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Effectiveness of Machine Learning Techniques for Macula Edema Detection

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ABSTRACT
Macula Edema is an abnormality in the retina seen in patients with prolonged diabetes. If left untreated, it can cause vision loss. Macula Edema is characterized by swelling of macula or proximity of surrogate exudates to the fovea. Ophthalmologists use subjective approach to diagnose Macula Edema and normally perform pupil dilation which causes inconvenience to the patients. Moreover this procedure is time consuming and laborious. Instead of using this conventional method based on surrogates which are exudates, the paper has concentrated on the exclusive features that represent macula swelling. A total of 23 such features are extracted. Support Vector Machine and Random Forest (RF) classifiers are used for detection of Macula Edema for the chosen database. It was found that the RF algorithm performed better with an accuracy of 80.95 % in comparison with SVM at 71.43 %.

General Terms
Image, Macula, processing,

Keywords
Macula Edema, Support Vector Machine, Random Forest Classifier

1. INTRODUCTION
Diabetes is a group of metabolic diseases in which the affected person has high blood glucose (blood sugar) levels. The symptoms of diabetes include frequent urination (polyuria), intense thirst (polydipsia), intense hunger (polyphagia) and unusual weight loss. In the long run, this disease affects heart, eyes, kidneys and nervous system if not diagnosed and treated. The complications resulting from effect of diabetes on eye are Glaucoma, Cataracts and Diabetic Retinopathy (DR). Approximately 40% of diabetic people are affected by DR. About 10% of the DR patients have chances of completely losing the vision [1]. There are two stages in DR: Non Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR). NPDR is further classified as mild, moderate and severe. DR is a common cause of Macula Edema (ME) or Diabetic maculopathy.

Macula is situated at the centre of retina as shown in Fig1. It is dark in color and has millions of cones. It is responsible for clear, sharp and detailed vision. The fine details we see in an image are because of fovea, which is centre of macula. Macula is thinnest at centre, thickest with 3mm diameter off the centre and thinner again towards the periphery. It is 5mm in diameter and is situated at approximately two and a half disc diameter distance from Optic Disk (OD).

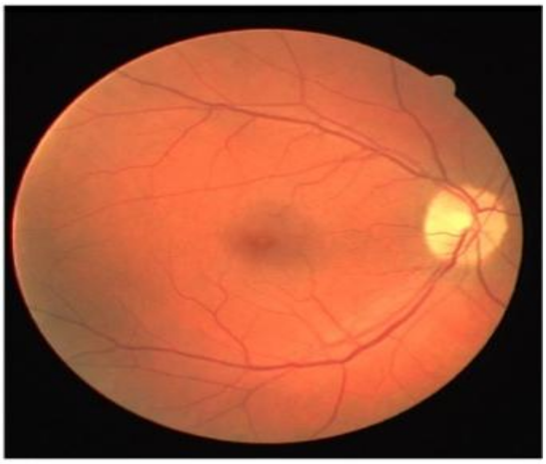

Fig 1: Retina image with macula at centre

Macula Edema (ME) causes blurred and distorted vision. Person affected with ME faces difficulty in reading. If left untreated, it can cause total vision loss. It is hard to diagnose ME in the early stages as it is painless. By proper management of Diabetes mellitus and regular eye examination, the loss of vision in diabetic patients can be prevented to a great extent. Hence for patients with diabetes, early detection of DR and Diabetic Macula Edema is essential. It can be done through Optical Funduscopy or Optical Coherence Tomography (OCT). Funduscopy is a common technique used by ophthalmologists for diagnosing the internal structure of retina and identifying the abnormalities. It gives accurate, detailed and quantifiable information about the retina. However, the number of Ophthalmologists is very less compared to the number of Diabetic patients an estimated figure being 1 per million population [2].The ratio is further poor in rural areas of India. In this scenario and with advancement in the field of medical imaging along with machine learning, artificial intelligence, an automated system for diagnosis of condition of retina is highly desirable as it helps the ophthalmologists in the quick and easy diagnosis of ME.

The automated grading of Macula Edema is a complex task as we are expected to get sufficiently good values of accuracy, sensitivity and specificity. A good value of sensitivity is to make sure that patients are correctly identified to their severity and good value of specificity is to make sure that patients not having ME are correctly identified.

In the proposed work, however, the swelling of macula represented by features is used for detection of ME. Initially preprocessing is performed which includes color conversion to green channel and grey. Template matching technique with normalized cross correlation is used for OD localization. Following this Macula is detected based on distance criteria. Finally features are extracted and fed to the classifier.

Section 2 explains the different techniques used by various researchers. Section3 explains the methodology used in the proposed work followed by results in section 4.Finally conclusion is presented in section5.

2. RELATED WORK

Many approaches for detecting macula are discussed in literature. The computer has to interpret and analyze the images of retina to automatically detect ME. There are certain parts of the eye such as optic disc which have similar intensities associated with the disease discriminating features. Hence localization and sometimes elimination of OD is needed, before extracting features to classify the stage of ME.

A good quality image is an essential requirement for proper execution of any algorithm. However, in practice the images available are not of directly usable quality. A color Fundus image also needs processing due to curved surface of retina, variable degrees of dilation of pupil, movement of optic lens and presence of other eye disease symptoms such as cataract etc. Hence preprocessing is necessary to improve the quality of image and to make further processing more effective. Different preprocessing techniques used are color conversion, filtering, shade correction, contrast enhancement, normalisation and thresholding. As green channel has highest local contrast, it can discriminate well between the feature and background [3]. Researchers have performed shade correction to take care of non-uniform illumination [4]. To enhance the contrast, Contrast Limited Adaptive histogram Equalization (CLAHE) is performed [5, 6, 7]. Normalisation is another preprocessing technique performed, wherein histogram specification is performed to bring all the input images to follow a preferred histogram [8]. J. H. Tan converted the RGB image to LUV space, performed the procedures for removal of non-uniform illumination and varying contrast and then converted back to RGB before further processing [9].

Once preprocessing is performed, the next step is OD detection. OD is a bright yellowish disc which transmits electrical impulses from retina to brain. It measures 1.5 mm to 2 mm in diameter. It is approximately one seventh of the size of entire fundus image. Different approaches for detecting OD are used such as morphological operations, edge detection, template matching, entropy based detection, Hough transform and Convolutional Neural Network (CNN). OD localization can be done using entropy. A window of 50 X 50 pixels is used and entropy is calculated. The one with maximum entropy is chosen as suitable candidate. Sobel filter is applied to detect edges. The maximum value of vertical and horizontal histogram of filtered image is used for locating OD [10]. L. Seoud et al used entropy based approach for estimating OD centre. OD consists of Blood Vessels (BV) with high directional entropy. The image with sub region of Interest is convolved with a multi scaled ring shaped matched filter. The point with minimum convolution is considered as OD centre and associating with corresponding radius gives OD [11]. Dehghani et al developed a robust method for optic disc localisation and determination of its centre. Four images of data set are used to build the template. Using a range of intensity values, a Region of Interest is considered. From each of the images, the three histograms of the individual colors are obtained, using the intensity values obtained for each image. This is used to perform template matching by moving an 80 x 80 window over the entire image to find the region with maximum correlation. Weights are assigned to each output to obtain better accuracy. The centre is detected using thresholding of 0.5 times the maximum value of correlation function [12]. Soparak et al performed morphological closing operation, followed by thresholding using Otsu algorithm for OD Detection [5]. Another approach used by Mahendran et al. is using canny edge detection to enhance the blur edges. A mask image is created with region outside the OD appearing dark. This mask is subtracted from the edge detected image thereby eliminating OD [13].To detect the location of macula different techniques such as windowing, CNN are used. M. K. Dutta et al adapted the strategy of detecting the darkest object in a predefined region of 3D x 2D size, where D is the diameter of OD on the temporal side of OD [8]. A window of size (r/2) columns of the search region is then run over all the rows to find the row with minimum intensity. Then the window of size (r/2) x (r/2) is moved over all the columns of the obtained row to find the minimum, thereby giving the centre of macula. J. Mo et al used cascaded deep residual networks for ME detection using exudates [14]. A fully convolutional residual network is used to segment the exudates to overcome inter class variation. Then region around the pixel with maximum probability is cropped and fed to a second network for classification.

3. METHODOLOGY

In the proposed work, preprocessing is performed for eliminating the non-uniform illumination and improving the contrast. OD is detected using template matching technique. Using the bounding box, the OD centre is obtained. The macula is detected based on distance criteria. The image with only macula is extracted, by considering only the portion of macula corresponding to a radius of size of OD, from centre of macula. Vital Features which are important for classification are extracted.

3.1 Preprocessing

Preprocessing is a very essential step. Pre-processing is required to correct the non-uniform illumination and improve the contrast and eliminate any noise in an image. This will help to improve the quality of image and making further processing more effective. The input images being RGB color image and green channel gives better contrast, it is chosen for further processing.

3.2 OD Detection

Initially, average filtering is performed to remove the noise. Pixel with maximum intensity is obtained after taking average of three color planes. An approximate region around this pixel is obtained using thresholding (0.75 of maximum intensity). The resultant image is converted to grey scale image and then to binary image. All objects with limit on pixel count are removed to eliminate any artefacts .The one with maximum area is considered as the region with the OD. The region with area slightly larger than this object is considered as template for further computation. The Normalized correlation between each sub image and ROI is performed. The sub image with the largest value for correlation will be the candidate containing the OD. The centre of the bounding box associated with the OD is used to get the centre of OD [15]. Figure 2 shows the result obtained for a sample image from the database.

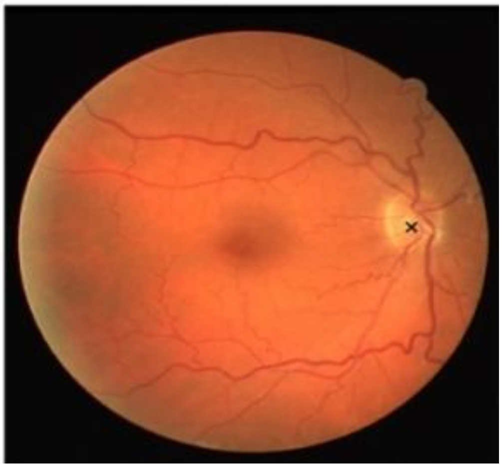

Fig 2: Image with OD centre marked

3.3 Localization of Macula

The retina images are obtained under varied conditions. There are two issues that need to be taken care of while locating the macula. Firstly, depending on whether the OD is on the right side or left side of the retina image, the macula is temporally located. Secondly, the macula may not be horizontally aligned with the OD. Based on position of OD whether right side or left side, the distance of ± d, where d is distance from OD centre to fovea is considered. To correct the issue of horizontal alignment, all points over an angle of $\pm 30^{o}$ and radius of one and half times the diameter of OD are obtained. The point with the minimum intensity is then considered as centre of macula. A circle is drawn with diameter of OD for locating the region of macula as shown in Fig.3. This is specifically taken as we are considering features for determining the macula edema. Also this reduces the computational cost as we are operating on small portion of the entire image. Then mask is created and overlaid to obtain image with only macula.

A total of 23 features are extracted which includes a combination of statistical, color and texture features. Firstly,

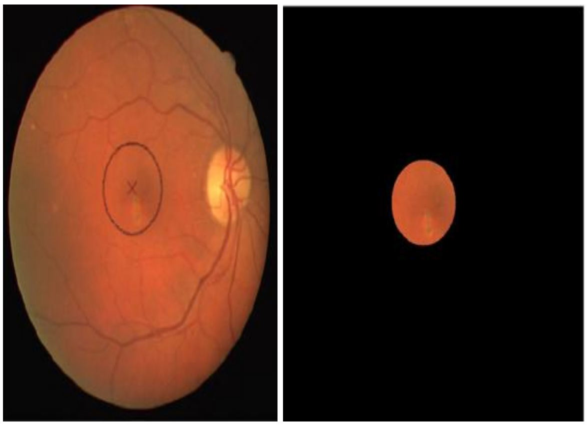

Fig 3: (a) Image with macula and centre marked (b) Image with only Macula

all the statistical features are obtained. As the detection of macula is based on swelling, color plays a very important role. All the three colours red, green and blue are taken in normal form and normalized form. As the image is 2D to reflect the spherical nature, spherical co-ordinate features are extracted. To understand the physical nature of the image, Law texture features which measure the average grey level, spots, wave, ripple and edges are obtained [16].

Two classifiers namely Support vector Machine (SVM) and Random forest algorithm are used for classification. SVM classifier maps the input space into higher dimensional feature space using a hyperplane for separating the classes. There are different types of kernels used such as radial, linear, polynomial, Gaussian and sigmoid based on how the samples are distributed. Random forest is an ensemble learning method, which combines results from various learners. During the training phase, it grows multiple trees randomly. The results of each tree is combined using voting method .The Forest uses the highest voted class for prediction.

4. RESULTS AND DISCUSSIONS

The proposed system is implemented using Matlab2016a for preprocessing, OD detection, Macula detection and extraction of features of macula. The data is analyzed using R tool. The classification methods used are supervised classifiers SVM and RF. The color fundus images are taken from a random selection of images obtained from tertiary Reference Centre of Medical College and publically available dataset [17]. A total of 102 images are provided to the system. The proposed technique can help the Ophthalmologist for better Macula Edema detection. This will help in the early treatment of the disease.

The performance of the proposed methodology is compared with ground truth as defined by the ophthalmologist as reference. The results of the proposed work for SVM and RF classifiers are quantified in terms of evaluation parameters accuracy and sensitivity as shown in Table 1. The Random Forest classifier outperforms with respect to SVM.

Table1. Performance evaluation for Macula Edema detection

Classifier	No. of test images	No. of detected images	Accuracy (%)	Sensitivity (%)
Support Vector Machine	21	15	71.43	92.3
Random Forest	21	17	80.95	92.3

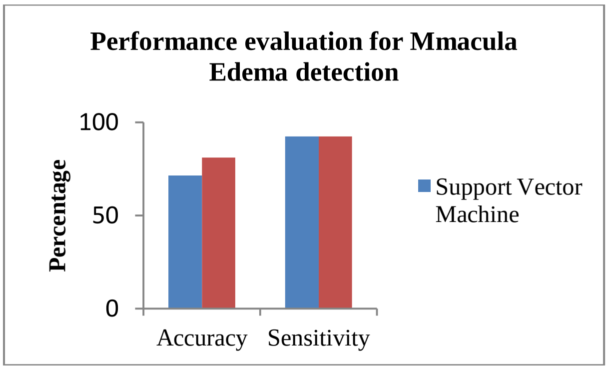

Fig 4: Graphical interpretation of the performance evaluation for Macula Edema detection

5. CONCLUSION

In the proposed work, for detecting Macula Edema the features which are indicators of swelling of macula is considered, instead of proximity of exudates to macula. First the green channel of the image is extracted, followed by OD using template matching and cross correlation. Then by distance criteria, macula is detected. Suitable features are extracted and classification performed. It was observed that RF performed better than SVM. Computational cost is reduced as only a portion of image is used for detection. Some more suitable features can be extracted to improve the performance. Further, work can be done to determine the severity of Macula Edema

6. ACKNOWLEDGEMENT

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