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Detection and Classification of Cotton Wool Spots in Diabetic Retinopathy

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Abstract- Diabetes is a disorder that occurs when blood sugar level increases. Further increase of blood glucose lead to serious complications and it will affect major organs of our body. Diabetes affects both of the eyes called Diabetic Retinopathy (DR). If it is treated properly eye blindness can be prevented. The main objective of this paper is to detect Cotton Wool Spots (CWS) using morphological operations and the spots are segmented using k-means segmentation. Distinct features are extracted from the segmented image to train and test the Support Vector Machine (SVM) classifier. It is used to classify the lesions and the stages of diabetic retinopathy. It is noticed that sensitivity is 95% and the specificity is 86%.

Keywords- Diabetic Retinopathy; cotton wool spots; Support Vector Machine (SVM); Morphological operations.

I. INTRODUCTION

Diabetic Retinopathy affects people in all categories and not depends on age but risk increases when age increases. Treating DR clinically is time consuming and hence automated system is preferred. An automated method of eye-testing is less time consuming and it is speed and effective. Early diagnosis and effective treatment can prevent the eye from retinal detachment and total blindness.

Diabetic Retinopathy is an eye disease that affect retina and high blood sugar causes retinal blood vessels to swell or leak blood. Insulin, a hormone is in control of bringing out blood glucose to enter cells. When it is not sufficient or ineffective it will pave the way for the advancement of diabetes. The early stage lesions of diabetic retinopathy include Microaneurysms (Ma), Haemorrhages (He) & Hard Exudates and in the moderate stage, cotton wool spots (Soft Exudates) will appear in the retina. Cotton wool spots are circular or non-circular yellowish-white fluffed up deposits in the retina and it is caused by swelling of nerve fibres (occlusion of axoplasmic flow) in the retina. The cotton wool spots are separated using k-means segmentation and classified by using SVM classifier.

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II. RELATED WORKS

The author analysed various [1] recent automated image processing algorithms to detect cotton wool spots in hypertensive retinopathy. The results were analysed in terms of sensitivity, specificity and accuracy. Finally author has concluded that feature based segmentation is the extent for improving the accuracy. The proposed method [2] focused on combined features to train deep neural network with the approach of Boltzmann machines. Author suggested this techniques because of speed and accurate. The author has reviewed [3] recent algorithms used for the detection of early stage lesions in diabetic retinopathy. The input image is pre-processed [4] to extract green channel component and quality enhancement. Fuzzy C means clustering algorithm is used to extract dark & bright points in the image. Optic disk & blood vessels are eliminated to point out Microaneurysms, Hemorrhages & Hard Exudates. Features such as color, area, size, shape and position are extracted to train & test the classifier. Efficiency is tested in the form of actual value and predicted value.

Colour fundus image is pre-processed by gray scale conversion [5] and contrast enhancement. Optic disc and the surrounding region are extracted and cotton wool spots are segmented using Fuzzy C-Means clustering technique. From the input fundus image [6] optic disc was removed and multi resolution analysis was performed to extract cotton wool spots. K-Means clustering was used to perform classification and achieved 92% accuracy. The author has taken early stage lesions of diabetic retinopathy [7]. Input fundus image is converted into gray scale image and the optic disc and blood vessels are removed through Morphological operations. Fuzzy c means clustering algorithm is used to form two different clusters corresponding to darkest point and brightest point of the input image. Decision tree classifier is used to classify all early stage lesions in diabetic retinopathy.

Malarial Retinopathy [8] affects retina of the eye. The lesions such as whitening of retina, CWS and Haemorrhages are extracted using image processing algorithms. Totally 48 features are extracted and top 5 are selected to train classifiers: Decision trees, KNN and SVM classifier. System accuracy is 97.3%. In [9] input fundus image is pre-processed by using green channel extraction & median filtering. The blood vessels are eliminated and the resultant image is moved through Gabor filter bank to detect the cotton wool spots. Optic disk and other false regions are eliminated.

The achieved value of sensitivity and PPV are noted as 82.21 % & 82.38% respectively.

In this proposed method [10] input image is pre-processed by median filtering and colour conversion. Accuracy of 96.2% is achieved by implementing Neuro Fuzzy algorithm to extract exudates part of fundus image. The input fundus image [11] is pre-processed by: Median filtering, Normalisation and Contrast enhancement process and exudates regions are segmented by two stage colour segmentation algorithm such as Gaussian smoothed histogram analysis & fuzzy c means clustering algorithm. Size, edge strength and texture features are extracted to train the multilayer perceptron neural network. These exudates detection algorithm has got accuracy in relate with both pixel and image-based resolution.

III .PROPOSED METHODOLOGY

In this proposed system, the lesion of diabetic retinopathy i.e. cotton wool spots are detected and classified by support vector machine (SVM) classifier. The block diagram of proposed method is shown in Figure 1.The input image is taken from fundus camera and it may be a low illuminated and spurious dark spots image. It should be preprocessed to make it an intelligible image. After the pre-processing step cotton wool spots are detected and enhanced by K-Means segmentation. From the segmented image, hybrid features are extracted. These features are used to train the SVM classifier. The training of classifier is done with both normal fundus image and diabetic retinopathy images. During testing stage, the test image features are compared with features used for training stage. Depend upon the closeness the classifier result will be either normal fundus image or cotton wool spots affected diabetic retinopathy image. The input fundus image is shown in Figure 2.

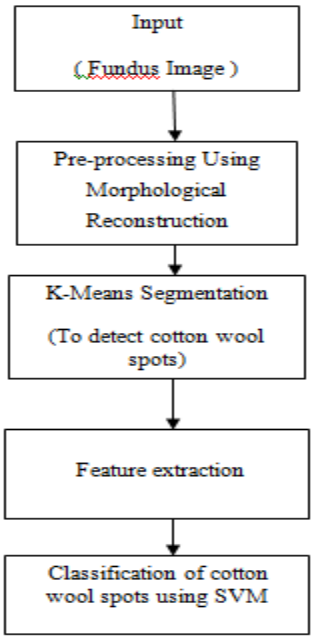

Fig. 1. Steps in the proposed algorithm

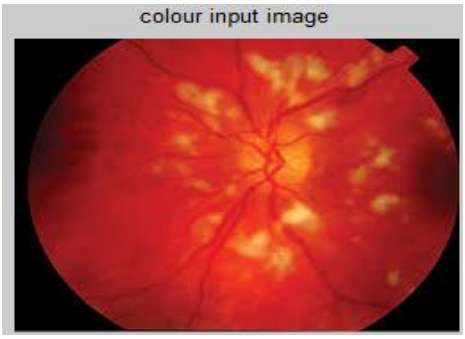

Fig. 2. Input fundus image

A. Pre-processing

In Pre-processing technique, morphological reconstruction is performed.Unlike morphological operation with structuring element in dilation and erosion,it consists of marker image and mask image.Mask image is the image that we want to emphasize.Morphological reconstruction processes the marker image based on the mask image.The steps are:1) Creating a marker image 2) Reconstructing the image morphologically.In the second step, repeated dilations of the marker image is done. This is preferred because fundus image may have many spurious red or white spots that must be filtered out to retain only faithful CWS. The output for morphological reconstruction and the gray scale conversion is shown in Figure 3 & Figure 4 respectively.

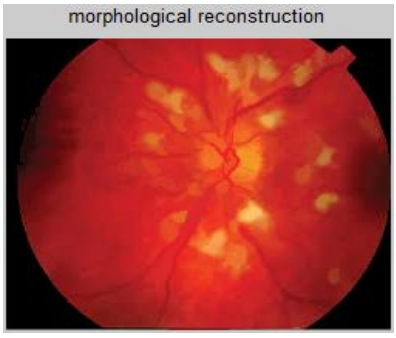

Fig. 3. Morphologically reconstructed image

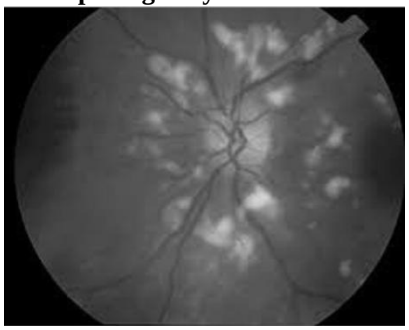

Fig. 4. Gray scale image

B. Segmentation

In this step, unsupervised segmentation is done to divide the image parts into groups. This is an iterative process to assign each pixel to one of the groups based on the pixel similarity.

The steps involved in K-means segmentation are: 1) Determining the number of clusters. 2) Estimating the centroids. 3) Pixel assignment 4) Updating the value of centroids. Each pixel will be assigned to centroid which is present nearby based on Euclidean distance and it is given by,

$$\arg\min dist\,(k_i, p)^2 \quad (1)$$

where ki is the group of centroids and p is the pixel element. In the centroid updation step, the value of each centroid will be revalued by considering the mean of all pixels which are assigned to that cluster. The algorithm will be iterated till reach the minimum sum of distances. Another advantage is, If neighbouring pixel is having high probability to lie in the same cluster, it can be made by gazing at the neighbouring pixels. The output from k-means segmentation is shown in Figure 5.

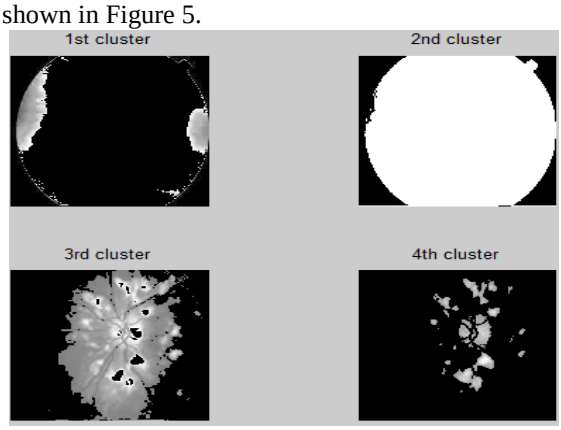

Fig.5. K-Means segmentation

C. Feature Extraction

After the cotton wool spots are segmented, histogram of gradient (HOG) features is extracted. HOG is calculated for the detection of cotton wool spots. It divides the entire image into block of pixels. For each pixel's block histogram of oriented gradients is calculated and it is followed by normalisation step. The HOG image is shown in Figure 6 and the extracted features after PCA reduction is shown in Figure 7.This is an advanced feature and it is helpful for any case of input image like image with low illumination or image with rotation. Irrespective of image rotation, it will always provide standard feature values and the feature values are independent of any distractions.

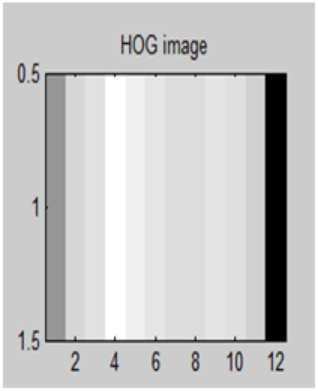

Fig. 6. HOG image

hog <12x1 double>

	1
1	0.0059
2	0.0072
3	0.0075
4	0.0081
5	0.0078
6	0.0076
7	0.0074
8	0.0074
9	0.0075
10	0.0074
11	0.0071
12	0.0027

Fig.7. HOG features

D. Classification of cotton wool spots using SVM classifier

In this classification step, SVM classifier separates the features into two classes: normal class and diabetic retinopathy class. It is a supervised learning algorithm and it is trained with 50 normal images and 60 diabetic retinopathy images. Classification is accomplished by drawing the hyperplanes. Those hyperplane which differentiates two classes very well give maximum separation margin and can be used for classification. The example of class separation using hyperplane is shown in Figure 8 and the detection of cotton wool spots is given in Figure 9 and disease severity is shown in Fig.10.Classifier's sensitivity, specificity and accuracy performance is shown in Table 1.

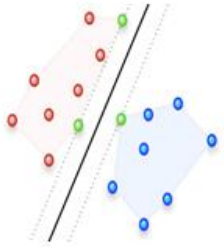

Fig.8

Fig. 9. output of classifier

Fig.10 .Disease severity

TABLE 1: SENSITIVITY, SPECIFICITY AND ACCURACY OF THE SVM CLASSIFIER

Classifier-Support Vector Machine	Input Images	*Training Stage*		*Testing Stage*		*Accuracy (%)*	*Sensitivity (%)*	*Specificity (%)*
		Total Inputs	Correct trained outputs	Total No of inputs	No of Correct Test o/p			
	Normal	50	50	75	71	95		
	DR	60	60	75	70	93	93.3	94.6

THE SVM CLASSIFIER

IV. RESULTS AND DISCUSSION

This automated system is directed at detection & classification of cotton wool spots in fundus images taken from various hospitals. Sensitivity, specificity & accuracy values are determined using the following equations.

Sensitivity = True positive/ (True positive + False negative) (2)

Specificity=True negative/(True negative+ False positive) (3)

Accuracy of the PNN Classifier is calculated using the equation which is given below:

$$\text{Accuracy} = \frac{Total\ No\ of\ correct\ test\ outputs}{Total\ No\ of\ test\ inputs} \times 100 \qquad (4)$$

The average classification accuracy is evaluated as 94% and the sensitivity & specificity values are 93.3% & 94.6% respectively. It is shown in Fig.11.

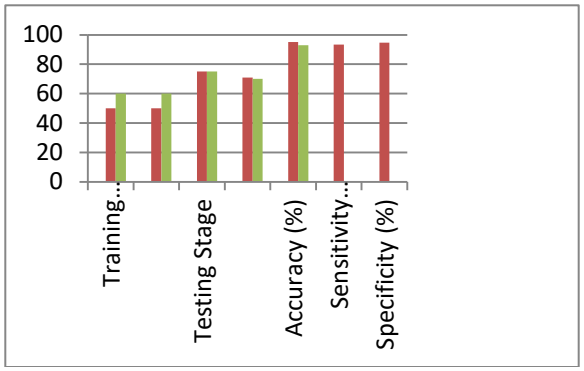

Fig. 11: Accuracy, sensitivity & specificity of SVM classifier

V. CONCLUSIONS AND FUTURE ENHANCEMENTS

This automated system is able to detect cotton wool spots in non-dilated diabetic retinopathy fundus images and also this is helpful to identify the NPDR and PDR stages of diabetic retinopathy. Histogram of oriented gradients features are extracted which are scaling, shifting, rotation and low illumination invariants. With this system patients can go for self eye screening and control of diabetes can also be achieved. Detection of Neovascularisation can be added to this system for identifying advanced stage of diabetic retinopathy

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