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Exudates Identification and Classification using Kirsch Template and K-means Clustering in Fundus Eye Images

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ABSTRACT

Diabetic retinopathy (DR) which is caused due to the damage of blood vessel present in the retina is one of the major diseases that cause vision loss in diabetic patients. Exudates are the preliminary symptoms of diabetic retinopathy; if it is not treated properly it leads to complete blindness. Exudates are nothing but a lipid effusion from blood vessels that are visible signs of retinal abnormality which occurs at an earlier state. However, manual testing and evaluation of the exudates takes much time, effort and also sometimes mistakes in identifying the disease may arise. So in this paper, we have developed a computational tool that can help to detect and classify exudates in fundus images. Initially, Kirsch template followed by morphological operations was applied on the image to detect and eliminate the optic disc. Then the proposed exudates segmentation and classification methodology works by combining different techniques like K-means clustering, connected component labeling and SVM. To test the performance of the system DIARETDB1 fundus image database is used and the results are promising with an overall classification accuracy of 84.68%

Keywords: Optic disk, fundus image, segmentation, Kirsch template, thresholding, morphological operations, k-means clustering, connected component labeling, SVM classifier.

I. INTRODUCTION

The retina converts the light signal to neural signals which reaches the brain via the optic nerve where it is processed by the visual cortex. Retina is the most important and inner most layer of an eye where every problem in an eye can be identified.

Fundus Eye Image

Retina is the most important and inner most layer of an eye where every problem in an eye can be identified. Fundus photography documents the interior lining of the eyeball, including the retina, optic disc and the macula [1]. The fundus image is obtained by looking through the pupil to image the interior of the eye. In this the images from the DIARETDB1 fundus image database [2] is used to detect and classify exudates. Fig.1 shows a fundus eye image taken from DIARETDB1 fundus image database.

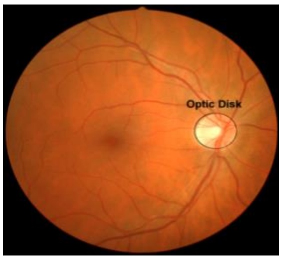

Figure 1. Fundus image of eye showing optic disk

All kinds of diabetic eye diseases can cause extreme vision loss and complete blindness. Diabetic eye diseases include diabetic macular edema, cataract, glaucoma and diabetic retinopathy.

Exudates

In that diabetic retinopathy is the major disease, which affects the retinal blood vessel causing them to bleed or leak fluid like lipid substances.

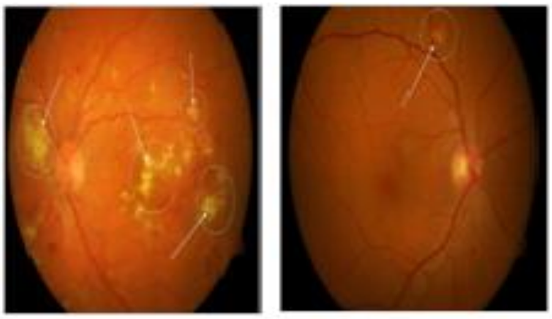

Figure 2. Hard and soft exudates

Exudates are the initial stage of diabetic retinopathy and wet macular degeneration. Exudates are formed by the leakage of lipid proteins from the blood stream into the retina through damaged blood vessels [3]. Exudates can be classified as hard exudates and soft exudates. Hard exudates are identified as bright yellow injury with many different shape and size. Soft exudates are defined as very light lesions with minimal numbers. Figure 2 shows hard and soft exudates.

Optic disc is also called as optic nerve head which is a bright circular region that enters into the eye from the brain [4] and is shown in Figure 1. The optic disc and the exudates have similar range of brightness and colour intensity. This may result in misclassification and so it is necessary to eliminate the optic disc from the image before exudates are detected and classified. Here to eliminate optic disc, Kirsch template along with morphological operation is employed and then K-means clustering and connected component labeling is used to identify the exudates. Subsequently from the detected exudate regions intensity and contextual features are extracted which are then fed to the SVM classifier to categorize the exudates as either hard or soft.

II. LITERATURE REVIEW

This section reviews literature related to optical disk and exudates segmentation and classification from fundus eye images for diagnosing diabetic retinopathy. Sub-section A gives a detailed survey on optical disk segmentation techniques seen in the literature and sub-section B elaborates on the literature related to segmentation of exudates.

A. Optical Disk Segmentation

The literature survey on optic disk segmentation is given in this sub-section. A combination of low resolution sliding band filter and a high resolution sliding band filter are used to obtain a set of pixels that most resemble the OD contour in [5]. The outliers are then eliminated by applying a smoothing algorithm. Optic disk Localization in [6] is based on principal component analysis and different techniques such as watershed, and geodesic transformation were employed for segmenting OD.

The authors in [7] arrived at the approximate boundary of the OD by using used morphological and edge detection techniques followed by the Circular Hough Transform. For this the authors made use of a voting scheme that locates a pixel on the OD contour as initial information.

Level sets were applied to detect the exact contour of OD [8-10]. The method proposed in [8] modified the original ASM to detect OD contour. Here the contour deforms to the location with minimum energy, and then segments into two groups namely edge point group and uncertain group which are further refined using local and global information.

Active contour model and color morphology in Lab Space is used by the authors in [11] to extract the OD boundary. The color morphology in Lab space is used to have homogeneous OD region and then the boundary of the OD is estimated by using level sets.

In the proposed work, to remove the influence of blood vessels in hindering the OD segmentation process, the R-channel image alone is considered and then Kirsch template is applied to detect the OD edges followed by morphological operations.

B. Segmentation and Classification of Exudate

This section deals with literature related to the segmentation and classification of exudates as hard or soft exudates. The authors in [12] have examined hard exudates (HEs) detection using k-means clustering algorithm and mathematical morphology in retinal images. In order to detect exudates the authors in [13] divided the image into 64 sub-images before applying a combination of region growing and edge detection.

The exudates detection in [14] employs mixture models to segregate the exudates form the background and then edge detection is done to detect the exudate boundary. A combination of local and global threshold was employed by the authors in [15] to segment the exudates. Three classifiers such as multilayer perceptron (MLP), radial basis function (RBF) and support vector machine (SVM) were used and SVM outperformed RBFNN and MLP in correctly detecting the exudates.

The work in [16] uses fuzzy c-means (FCM) clustering technique to detect exudates in fundus images. The experiment was conducted to find out the optimal number of clusters by varying the number of clusters from 2 to 8. The extracted features were fed to the FCM classifier and the authors achieved very high sensitivity and specificity.

III. PROPOSED METHODOLOGY

The proposed exudates detection and classification methodology is shown in Figure 3. This work consists of five steps viz., pre-processing, and segmentation of optic disk, detection of exudates, feature extraction and classification.

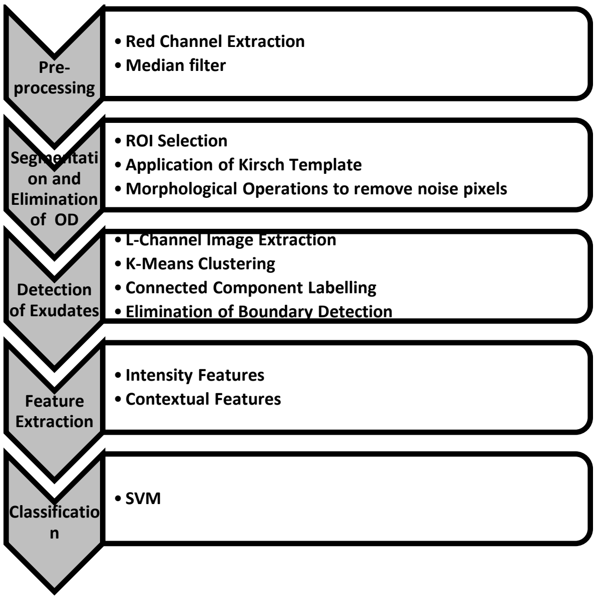

Figure 3. Overall block diagram of the proposed exudates detection and classification method

A. Pre-processing

In this work images from the DIARETDB1 fundus image database is used to detect and classify exudates. The blood vessels in an eye spread from the optic disc region and have the same brightness as that of the optic disk. This intensity similarity may hinder in the process of optic disk segmentation. Fundus image is a colour image and here the R-channel image alone is considered for optic disk elimination as the blood vessels gets suppressed and the optic disk region gets highlighted in the R-Channel image. Then a 3x3 median filter is applied to the R-Channel image to remove speckle noise if any.

B. Segmentation and Elimination of Optic Disk

The block diagram of the proposed optic disk segmentation method is shown in Figure 4. The optic region is dynamically cropped during run time and Kirsch template is applied to the cropped region to detect the edges. Kirsch proposed an edge-detection method by using a single mask which is rotated in 45^0 increments to include the 8 directions namely North, South, East, West, South West, South east, North west And North East. Then the magnitude of the edge in all the 8 directions is computed and the final edge magnitude is the maximum magnitude across all directions [17]. These

8 masks are applied to each pixel in an image and the response is calculated. The code of the edge direction is nothing but the masking sequence number of largest response.

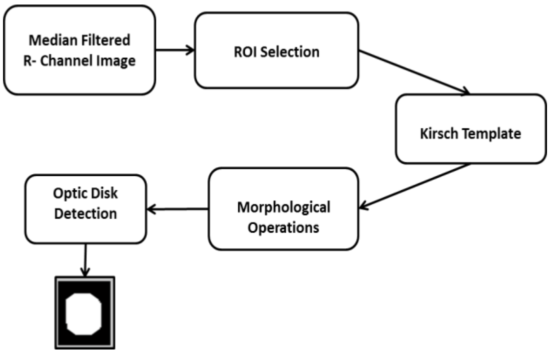

Figure 4. Optic disc segmentation

Then noisy pixels and outliers are eliminated by the use of morphological close operations. The detected optic disk pixels are then used to eliminate the optic disk in the original image. The results are given in Section 4.

C. Detection of Exudates

In this work a method to identify and classify the exudates as hard and soft exudates using K-means clustering and CCL is presented. Finally, the exudates are classified as hard and soft exudates based on features extracted using SVM classifier. The block diagram of the proposed exudates detection and classification system is shown in Figure 5.

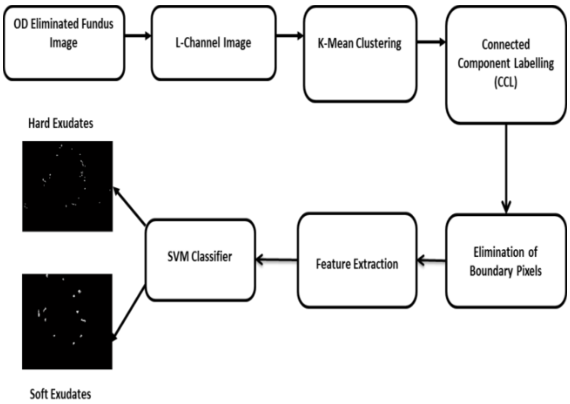

Figure 5. Block diagram of the proposed segmentation and classification system for exudates

The Optic disk eliminated retinal image is now used for detecting the exudates. In this work for detecting exudates the L* channel alone is selected because it exhibits high intensity variations between the exudates and the background image and also suppresses the blood vessels. Now K-means clustering [18] using Euclidean distance is applied to the L-Channel image to detect candidate exudate regions.

To apply a set of selection /rejection criteria to identify the likely exudate regions connected component labeling [19] is applied to the resultant clusters. Connected components labeling using four pixels connectivity labels each discrete region in the binary segmented image. To select the likely exudate region two each of the resulting connected regions are subjected to two set of rules. This helps to eliminate regions that do not strongly resemble a circumscribed mass in terms of their area and their statistical characteristics such as their pixel's intensity, higher order moments, etc.

Then the regions that lie on the boundary are eliminated by the method proposed in this work by computing the points A, B, C, D, E, and F as shown below.

Let X= m/4; Y = n/4; here m denotes the number of rows and n denotes the number of columns respectively.

A = (X, 0); B = (X*3, 0); C = (X*3, n); D = (X, n); E = (0, Y*2) and F= (m, Y*2).

All the regions that lie in the shaded region shown in the Figure 6 are not exudates and so they are eliminated before connected component labeling is applied to the resultant image. CCL is again applied to the resultant image and the obtained discrete regions are subjected to rule based classification which helps to determine the discrete regions that may be an exudate in terms of the number of pixels. The result of exudates detection is given in Section 4.

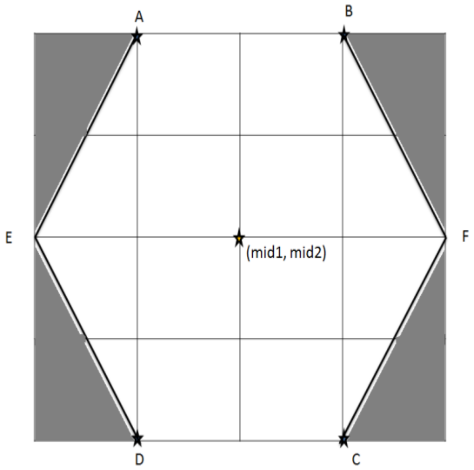

Figure 6. Proposed method for elimination of boundary pixels

D. Feature Extraction

Five intensity features such as maximum gray value ($Gray_{Max}$), minimum gray value ($Gray_{Min}$), mean gray value ($Gray_{Mean}$), median gray value ($Gray_{Median}$) and standard deviation ($Gray_{Std}$) are extracted from each candidate exudate regions. Also the number of pixels (Area) of each exudate region is taken as a feature. Totally 6 features are extracted from each exudate region.

E. Classification of Exudates

The extracted features are modeled using the SVM classifier [20] to classify the detected exudates as either hard or soft using the ground truth available in the DIARETDB1database.

IV. EXPERIMENTAL RESULTS

In this work the R-channel image alone is considered for optic disk elimination as the blood vessels gets suppressed and the optic disk region gets highlighted in the R-Channel image. Then a 3x3 median filter is applied to the R-Channel image to remove speckle noise if any.

The optic region is dynamically cropped during run time and Kirsch template is applied to the cropped region to detect the edges. This is followed by morphological close operation to remove noise pixels and outliers. The result of optic disk elimination is shown in Figure 7

To detect and classify exudates the L- channel is used in this work because it exhibits high intensity variations between the exudates and the background image and also suppresses the blood vessels. Next K-Means clustering is applied to the L* channel image which helps to combine all high intensity pixels. These pixels also include boundary pixels and connected component labeling using 8-pixel connectivity is applied to identify connected regions.

The boundary pixels are now eliminated using the proposed method and to classify the resultant exudates are either hard or soft a set of 6 features are extracted from each exudate region and support vector machine is used to classify the exudates into either hard or soft. The exudates detection and classification results are shown in Figure 8

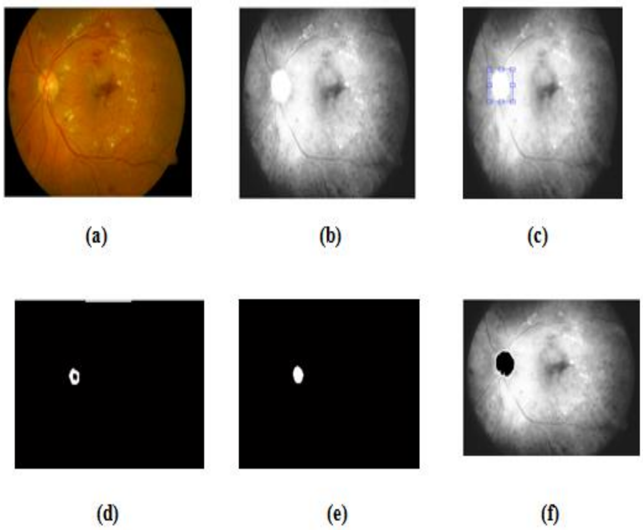

Figure 7. (a) Original image (b) Red channel image (c) ROI selection (d) OD detection (e) Morphological close operation (f) OD eliminated image

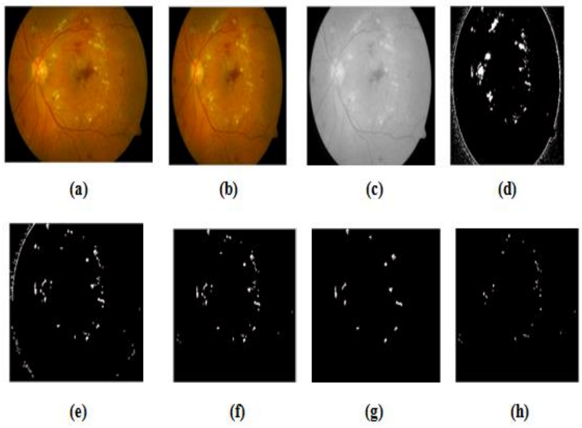

Figure 8. a) Original image (b) Resize image (c) L* channel image (d) Segment the exudates using K-Means clustering (e) CCL applied image (f) Elimination of boundary pixels using the proposed method and detection of Exudates (g) Soft exudates (h) Hard exudates.

V. PERFORMANCE EVALUATION

The performance of proposed exudates detection and classification algorithm is tested with publicly available dataset DIARETDB1. The DIARETDB1 database totally consists of 89 colour fundus images out of which 5 are normal images and the remaining 84 images contain signs of the diabetic retinopathy (DR). The experts have marked the areas related to the hard and soft exudates in the fundus images affected by DR. This ground truth information, is used in this work to calculate the performance of the proposed system.

The following performance metrics are utilized to measure the classification efficiency.

$$\text{Sensitivity(Se)} = \frac{\text{TP}}{\text{TP} + \text{FN}} ,$$

$$\text{Specificity(Sp)} = \frac{\text{TN}}{\text{TN} + \text{FP}} ,$$

$$\text{Accuracy(Acc)} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{FN} + \text{TN} + \text{EP}}$$

Here TP: the regions correctly classified as non-exudates; TN: the regions correctly classified as exudates; FP: the regions incorrectly classified as exudates; FN: the regions incorrectly classified as non-exudates. Table 1 summarizes the results of this proposed work on randomly selected 10 fundus images containing exudates.

Table 1. Performance Of The Proposed Exudates Classification System

Image	Sensitivity	Specificity	Accuracy
Image1	80.88	94.73	91.66
Image2	90.90	92.59	92.10
Image3	68.33	78.53	82.60
Image4	93.55	94.73	79.94
Image5	90.47	88.88	88.90
Image6	90.62	93.75	75.86
Image7	92.30	84.21	87.50
Image8	95.23	83.33	88.23
Image9	91.63	87.50	90.00
Image10	93.66	75.00	70.00

The performance was calculated with all the 84 fundus images affected by DR and the system gave an overall accuracy of 84.68 %, sensitivity of 88.78% and specificity of 87.33%. The results indicate that the proposed system could be employed to automatically detect and classify exudates from colour fundus images.

VI. CONCLUSION

The computer aided automatic segmentation and classification system for retinal exudates has been proposed in this work. The segmentation of exudate was essential for diabetic retinopathy (DR) severity classifications and diagnosis. This work proposed a methodology which automatically detected and segmented the exudates by eliminating the OD region from the retinal image in order to improve the performance of the proposed segmentation methodology. Further six features were extracted from the exudates region which was used to classify the exudate into either hard or soft. The proposed system achieved an average segmentation accuracy of 84.68%, with their corresponding ground truth images. False negatives and false positives are also reported. So, to improve the performance, apart from the six features considered in this work for classification, other features could also be attempted with in future.

VII. REFERENCES

[1]. Christye Sisson, Ophthalmic Imaging: Posterior Segment Imaging, Anterior Eye Photography, and Slit Lamp Biomicrography, Taylor & Francis, 2017

[2]. http://www.it.lut.fi/project/imageret/diaretdb0/

[3]. V. Esmann , K. Lundbaek, P. H. Madsen, "Types of Exudates in Diabetic Retinopathy", Journal of Internal Medicine, Vol 174, Issue 3, 1963.

[4]. M. Lalonde, M. Beaulieu and L. Gagnon, "Fast and robust optic disc detection using pyramidal decomposition and Hausdroff-based template matching",IEEE transactions on medical imaging, Vol 20, No. n, pp. 1193-1200, November, 200l.

[5]. DashtbozorgBehdad, Ana Maria Mendonc¸ a, AurelioCampilho, Optic disc segmentation using the sliding band filter, Comput. Biol. Med. 56 (2015) 1–12.

[6]. S. Morales, V. Naranjo, J. Angulo, M. Alcaniz, Automatic detection of optic disc based on PCA and mathematical morphology, IEEE Trans. Med. Imaging 32 (2013) 786–796. 46 P.S. Mittapalli, G.B. Kande / Biomedical Signal Processing and Control 24 (2016) 34–46

[7]. Aquino Arturo, Manuel Emilio Gegundez, Diego Marin, Detecting the optic disc boundary in digital fundus images using morphological, edge detection, and feature extraction techniques, IEEE Trans. Med. Imaging 29 (11) (2010) 1860–1869.

[8]. J. Xu, O. Chutatape, E. Sung, C. Zheng, P.C.T. Kuan, Optic disk feature extraction via modified deformable model technique for glaucoma analysis, Pattern Recognit. 40 (2007) 2063–2076.

[9]. F. Mendels, C. Heneghan, J.P. Thiran, Identification of the optic disk boundary in retinal images using active contours, in: Proceedings of the Irish Machine Vision and Image Processing Conference, IMVIP 1999, 1999, pp. 103–115.

[10]. D.T. Morris, C. Donnison, Identifying the neuroretinal rim boundary using dynamic contours, J. Image Vis. Comput. 17 (1999) 169–174.

[11]. KandeGiriBabu, P.V. Subbaiah, T. SatyaSavithri, Feature extraction in fundus images, J. Med. Biol. Eng. 29 (3) (2009) 122–130.

[12]. Feroui Amel et al, "Improvement of the hard exudates detection method used for computer – aided diagnosis of diabetic retinopathy", I.J.Image, Graphics and Signal Processing, DOI: 10.5815/ijigsp.2012.04.03.

[13]. H. Li and O. Chutatape, "Automated feature extraction in color retinal images by a model based approach," IEEE Trans. on Medical Engineering, vol. 51, pp. 246-254, 2004.

[14]. C. I. Sanchez, M. Garcia, A. Mayo, M. Lopez and R. Hornero, "Retinal image analysis based on mixture models to detect hard exudates," Medical Image Analysis, vol. 13, pp. 650-658, 2009.

[15]. M. Garcia, C. I. Sanchez, M. I. Lopez, D. Abasolo and R. Hornero, "Neural network based detection of hard exudates in retinal images," Computer Methods and Programs in Biomedicine, vol. 93, pp.9-19, 2009.

[16]. AkaraSopharak, BunyaritUyyanonvara, Sarah Barman proposed an "Automatic exudates detection fordiabetic retinopathy screening" doi:10.2306/scienceasia1513-1874.2009.35.080

[17]. Gudmundsson, M., E.A. El-Kwae and M.R. Kabuka,m 1998. Edge detection in medical images using a genetic algorithm, IEEE

Transactions on IEEE Transactions on Medical Imaging, 17(3): 469-474.

[18]. R. S. Biyani, B. M. Patre, "A clustering approach for exudates detection in screening of diabetic retinopathy", IEEE International Conference on Signal and Information Processing (IConSIP), 2016 DOI: 10.1109/ICONSIP.2016.7857495

[19]. Soju George and Bhailal Limbasiya, "A Review Paper On Detection And Extraction Of Blood Vessels, Microaneurysms And Exudates From Fundus Images", International Journal of Scientific & Technology Research Volume 2, Issue 11, November 2013

[20]. Thorsten Joachims. 2002. Learning to Classify Text Using Support Vector Machines: Methods, Theory and Algorithms. Kluwer Academic Publishers, Norwell, MA, USA.