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Severity Level Detection in Retinal Fundus Images for Diabetic Retinopathy

K. Ramanjaneyulu, K. Rasajna, A. Jawahar Reddy, CH.S.N.V. Krishna Teja, D. Venkata Teja

Abstract: Diabetic Retinopathy is the disease caused for diabetic people which doesn't have symptoms in the first phase. As it progresses, it becomes symptomatic. This disease, sometimes, might lead to complete blindness. Red lesions contain microaneurysms, haemorrhages and exudates. This work focuses on detection of red lesions in fundus image. Ophthalmologists use pupil dilation of chemical solutions in order to detect the abnormality which takes time and also causes irritation to patients. Image processing techniques are used to avoid these limitations. Morphological operations are used to identify the pixels belonging to the red lesions. Gabor filter is used for separating the blood vessels. Some spots are formed near macular region because blood vessels become leaky which leads to exudates. The severity level of the disease is determined by finding the distance between lesions and macular region. The disease is considered as severe if the distance between them is closer and confirms as less if the distance is far.

Key Words: Diabetic Retinopathy, Fundus Images, Gabor Filter, Haemorrhages, Red Lesions.

I. INTRODUCTION

Now-a-days, most of the diabetic people are suffering from Diabetic Retinopathy. It became common problem to all the diabetic patients all over the world. The diabetic person who suffers from Diabetic Retinopathy faces the light sensitivity problems with the eye. The main reason for the disease is the light sensitive tissue is affected which is present at the back side of the eye. The tissues are the tiny blood vessels present in the retina. These effects vary from person to person. The retina is a thin layer of tissue that is located near the optic nerve. Retina receives light from some object through the lens and it converts the light into neural signals and then it sends these signals on to the brain for visual recognition. As per the survey, 5% of the people among 40% of people suffering from diabetic retinopathy are having severe problem.

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* Correspondence Author

Dr. K. Ramanjaneyulu, Electronics and Communication Engineering, PVP Siddhartha Institute of Technology, Vijayawada, AP, India Email: kongara.raman@gmail.com

K. Rasajna*, Electronics and Communication Engineering, PVP Siddhartha Institute of Technology, Vijayawada, AP, India. Email: rasajnakasukurthi278@gmail.com

A. Jawahar Reddy, Electronics and Communication Engineering, PVP Siddhartha Institute of Technology, Vijayawada, AP, India. Email: jawaharreddy.aviluri05@gmail.com

CH.S.N.V. Krishna Teja, Electronics and Communication Engineering, PVP Siddhartha Institute of Technology, Vijayawada, AP, India Email: Saiunique123@gmail.com

D. Venkata Teja, Electronics and Communication Engineering, PVP Siddhartha Institute of Technology, Vijayawada, AP, India Email: dasarisaiteja121@gmail.com

People having red lesions are suffering a lot with vision problem. Due to blood leakage from veins in the eye, red lesions are formed.

Rigorousness of swelling can determine the nature of the red lesions. If the red lesion size is small then it is not so risky and termed as a micro-aneurysms which exists for only few hours. If the red lesions become larger in size with progress in time then they are more risky and classified as haemorrhages.

Excess glucose in the diabetic patients leads to damage of blood vessels within the eye. Leakage of blood from the damaged vessels into the tissues might cause blurred vision. Eye related problems like cataracts and glaucoma are increased due to diabetes. If the blood sugar is not controlled in the diabetic patients then it is very difficult to prevent damage of eye blood vessels. The starting stage of Diabetic Retinopathy (DR) is Non-Proliferative Diabetic Retinopathy (NPDR). In this stage, there will not be vision problem. As damaged blood vessels start leaking fluids onto the macula, a problem called macular edema will be developed. This fluid makes the macula to swell. This stage of DR is called Proliferative Diabetic Retinopathy (PDR).
As PDR progresses, we can observe the following symptoms.

a. Missing areas of vision or shadows
b. Slow vision loss over time
c. Vision loss at night
d. Vacant spot in the centre of vision
e. Adjusting from dim light to dark light is difficult

Remainder of the paper is organized as follows. Section 2 describes the literature survey. In section 3, proposed method is described. Experimental results, conclusions and future scope are presented in section 4, section 5 and section 6 respectively.

II. LITERATURE SURVEY

Several methods were proposed in the literature for DR detection. One algorithm uses the segmentation technique for separating red lesions and hard exudates from the fundus images. In finding the severity of the disease, distance of abnormalities from the macula is measured. In another method, threshold techniques are used for extracting red lesions.

In [1], a spot lesion detection method for retinal images was presented. It deals with all DR related spot lesions of different profiles and dimensions. It is based on a unique adaptive multi-scale morphological processing. Computer vision algorithms are also used in the past for extracting red lesions from fundus images.

Real-time analysis, computational efficacy and automated decision making capabilities are important. In addition, many techniques have been considered for the detection of microaneurysms in retinal fundus image but none of them was compared with each other on the same data [2].

Intensity and geometrical features are used for detecting haemorrhages in [3]. Another method was proposed for detecting haemorrhages from fundus image based on gamma correction, brightness adjustment and density analysis [4]. Eigen vectors based method was also proposed for extracting microaneurysms. As microaneurysms are located with small sizes in the low intensity regions, their detection is complicated. For accurate detection of microaneurysms, it is necessary to supress large structured entities like haemorrhages and affinity matrix is used for that purpose. This creates similar affinity distribution for pixels of microaneurysms [5].

Staging of diabetic retinopathy is very important as Diabetic Mellitus [DM] is a worldwide major medical problem. Authors in [6] focused on estimation of diabetes and its effect on retina. In that paper, various convolutional neural networks are introduced to find blood vessels in the fundus images.

The science of the causes and effects of diseases related to retina is called retinal pathology. Retinal pathology is very much useful for the diagnosis of eye related diseases if macular degeneration and exudates are detected. These diseases are appeared as yellowish exudates, cotton wool spots. This detection method is useful for less colour contrast and low intensity fundus images [7].

In [8], the focus is on the development of automated diagnosis system. As a part of that authors aimed to find anomalies and classify the severity level of diabetic retinopathy. The retinal lesion detection depends on segmentation, refinement stage and heuristic rules. In [9], an effective method is proposed based on local thresholding and measurement of the spatial density of the selected pixels.

In [10], a method is proposed for detecting the existence of diabetic eye disease. This is an analytical approach used to identify both bright and red lesions without using pre/post processing on fundus image.

III. PROPOSED METHODOLOGY

In general, fundus image of a diabetic patient consists of microaneurysms, haemorrhages, exudates and red lesions. In the first stage of DR, the presence of swelling in the small blood vessels of retina is called microaneurysms. They appear as reddish, smaller and circular dots. If the disease progresses, there is continuous distortion in the vision and small blood vessels start swelling. As a result, the size of the microaneurysms gets increased. They are known as haemorrhages. This is due to restricted blood supply to tissues in the retina and damage of retinal blood vessels. Haemorrhages will be developed in different shapes and sizes.

Yellow coloured liquid deposits in the retina are called exudates. Exudates consist of fluids, cellular debris and proteins. They look as bright spots and appear with different shapes and sizes. They have sharp boundaries. Two types of exudates are identified. They are soft and hard exudates. Soft exudates are formed due to restricted blood supply to tissues of retina. They are also known as cotton wool spots. Hard exudates are formed due to accumulation of fats and proteins.

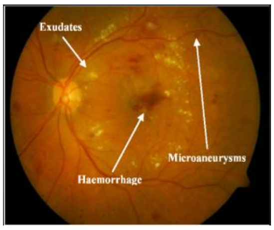

Fig. 1 Red lesions in the image

Extraction of red lesions, removal of optic disk and determining the severity level of the disease are important phases in the proposed methodology. Flow chart for separating red lesion is shown in Fig. 2.

A. Fundus Image Acquisition

Fundus imaging is the process of acquiring an eye image which is useful for the diagnosis of diseases related to eye.

They are many challenges associated with fundus imaging. In this work, fundus images are taken from DIARETDB1 databases which are available in internet. The non-dilated fundus image shown in Fig. 3 is the input image.

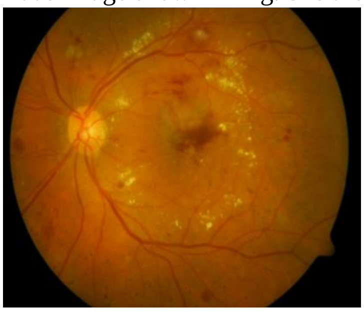

Fig. 3 Input/ Original Image

B. Adaptive histogram equalization

In the proposed algorithm, the retinal fundus image which we have taken is a three channel RGB colour image. RGB colour image format is not an efficient representation with respect to storage and transmission. A practical approximation to RGB image in the colour space is YCbCr. It is created from the corresponding gamma-adjusted RGB source. Y is the luma component; CB and CR are the blue-difference and red-difference chroma components respectively. Hence, RGB fundus image is converted into YCbCr colour format. As Y component contains most of the information about the red lesions, it is separated from YCbCr and it is used for further processing.

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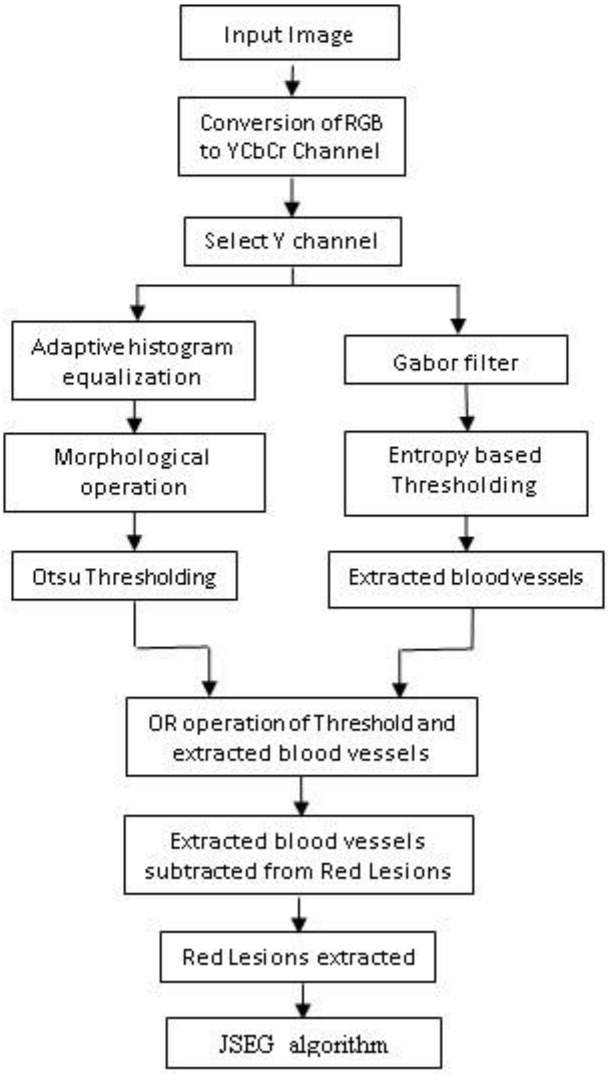
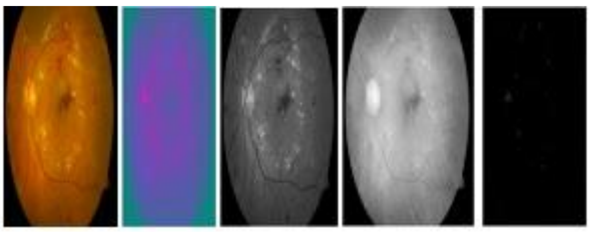


Fig. 2 Flow chart for the proposed method



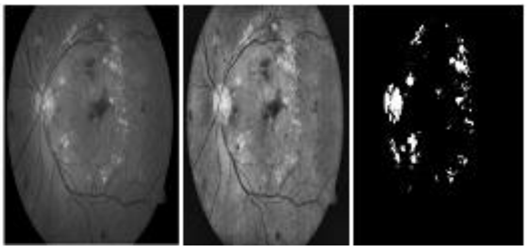
(a) (b) (c) (d) (e)

Fig. 4 (a) RGB fundus image (b) Image in YCbCr (c) Y component (d) CB component (e) CR component

Figure 4(a) shows RGB input colour image and the converted YCbCr image is shown in 4(b). Fig. 4(c) represents Y component which contains more information.

For contrast enhancement of the Y component, Histogram equalization technique is applied to Y component/channel. Several histograms are computed by using Adaptive histogram equalization in which each corresponding to different sections of an image. The high intensity values of the image are distributed by using those histograms and to highlight the low value pixels of red lesions by making them more prominent. Proper segmentation of the image is done by Adaptive histogram equalization technique.

In the original fundus image background, the presence of noise and non-uniform pixels will introduce trouble in segmenting red lesions. Morphological operations are used to remove the imperfections in the image structure. Histogram equalized Y component images are subjected to morphological operations like dilate erode and hole-filling to eliminate noisy pixels. Then, Otsu's threshold method is applied to the image obtained after the morphological operations. Binary image is obtained and it contains red lesions.



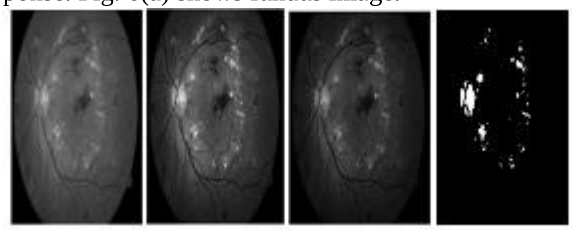
(a) (b) (c)

Fig. 5 (a) Y component image (b) Image obtained after adaptive histogram equalization (c) Image obtained after threshold operation.

Fig. 5(a) represents Y component image taken as input image and 5(b) represents resultant image obtained after the adaptive histogram equalization and 5(c) shows the binary image after applying Otsu's multilevel thresholding which consists of possible candidate pixels.

C. Gabor filter

Image texture provides the details about the spatial arrangement of intensities in an image. Gabor filter is a linear filter used for analysing texture in the image. Its response is highest at boundaries and at locations where texture changes. Its impulse response is by multiplying a sinusoidal wave with a Gaussian function. In the frequency domain, multiplication is equivalent to convolution operation. Frequency response of the filter is obtained by finding the Fourier transform of its impulse response. Fig. 6(a) shows fundus image.



(a) (b) (c) (d)

Fig. 6 (a) Fundus Image (b) Output of Gabor filter (c) Compliment image (d) Image obtained after threshold operation

Fig. 6(b) shows the output of the Gabor filter for the input of Y component. Fig. 6(c) shows compliment Fig. 6(b). After the application of the threshold operation, we get binary image indicated in Fig. 6(d).

D. Extraction of red lesions

Binary images obtained through adaptive histogram equalization and Gabor filtering are subjected to logical OR operation.

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Red lesions are obtained by subtracting the image obtained through OR operation from the binary image obtained through Gabor filter. Macula and optic disc are removed during the process of extracting red lesions. Red lesions extraction process is illustrated in Fig. 7. Various steps involved are described below.

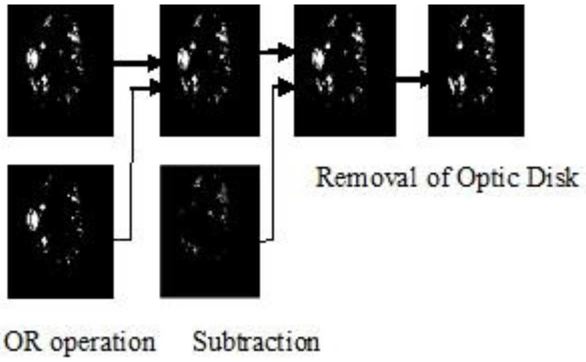

Fig. 7 OR and Subtraction operation

Steps for red lesion extraction

1. RGB image is converted into YCbCr image.
2. Separation of Y component from the YCbCr.
3. Finding adaptive histogram equalization of Y component.
4. Application of Otsu threshold technique for obtaining binary image.
5. Application of Gabor filtering for separating the blood vessels.
6. Application of intensity based threshold technique for obtaining binary image.
7. Performing OR operation on the two binary images.
8. Separating red lesions from the output of Gabor filter.
9. Application of noise removal technique.
10. Removal of optic disc and extraction of red lesions.

E. JSEG Algorithm

JSEG algorithm [11] is used for the segmentation of colour-texture regions that are present in the images. This algorithm does not require manual parameter adjustment. Outcome of this process is class maps of important texture areas of the input image.

This method of segmentation passes through two important stages. Stage 1 is colour space quantization. In this stage, colours of the image are quantized into number of representative classes. Some colours which are not significant will be supressed. Stage 2 is called spatial segmentation. Merging of similar colour areas/regions is done in stage 2. Merged colour regions are called hit rate regions. Finally, a class-map of the image is created with colour class labels. The class-map is regarded as the special kind of texture composition. Fig. 8 shows class map of the image.

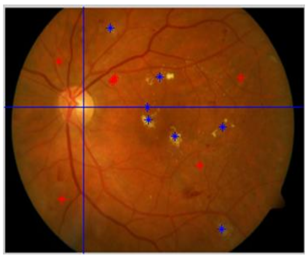

Fig. 8 Mapped image (Blue-exudates, Red-micro-aneurysms, cyan-haemorrhages)

IV. EXPERIMENTAL RESULTS

The dataset is taken from DIARETDB1 databases which are available in the internet. This is a labelled dataset and it contains the required information about the red lesions. The dataset contains 89 images. 84 images are showing signs of DR and the other 5 are healthy images.

JSEG algorithm is applied on extracted red lesions to find the disease severity level. The count, size and the distribution of microaneurysms, exudates and haemorrhages are required to predict the severity level of DR. Surrounding region of optic disc is partitioned and each part is focused for its segmentation based on JSEG. Normal, mild, moderate and severe are the 4 levels of DR as per International Council of Ophthalmology. Following is the information on severity level of DR.

Table: Information on severity level of DR

Observation	Severity of DR
No abnormalities	normal
Presence of microaneurysms	mild
Presence of microaneurysms & exudates or hemorrhages	moderate
Presence of numerous microaneurysms, hemorrhages and exudates	severe

V. CONCLUSIONS

Due to DR, diabetic patients will suffer from vision problems. DR affects and damages the blood vessels of retina. For better treatment of DR patients, finding disease severity level is essential. In this work, an algorithm is proposed to find the severity level of DR based on the JSEG. Firstly, Red lesions are extracted fundus image by performing various operations like adaptive histogram equalization, morphological operations, Otsu threshold technique, Gabor filtering and logical OR operation etc. JSEG segmentation technique is used to create class-map of the image with colour class labels. Separation distance between exudates affected region and macula determines severity level of the DR. If the separation distance is small then disease severity level is more. If the separation distance is large then it indicates less severity. The image is said to be normal if the exudates are absent.

FUTURE SCOPE

Performance of proposed method may be improved by using Deep learning techniques for classification of red lesions and to find disease severity level of DR.

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AUTHORS PROFILE

Dr. K. Ramanjaneyulu is working as a Professor in the Department of ECE, PVP Siddhartha Institute of Technology, Vijayawada. He did his B. Tech in Bapatla Engineering College during 1986-90 and then completed M. Tech in Pondicherry Engineering College in 1993. After that, he received Doctoral Degree from Andhra University in 2012. He worked in the area of Digital Image Watermarking for his Ph.D. He started his teaching career as a faculty member in Bapatla Engineering College, Bapatla. He worked there for 20 years in various capacities (Assistant professor, Associate professor, professor and HOD). He guided several student projects at the level of both UG & PG. He has over 27 years of teaching experience and 14 years of research experience. He has over 40 publications in various Journals and Conference Proceedings. His research interests are in the areas of Image Processing, Digital Image Watermarking and Wireless communications.

Rasajna Kasukurthi is pursuing Bachelor of Technology in the stream of Electronics and Communications Engineering, in Prasad V. Potluri Siddhartha Institute of Technology, Kanuru, Vijayawada. She has done internship and completed project based on image processing in Indian Institute of Sciences, Bangalore.

Aviluri Jawahar Reddy is pursuing Bachelor of Technology in the stream of Electronics and Communications Engineering, in Prasad V. Potluri Siddhartha Institute of Technology, Kanuru, Vijayawada.He is member of IETE student forum.

Ch.S.N.V.Krishna Teja is pursuing Bachelor of Technology in the stream of Electronics and Communications Engineering, in Prasad V. Potluri Siddhartha Institute of Technology, Kanuru, Vijayawada. He is member of IETE student forum.

Dasari Venkata Sai Teja is pursuing Bachelor of Technology in the stream of Electronics and Communications Engineering, in Prasad V. Potluri Siddhartha Institute of Technology, Kanuru, Vijayawada. He is member of IETE student forum.