9] [10] and Averaging Filter [11] are methods widely used for smoothing the image, reducing distortions in an image and suppressing the noise preserving the sharp edges whereas Contrast Limited Adaptive Histogram Equalization (CLAHE) [10], Histogram Thresholding [12] and Histogram Equalization [13] is used to improve and enhance the image contrast. It is used to highlight the DR features. Laplace Edge Detection is used for brightening the foreground edges and hiding the background pixels [12]. Resizing of the image can be done to get the region of interest [14] [15] [16] [11]. Mask separation and optic disk removal is used in diabetic retinopathy as pre-processing step by extracting the green channel and performing binarization by thresholding. [17]

Feature Vector Extraction

Features are prominent characteristics of the image.

Sobel Edge Detection is a gradient based edge technique which is used to separate background from the image, In DR, it is used for detecting edge of eyeball and optic disk respectively [18] [19]. In Diabetic Retinopathy, Segmentation of exudates can be done by using K-means colour compression [18]. Histogram thresholding can be used for optic edge detection and after histogram thresholding, smoothing and edge detection, the image is divided. For classifying each pixel into vessel or not, KNN is applied for the detection of exudates [19]. Top hat and morphological closing operation are also used for the detection of exudates and haemorrhages. Morphological Closing Operations consists of Dilation and Erosion which is used for object's Contour, eliminates small holes and fuses gaps between objects [10]. Texture Features can be considered in some cases instead of Lesion in Diabetic Retinopathy [19]. Wavelet Features of the binarized DR image can be extracted by using DWT. The Output of DWT is HH, HL, LH and LL. LL band is taken for further processing and Grey Level Co-occurrence matrix features (texture feature) are extracted from LL band [12]. Eigen Values can be calculated by using Hessian Matrix by applying FFT [2]. [15] Different Transforms can be applied such as Discrete Wavelet Transform to get the Feature such as Energy. While using DWT, the images can be divided into windows by applying segmentation by thresholding and applying Discrete Wavelet Transform to each window and calculating the energy and standard deviation. Window containing more energy will contain features such as optic disk [11]. When comparing different transforms such as Wavelet Transform, Curvelet Transform and Counterlet Transform, it is found that Counterlet Transform is better as it saves time by doing multiple decomposition focus on improving texture and contour quality of the original image [20]. Combined approach of Haar and First Order Statistical Feature can be used to detect non-proliferative diabetic retinopathy lesions [21] [17].

Classification

Classification is the process of classifying images [18] Fuzzy Classifier can be used with three classes normal, intermediate and severe for the classification of the images. [9] Decision tree in data mining also provides better classification to accurately classify the disease associated with the retina. [10] Classification can also be done by finding the location of Haemorrhages to detect the severity of the disease. Convolutional neural network can be used with Quadratic Kappa Metric for classifying the normal and abnormal images [1]. KNN classifier is used to classify abnormal and normal by calculating the Euclidian distance between the features [12] [21]. KNN with Gaussian Mixture Model can also be a good method for the classification [22]. In [13] when the comparison of different classifiers is done and accuracy is checked respectively, it is found out that SVM classifier gives the best accuracy. Classifier can also classify the texture features of image, where Local Binary Pattern can be used as a good texture descriptor for the classification of normal and abnormal images [19]. Multi-Layer Perceptron Neural Network and Artificial Neural Network and Feed

Forward Neural Network can be used along with the Sigmoidal output for the classification of the images [5] [15] [16]. K-means an unsupervised learning method can also be used for classifying non-proliferative diabetic retinopathy lesions [17].

III PROPOSED METHODOLOGY

This section presents the approaches that has been implemented to carry out the research work. It can be divided into following categories:

A. Fundus Image Acquisition

For the proposed work, Database has been downloaded online from DIARETDB1 database. This database is open source. The database contains 89 fundus images and their respective ground truth images which have the defects of each image detected and categorized separately with the help of some efficient algorithms. Of the 89 images 5 images are normal and 84 abnormal i.e. containing at least micro-aneurysms. The images were taken in the Kuopio university hospital. The images were selected by the medical experts, but their distribution does not correspond to any typical population, i.e., the data is biased and no a priori information can be devised from it. Images were captured using the same 50-degree field-of-view digital fundus camera with varying imaging settings. The data correspond to a good (not necessarily typical) practical situation, where the images are comparable, and can be used to evaluate the general performance of diagnostic methods. This data set is referred to as "calibration level 1 fundus images" [23].

Figure 2(a)

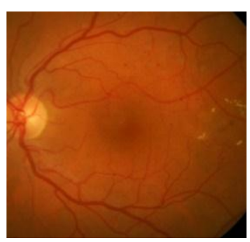

Figure 2(b)

Figure 2(a) and 2(b) are the sample fundus images of the database

B. Pre-processing

All the Fundus images of size 1500*1152 are cropped to 1024*1024 pixels extracting the Region of Interest (ROI).

C. Feature Vector Generation

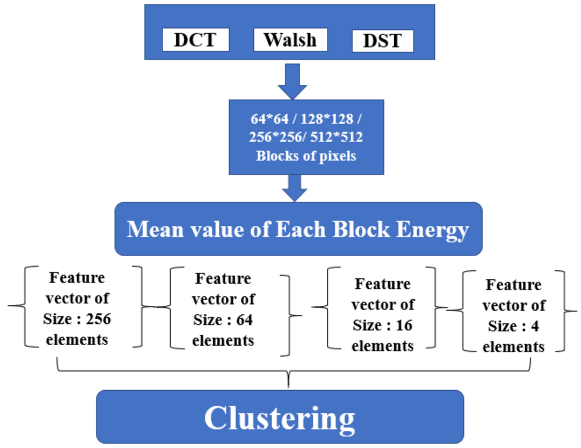

Figure 2 Steps followed for Feature Vector Generation

Figure 2 depicts the steps followed in the feature vector database 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, 512*512 blocks of pixels, thus 256 blocks, 16 blocks and 4 blocks are obtained respectively. Extracted a non-overlapping block from each and apply DCT on the block and made all the negative values to zero and calculated 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

Total Energy obtained from this formula is used as a Feature. Feature Vector is generated by taking the Total Energy from all the blocks of pixels of each image and stored in an array. Taking the mean of the Total Energy of each image leads to Feature Vector Database of DCT. Similarly, DST and Walsh Hadamard Transforms are applied to get the Feature Vector Database of DST and Walsh Hadamard respectively. The Feature Vector Database of each transforms and each block are given to the Clustering step.

A. Clustering

Clustering is applied by using K-Means on the Feature Vector Database. All the Energy Level of same range group under one cluster. Clustering is done for three, four and five groups. The same approach is applied to different block size of pixels such as 256*256, 64*64, 512*512. Different Transforms such as Walsh, DST is applied by using the same approach.

B. Performance Evaluation

Performance Evaluation is done by two ways:

a. Subjective Analysis
b. Objective Analysis

In Subjective Analysis, Visual Analysis is done. After Clustering the images falling under same group of clusters of the ground truth images are analyzed visually to check the concentration of energy in the image. The concentration of energy is divided into three levels Low, High and Medium. All the Low, Medium and High concentrations of image of each cluster are observed manually to check which cluster have more concentration of white patches [defects] in the image. The normal images can be classified with no concentration or energy level.

In Objective Analysis, Ground Truth Images are pre-processed by taking the region of interest and calculating the energy of these images of each severity level. Image which have no concentration level in all the severity level is normally has zero energy value; considered as normal image. Comparison of both the analysis is done.

IV. RESULTS AND DISCUSSIONS

Normal Images are very well classified with the proposed approach. As per the results obtained from clustering, the images were distributed along the severity levels randomly.

The Results after Subjective Analysis are as follows:

Figure 3 Chart displaying severity of images w.r.t clusters applying DCT

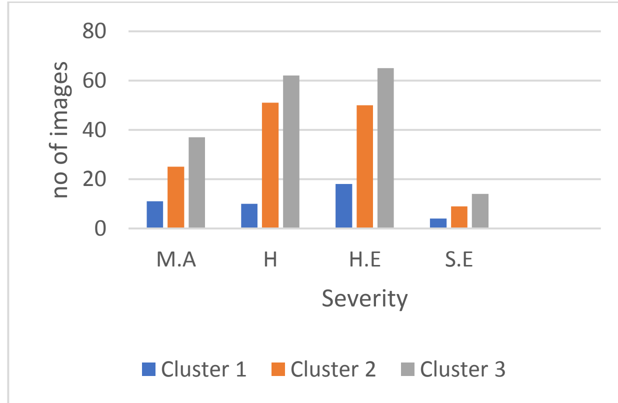

Figure 4 Chart displaying severity of images w.r.t clusters applying DST

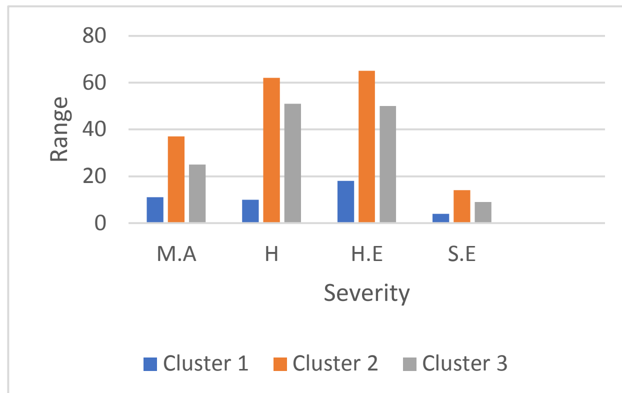

Figure 5 Chart displaying severity of images w.r.t clusters applying WALSH-HADAMARD

Figure 3, 4 and 5 depicts the bar chart showing the number of images distributed in different clusters across different severity levels. MA represents Micro-aneurysms, H represents Hemorrhages, H.E represents Hard exudates, S.E represents Soft Exudates. In all the 3 figures, after applying DCT, DST and Walsh-Hadamard is applied, it is observed that Cluster 1,2 and 3 having maximum number of images is in Hard Exudates, 2nd group having maximum number of images is in Hemorrhages and then in Micro-aneurysms and the group which have the least number of images is Soft Exudates.

The Results after Objective Analysis are as follows:

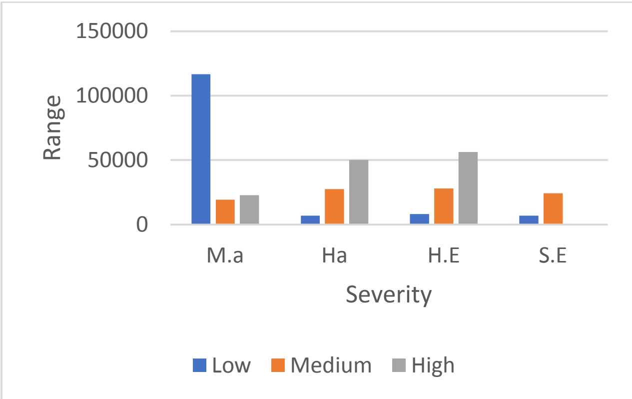

Figure 6 Chart displaying severity of images w.r.t concentration in images

Figure 6 shows the chart displaying various severity levels with respect to Low, Medium and High concentrations in the image. It can be observed that the Low values are maximum in Micro-aneurysms, Medium values are maximum in Micro-aneurysms and High Values are maximum in Hemorrhages.

In Table 1, it can be seen that, All the Block sizes are giving the same results under the same transform. Prominent severity implies maximum number of images in the respective severity. When applied DCT, the percentage of the maximum number of images which are in Hard Exudates are giving the percentage of concentration of severity as 75% which is highest among all the three transforms. The following equation calculates the severity concentration.

$$\textbf{\textit{Severity Concentration}} = \frac{\textit{Number of images having Prominent Severity}}{\textit{Total number of images}}$$

Table 1: Table displaying results of Objective Analysis

Transforms	**Block size**	**Prominent Severity**	**Cluster**	**Severity concentration**
DCT	64*64	Hard Exudates	1	75 %
	128*128	Hard Exudates	1	75 %
	256*256	Hard Exudates	1	75 %
	512*512	Hard Exudates	1	75 %
DST	64*64	Hard Exudates	3	73 %
	128*128	Hard Exudates	3	73 %
	256*256	Hard Exudates	3	73 %
	512*512	Hard Exudates	3	73 %
WALSH-HADAMARD	64*64	Hard Exudates	2	73 %
	128*128	Hard Exudates	2	73 %
	256*256	Hard Exudates	2	73 %
	512*512	Hard Exudates	2	73 %

V. CONCLUSION AND FUTURE SCOPE

Diabetic Retinopathy is considered as a leading cause of blindness. This paper proposes methods based on frequency domain to get efficient results. Feature Vector is calculated by applying different transforms to the pre-processed image, K-Means Clustering is applied to the Feature vectors of the images. Algorithmic Performance is calculated by subjective and objective analysis. In objective analysis, the normal images were very well classified. Different block sizes of 64*64, 128*128, 256*256 and 512*512 were taken which were giving the same results under a transform. Hard Exudates have the maximum number of images in the clusters in all the three transforms i.e. DCT, DST, Walsh-Hadamard. DCT is giving the best results by giving maximum concentration severity of 75% which is the highest among all the three transforms. Further Improvisation of the proposed work can be done by applying different transforms and increasing the number of clusters of K-means for categorization of the images. Different Clustering approaches can also be applied for Manual work can be automated to save time.

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