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Color Retinal Image Analysis for Automated Detection and Severity of Exudates

Sarika Madhu*
M.Tech Student, Department of ECE,
Nehru College of Engineering and Research Centre,
Pampady, Thiruvilawamala, Kerala, India
shaaripillai@gmail.com

Parameshachari B D
Associate Professor, Dept. of ECE,
Nehru College of Engineering and Research Centre,
Pampady, Thiruvilawamala, Kerala, India.
parameshbkit@gmail.com

Nithin Joe
Assistant Professor, Department of ECE,
Nehru College of Engineering and Research Centre,
Pampady, Thiruvilawamala, Kerala, India.

H S DivakaraMurthy
Dean and HOD, Dept. of ECE
Nehru College of Engineering and Research Centre,
Pampady, Thiruvilawamala, Kerala, India.

Abstract— Diabetic macular edema (DME) is an advanced symptom of diabetic retinopathy and can lead to irreversible vision loss. In this paper, a two-stage methodology for the detection and classification of DME severity from color fundus images is proposed. DME detection is carried out via a supervised learning approach using the normal fundus images. A feature extraction technique is introduced to capture the global characteristics of the fundus images and discriminate the normal from DME images. Disease severity is assessed using a rotational asymmetry metric by examining the symmetry of macular region.

Keywords - abnormality detection;hard exudate;rotational symmetry;motion generation;severity checking

I. INTRODUCTION

Retinal image analysis is commonly used for the diagnosis and monitoring of diseases. Monitoring the health of the retina is important for those people with signs of diabetic retinopathy (DR). Diabetic Retinopathy is a major cause of blindness. It is mainly due to the development of abnormal new blood vessels in the retina. Digital Color fundus images are widely used by ophthalmologists for diagnosing Diabetic Retinopathy. In [1], it is estimated that the number of people with diabetes is likely to increase to 366 million by the year 2030 from 171 million at cothe turn of century. In India, there will be 79 million people with diabetes by 2030 making it the diabetic capital of the world. Although DR is not a curable disease, Laser photocoagulation can prevent major vision loss. Therefore the timely diagnosis and referral for management of diabetic retinopathy can prevent 98% of severe visual loss. DR is a complication of diabetes when high glucose levels cause fine vessels on the surface of the retina to become damaged. This can lead to severe impairment or even loss of vision. It can be treated by laser surgery if diagnosed early.

Diabetic Macular edema (DME) has for a long time been one of the most important issues in retinal pathologies, as damage to the macula has an immediate effect on central visual acuity and may substantially affect a patient's quality of life. Macular edema is the result of an accumulation of fluid in the retinal layers around the fovea Macular edema is clinically defined as retinal thickening of the macula as seen on biomicroscopy. When moderate, the thickening may be difficult to diagnose, and contact lenses with good stereoscopy, such as Centralis DirectR (Volk), or noncontact lenses of 60, 78, or 90 dpt[2] could be used. Diabetic macular edema (DME) is a common vision threatening complication of diabetic retinopathy which can be assessed by detecting exudates (a type of bright lesion) in fundus images. Hard exudates have been found to be one of the most prevalent earliest clinical signs of retinopathy.

The paper is organized as follows: Section 2 discusses the brief overview of related work. Section 3 describes the generation of motion pattern. Section 4 shows experimental results. Finally in Section 5 the conclusion and future scope is described.

II. RELATED WORK

A. Detection of Hard Exudate:

Automatic detection of hard exudates from retinal images is clinically significant. Hard exudates are associated with diabetic retinopathy and have been found to be one of the most prevalent earliest clinical signs of retinopathy.Hard Exudates (HE) appears as clusters of bright, high contrast lesions and is usually well localized. These techniques include image contrast analysis Bayesian classifiers and neural networks. Because the brightness, contrast and color of exudates vary a lot among different patients and, therefore, different photographs, these methods would not work in all the images used in clinical environment.

The edge detection yields noisy results and hence preprocessing and post-processing steps are required to reduce the large number of false candidates. The distinct bright yellow color of HE has been the motivation for using color features. Even though the use of color seems to be sufficient in principle, high variation in color witnessed in images across and within different ethnicities require a color and luminosity normalization step before detection. Initial candidate detection is performed using a fixed threshold after a background subtraction step on the green channel image.

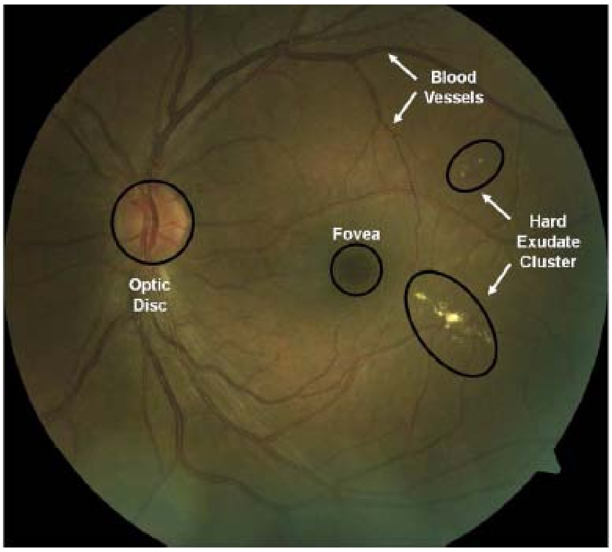

Figure 1 color fundus image with anatomical structures and lesions annotated

B. *Feature Extraction :*

By the hard exudates portion can be selected based on green channel extraction and inversion. A colored image is made up of red, green and blue components. The green channel shows the best vessel/background contrast. The red and blue channels show low contrast and are very noisy, so they are avoided. The green Channel background noise is less when compared to other channels of the RGB colored images. The green channel is inverted before ROI extraction. The vessels appear brighter than the background when inverted. By taking the input image and by resizing the image and adjusting the pixel value the image appears brighter. In order to develop a solution for automatic DME assessment, first a decision module is required to validate the presence or absence of HE in a given color fundus image. Once their presence is confirmed, a second module has to assess the macular region for measuring the risk of exhibiting DME. These sections are divided according to the above block diagram. The next section provides an overview of the earlier work carried out for detecting the presence of HE followed by an outline of the proposed methodology.

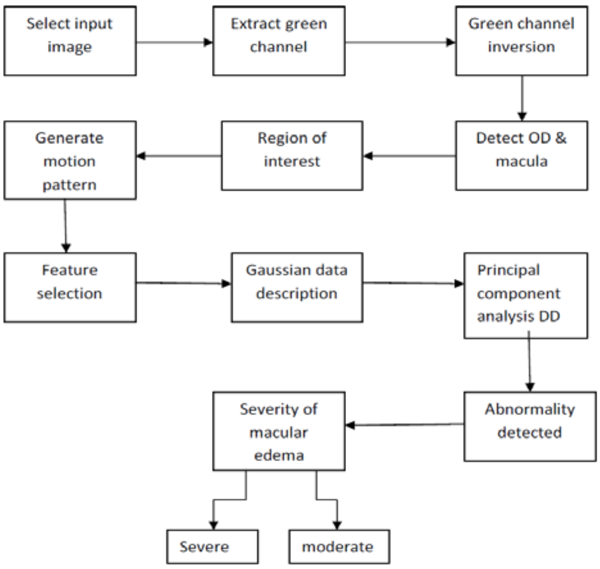

Figure 2 Generalised block diagram of localization hard exudates

C. *Rotational Symmetry of macula:*

A symmetry measure is defined as the second norm of the distance between the histograms of diametrically opposite pair of patches $P(\theta i)$ and $P(\theta i+\pi)$. Here eight angular samples were used to create eight patches (Pi) from the circular ROI was computed for every patch. Since the intensities corresponding to HE contribute mostly to the higher bins in the histogram, only the last five bins are used for measuring the symmetry. A preprocessing step was performed to eliminate any intensity bias as in[3]. A threshold on the symmetry measure is used for assessing the degree of abnormality of an image as moderate or severe risk of DME. Let *Smax* and *Smin* be the maximum and minimum symmetry values for normal images in the training set used for abnormality detection. Then the severity of a given abnormal image *Ia* is determined by comparing the symmetry measure of this image *S(Ia)* against a threshold *T* as follows:

$$\text{Severity}(Ia)= \begin{cases} \text{moderate}, & \text{If } S(Ia) \leq T \\ \text{severe} & \text{,otherwise} \end{cases} \qquad (1)$$

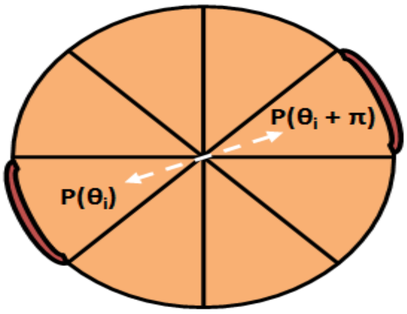

Figure 3 Illustration of using rotational symmetry of macula for describing severity of macula

III. GENERATION OF MOTION PATTERN

The creation of a motion pattern is motivated by the effect of motion on biological/computer visual system. These systems represent a scene as a set of spatially sampled (by the sensors/detectors) intensities or an image. This sampling is uniform in cameras while it is log polar in human eyes. When an object in a scene moves at a high speed, it usually leaves a smearing pattern in the captured image. Generally, the spatio-temporal changes recorded by the sensor are characteristic of the moving object [4]. In computer vision, the estimation and removal of the smear pattern, also popularly known as motion blur in images, has been an active area of research [5].

Signal aggregation at sensor locations in human eyes [6] and camera, gives rise to the smearing effect. In order to simulate this effect, we induce motion in a given image to generate a sequence of images. These are combined by applying a function to coalesce the intensities at each sensor location to give rise to a motion pattern. Let the given ROI be denoted as $I(r^*)$. A motion pattern *Imp* for *I* is derived as follows:

$$Imp(r^*) = f(Gn(I(r^*))) \qquad (2)$$

Where denotes a pixel location,*Gn* is a transformation representing the induced motion which is assumed to be rigid. Practically speaking, *Gn* generates *n* transformed images which are combined using *f* to coalesce the sampled intensities at each pixel location.

In the problem at hand, the choice of f should ideally 1)enhance the HE by increasing the extent of the smear caused by it in the motion pattern and 2) increase the homogeneity of retinal background. Accordingly, two functions namely *Mean* and *Maximum* were considered in this work. These are defined as follows:

$$Imp(mean)(r^*) = 1/n \sum_{n=0}^{N-1} R_{\theta n}(I(r^*)) \quad (3)$$

$$Imp(max)(r^*) = \max_{n=\{0...(N-1)\}} R_{\theta n}(I(r^*)) \quad (4)$$

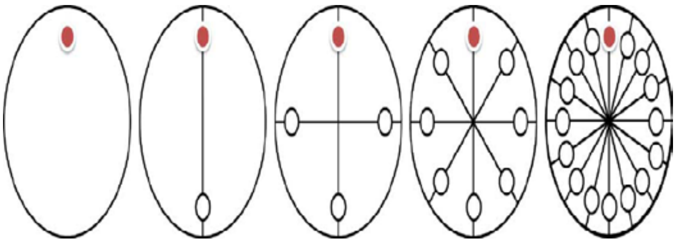

Figure 4 Graphical depiction of motion pattern generation

While the coalescing function *Mean* tries to achieve the averaging effect observed in motion blur, *Maximum* tries to exploit the fact that HE usually appear brighter than any other structures in the background at the same radial distance. The original and motion pattern images in Fig. 4 illustrate the effect of the two coalescing functions on a normal and two abnormal fundus images. It can be seen that the motion patterns are clearly distinct for these two classes.

IV. EXPERIMENTAL RESULTS

The annotations or lessions are required for both supervised and unsupervised classification schemes in order to find suitable system parameters for detection. The approach facilitates separating the normal patients from those showing disease symptoms, as practiced in DR screening. There is no need for either preprocessing the original images or post processing the results, to handle the false alarms due to variability observed across color fundus images. This is due to the proposed global features. The proposed method is shown to be effective in detecting DME for challenging cases. For the fundus image in Fig. 5(a), we can observe that HE manifest as faint lesions whereas in Fig. 5(b), faint HE can be seen over a complex background.

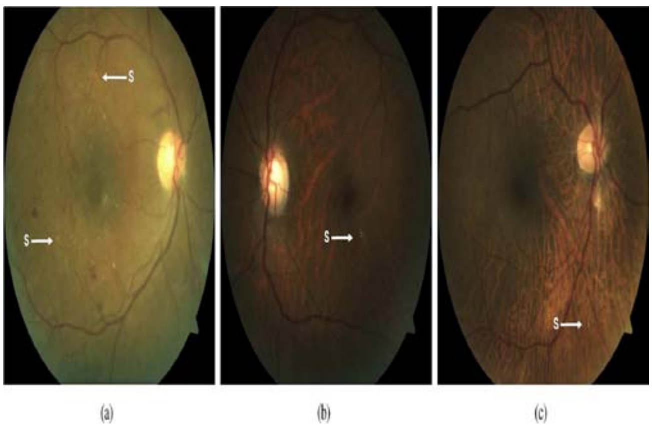

Figure 5 few challenging DME cases detected (a) Faint HE on a bright background (b), (c) Small and faint HE on tiger patterned background. Annotation (S)indicates location of subtle (faint) hard exudates in color fundus image.

Finally, analysed the effect of the threshold (T) (on rotational symmetry metric) in severity assessment. The threshold is expressed as a percentage of the symmetry measure of normal ROIs used in the abnormality detection task.

V. CONCLUSION AND FUTURE WORK

Screening of population for disease using images is a challenging problem. Several barriers in the form of social, educational and operational issues are integral to the disease screening problem. These affect the nature of computer aided diagnosis required to address disease screening, which is significantly different from conventional primary care. We have proposed and evaluated a method for abnormality detection and assessment in CFI. a supervised technique based on learning the image characteristics of only normal patients is used for detecting the abnormal cases. This approach has the inherent advantage of reducing the effort of building a CAD system by removing the need for annotated (at the lesion level) abnormal images. Such annotations are required for both supervised and unsupervised classification schemes in order to find suitable system parameters for detection. The approach facilitates separating the normal patients from those showing disease symptoms, as practiced in DR screening.

VI. ACKNOWLEDGMENT

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Short Bio Data for the Authors

**Sarika Madhu** is a student of M.Tech in Applied Electronics and Communication Systems in Department of Electronics and Communication Engineering at Nehru College of Engineering and Research Centre, Pampady, Thiruvilawamala, Kerala, India, affiliated to University of Calicut. She obtained her B.Tech in Electronics & Communication Engineering from Sarabhai Institute of Science & Technology, affiliated to Cochin university, Kerala. Her areas of interest are Networking, MEMS, Biomedical image processing.

**Nithin Joe** working as Assistant Professor in the Department of Electronics and Communication Engineering at Nehru College of Engineering and Research Centre, Pampady, Thiruvilawamala, Kerala, India, affiliated to University of Calicut. He obtained the Bachelor of Science Degree in Electronics with Computer Hardware from Presentation College of Applied Sciences affiliated to Mahatma Gandhi University, Kottayam. He received Master of Science degree in Applied Electronics, Nehru Arts and Science College affiliated to Bharathiar University Coimbatore, India and Master of Technology in Sensor Systems Technology from VIT University, Vellore, Tamil Nadu. His areas of interest are MEMS, Energy harvesting Device, and Sensors, biomedical image processing.

**Parameshachari B D** working as a Associate Professor and Department Coordinator in the Department of Electronics and Communication Engineering at Nehru College of Engineering and Research Centre, Pampady, Thiruvilawamala, Kerala, India, affiliated to University of Calicut. Worked as a Senior Lecturer and inchage HOD in the Department of Electronics and Communication Engineering at JSS Academy of Technical Education, Mauritius. He worked at JSSATE, Mauritius for Three years and also worked as a Lecturer at Kalpatharu Institute of Technology, Tiptur for Seven years. He obtained his B.E in Electronics and Communication Engineering from Kalpatharu Institute of Technology, Tiptur and M. Tech in Digital communication Engineering from B M S college of Engineering, Bangalore, affiliated to Visveswaraiah Technological University, Belgaum. He is pursuing his Ph.D in Electronics and Communication Engineering at Jain University, Bangalore, Karnataka, India under the guidance of Dr. K M Sunjiv Soyjaudah, Professor, University of Mauritius, Reduit, Republic of Mauritius and Co-guidance of Dr. Sumithra Devi K A, Professor and Director, Department of MCA, R V College of Engineering, Bangalore. Parameshachari area of interest and research include image processing, cryptography and Communication. He has published several Research papers in international Journals/conferences. He is a Member of ISTE, IETE, IACSIT, IAEST, IAENG and AIRCC.

**Divakara Murthy H S** has multi faceted experience in Research, Industry and Academic fields, He is working as a Dean and HOD in the Department of Electronics and Communication Engineering at Nehru College of Engineering and Research Centre, Pampady, Thiruvilawamala, Kerala, India, affiliated to University of Calicut and also served as a Principal at JSS Academy of Technical Education, Mauritius for two years. Involved in Administrative & Academic activities in development of infrastructure facilities marketing, mounting new courses and strategic planning. He worked at RGV telecom Ltd Bangalore as Deputy Vice president,for providing optical communication for Indian Railways for nealy two years and also worked nearly 27 years in Telecom in Industry at senior level in various capacities in Telecom Projects and Planning, Production and Marketing. During my intial career involved in Design and development of Instrumentation at NAL Bangalore. He obtained his B.E in Electronics and Communication Engineering from Siddaganga Institute of Technology, Tumkur from University of Mysore and MSc(Engg)in communication system from PSG Institute of technology, Coimbatore , from University of Madras. Divakara Murthy area of interest and research include Micro and Pico Satellite communication, Optical Communication and Wireless communication, GSM and WiMAX technology. He is a Member of ISTE, IETE.

