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An Approach for the Detection of Diabetic Maculopathy

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ABSTRACT
Diabetic Maculopathy or Macular Edema is a common complication of Diabetic Retinopathy caused by the presence of exudates in proximity with the macula. It affects the central vision and causes blindness. In this paper a method for the detection and classification of Diabetic Maculopathy from the retinal fundus image is proposed. First the Optic Disc is detected and eliminated. Then the features are extracted from segmented image and the feature vector are then classified into exudates and non-exudates using Support Vector Machine (SVM) Classifier. Finally the detection and classification of Diabetic Maculopathy is carried out. The evaluation is performed on publicly available MESSIDOR Database.

Keywords
Diabetic Maculopathy, Optic Disc, Feature Extraction, Exudates, Macula

I. Introduction

Diabetes is the one of the most common diseases due to the lack of insulin which causes high blood sugar in humans. Diabetic Retinopathy (DR) is a condition caused by affected retina due to the long term diabetes. In this condition retinal blood vessels will leak and ultimately causes the blindness. The percentage of diabetic patients is very high in almost every region in the world especially in industrialized areas. This makes high possibility of DR sufferers.

DR has several stages such as nonproliferative DR (NPDR), proliferative DR (PDR) and Maculopathy or Macular Edema. NPDR is known as background DR whereas PDR and Maculopathy are advanced stages of DR [1]. Exudates are one of the signs of retinopathy that occur in Diabetic patients. These consist of Hard Exudates and cotton wool spots (CWS). Hard exudates are yellowish deposits of protein and CWS are soft exudates which are white and fluffy lesions in the retina. In Diabetic Maculopathy patient's macula is surrounded by the exudates. The main parts of human retina along with the exudates are shown in Figure 1.

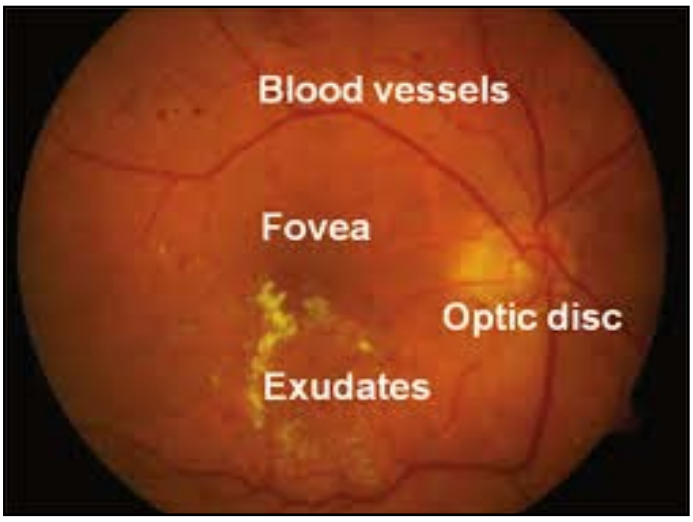

Fig.1 : Components of human retina with exudates

In Diabetic Maculopathy exudates are present near or on the macula. The central portion of the retina which is dark and rich in cones is known as macula [1].Fovea is in the center of the macula. There are two types of macular edema namely clinically significant macular edema (CSME) and non clinically significant macular edema (non-CSME).

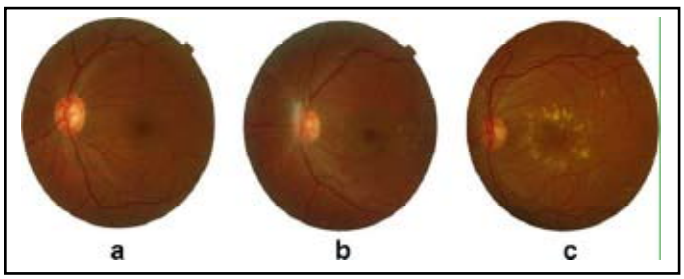

Fig.2 : a) Healthy retinal image, b) Non-CSME, c) CSME.

II. Literature Review

Main cause for Diabetic maculopathy is presence of exudates near or on the macular region. Alireza Osareh et al [2] proposed a system for the automatic recognition of exudative maculopathy. In this method exudates were used as the characteristic feature. Segmentation of color retinal image into homogenous regions is done by using Fuzzy C-Means clustering and classification is made by using neural network. In [3] automatic grading of diabetic maculopathy severity levels is presented. Based on optical disc diameter macular region is divided and retinal image can be classified as normal, non-CSME and CSME.Exudates detection through watershed transform fovea localization by pixels with minimum value and the classification of Macular Endema in digital fundus images is performed in [4].

K. Sai. Deepak et al [5] presented a paper for the automatic assessment of macular edema from color retinal images. Here the smearing patterns were used to represent the image since these contains the much information about the scene. An efficient integrated approach for the detection of exudates and diabetic maculopathy in colour fundus images [6] made use of k-means algorithm for the segmentation, SVM is used for the exudates/ non exudates classification, Bottom hat transform and Top hat transform were applied for detecting the diabetic maculopathy. By considering GLCM parameters as features and using adaptive neuro fuzzy interference system images were classified as normal, mild, moderate and severe [7].

Exudates are among the preliminary signs of diabetic maculopathy, a major cause of vision loss in diabetic patients. Early detection of exudates could improve patient's chances to avoid blindness. Using Echo state neural network hard and soft exudates were detected in [8] and segmentation is done through contextual clustering. Machine learning approach to automatic exudates detection in

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retinal images from diabetic patients [9] is presented by Akara Sopharaka et al. Naive Bayes and SVM classifier were used for the Exudates classification.FCM clustering and morphological reconstruction are used for the segmentation in[10] for the exudates detection but here some incorrect exudates detection was occurred. Exudates detection in retinal images using back propagation neural network is proposed in[11].For the feature selection two filter approaches namely Gain ratio and Correlation based feature selection are used. Morphological closing and enhancement for the exudate detection is used in [12] and classification was done through Gaussian Mixture Model.

Detection of the macula is the most important step for the treatment of maculopathy, if detected earlier it can be treated by laser. N. M. Tan et al [13] presented a technique for macula detection. Macula is located using the morphological properties of the optic disc, the distance between the optic disc and the macula, and the orientation of the optic disc. A line operator is used for the automatic detection of macula in [8].In this method Orientation of the line segment with the minimum/maximum variation has specific patterns that indicate the position of the macula efficiently. Automated system for macula detection in digital retinal images [9] presents detection of the macula based on blood vessel enhancement and thresholding.

T. Ashok Kumar et al in [10] used bit plane composition and mathematical morphology for the detection of macula. This method works well even the image is low contrast one.

III. Proposed Methodology

Early detection of signs of Maculopathy can prevent the patient's vision loss therefore it is important to develop a system for retinal diseases. This paper presents a method for the classification of Maculopathy that can prevent sudden vision loss. Proposed system consists of preprocessing, optic disc detection, exudates detection, macula detection and classification of Diabetic Maculopathy. Figure 3 shows the block diagram of the proposed method.

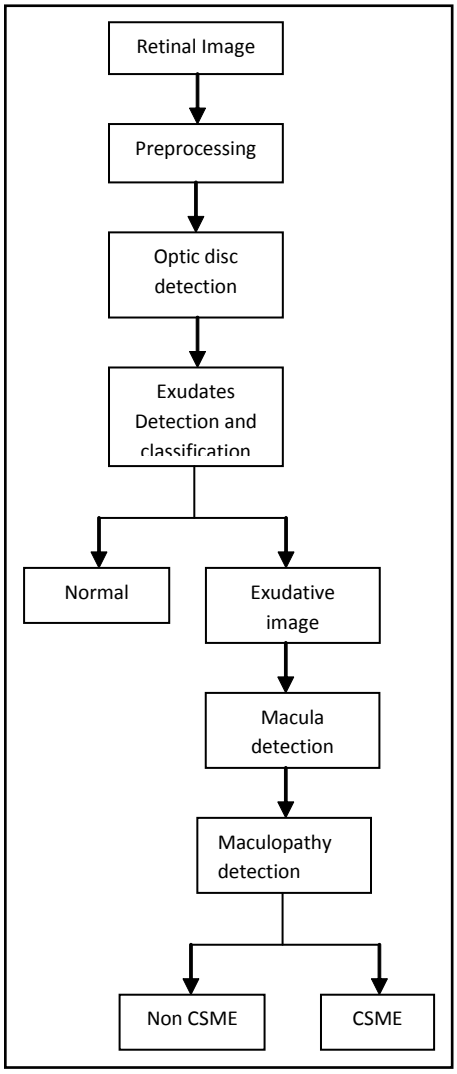

Fig.3 : Block diagram of the proposed method

A. Preprocessing

The MESSIDOR images are used as input retinal images which are first preprocessed for the further processing. Input RGB image is converted to HIS image, and then the intensity channel is extracted. Median filtering is applied on intensity channel to remove the noise. Contrast Limited Adaptive Histogram Equalization (CLAHE) is applied to enhance the image. Histogram equalized intensity channel is combined with Hue and Saturation then the image is converted back to the original RGB color space.

B. Optic Disc Detection and Elimination

Optic Disc (OD) is a light yellow region or bright region and its shape is circular or little oval. It has similar appearance of exudates, so it is important to eliminate the OD region to avoid the detection of the false positives. Green channel is selected and the morphological operations are performed

Finally optic disc is detected and eliminated as shown in the Figure 4.

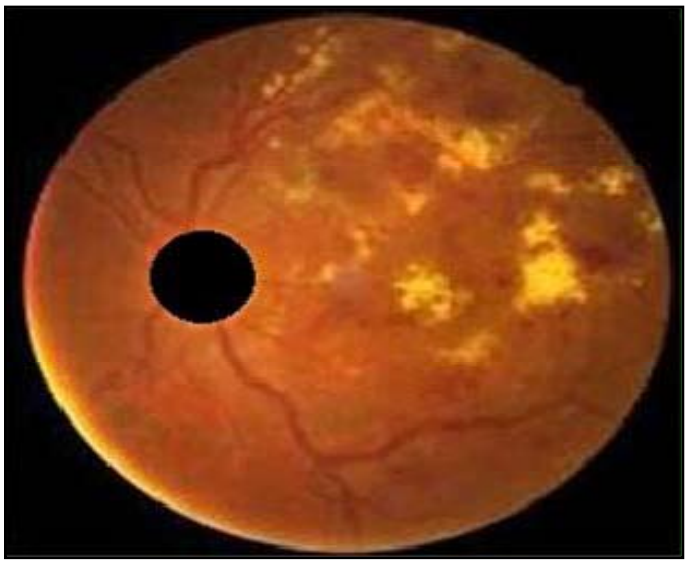

Fig.4 : Optic Disc detection and elimination

C. Exudates Detection and Classification

Optic Disc eliminated image is used for the detection of the exudates. Fuzzy C-means (FCM) clustering is used to segment the exudates region.

1. Segmentation using FCM

FCM clustering [18,19,20] is an overlapping clustering algorithm, where each point may belong to two or more clusters with different degrees of membership. In this case, data will be associated to an appropriate membership value. It is based on minimization of the following objective function.

$$J = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^2 \left||x_i - c_j\right||^2 \quad (1)$$

$J = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^2 \left||x_i - c_j$Where N is the number of features, C is the number of classes, u_{ij} is the degree of membership of x_j in the cluster j, x_i is the i^{th} of d-dimensional measured data, c_j is the d dimension center of the cluster, and ||*|| is the norm expressing the similarity between any measured data and the center.

Fuzzy clustering is carried out through an iterative optimization of the objective function J, with the update of membership u_{ij} and the cluster centers c_j.

$$u_{ij} = \frac{1}{\sum_{k=1}^{N} \left(\frac{||x_i - c_j||}{||x_i - c_{k||}}\right)^2} \quad (2)$$

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^2 x_i}{\sum_{i=1}^{N} u_{ij}^2} \quad (3)$$

This iteration will stop when the below condition is satisfied.

$$max_{ij}\left\{\left|u_{ij}^{k+1} - u_{ij}^{k}\right|\right\} < \varepsilon \quad (4)$$

Where ε indicates termination criterion and k is the maximum iteration step.

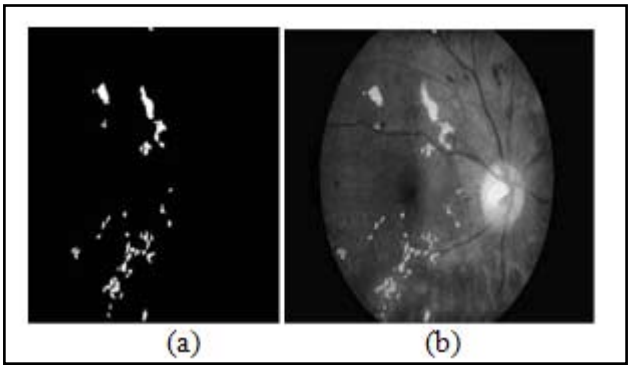

Fig.5 Exudates Detection. a) Result of FCM segmentation, b) Super imposition on the original image

To classify the segmented image into normal and exudative, the features based on colour as well as texture are extracted using Gray Level Co-occurrence Matrix (GLCM).In GLCM how often different combination of pixel brightness values occur in a pixel pair in an image are tabulated. The features used for the classification are contrast, homogeneity, entropy and variance given by Eq. (5), (6), (7) and (8). Each element (i, j) in GLCM specifies the number of times that the pixel with value i occurred horizontally adjacent to a pixel with value j. By analysing the GLCM matrix feature vectors are formed [21].

Classification of the images based on the extracted features is done using the SVM (Support Vector Machine) classifier. Then the images are classified in to normal and exudative, and the exudative images are used for the further processing.

$$Contrast = \sum_{n=0}^{N-1} n^2 \{\sum_{i=1}^{G} \sum_{j=1}^{G} P(i,j)\}, \quad |i\text{-}j|=n \quad (5)$$

$$Homogeniety = \sum_{i=0}^{G-1} \sum_{j=0}^{G-1} \frac{1}{1+(i-j)^2} P(i,j) \quad (6)$$

$$Entropy = \sum_{i=0}^{G-1} \sum_{j=0}^{G-1} P(i,j) log_2 P(i,j) \quad (7)$$

$$Variance = \sum_{i=0}^{G-1} \sum_{j=0}^{G-1} \{i + j - \mu_x - \mu_y\}^3 P(i,j) \quad (8)$$

D. Macula Detection and Maculopathy Classification

Macula is the darkest region in the macula. Based on this fact macula can be detected using morphological operations. After detecting the macula ,macular region is divided into three regions using circles of radii 1/3 of optic DD (Disc Diameter), 1DD & 2DD centered at macula[3]. Finally classification of Maculopathy is done using the following:

- If exudates are present outside 2DD then Non-CSME
- If exudates are present within 2DD then CSME.

In the case of CSME further classification is done. If exudates are present outside 1DD then mild. Presence of exudates within 1DD indicates moderate and severe case of CSME if exudates are inside 1/3DD.

IV. Conclusion

The diabetic maculopathy images are taken from MESSIDOR database. Input images are pre-processed to correct the intensity information, optic disc and exudates are detected and images are classified using SVM. Exudate presence in the macular region is checked for the detection of diabetic maculopathy. Early detection of diabetic maculopathy is very important because it enables timely treatment that can ease the burden of the disease on the patients and preventing severe vision loss and blindness. Therefore it is hoped that this system can assist the ophthalmologists to detect the signs of diabetic maculopathy in the early stage for the better treatment plan.

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