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DIAGNOSIS OF DIABETIC RETINOPATHY FROM FUNDUS IMAGE USING FUZZY C-MEANS CLUSTERING ALGORITHM

M. Jagannath[1] and K. Adalarasu[2*]

[1]*School of Electronics Engineering, VIT University Chennai, Tamil Nadu, INDIA*
[2]*Department of ECE, PSNA College of Engineering and Technology, Dindigul, Tamil Nadu, INDIA*

ABSTRACT

Diabetic retinopathy is a chronic disorder which is considered as a major source of vision loss in patients suffering from diabetes. It is characterized by the destructive of blood vessels that nourish the retina. However, early detection of such disorder through regular diagnosis, vision loss can be avoided. In order to reduce the diagnosis cost and enhance the automated analysis, modern image processing tools are used to detect the existence of disorders in the retinal images acquired during the initial process of screenings. This paper presents a methodology for the extraction of exudates within blood vessels from fundus images using Fuzzy c-Means (FCM) clustering algorithm. Matched filter was applied for vessel extraction with the help of adaptive histogram equalization, thresholding method and segmenting method, which incorporates spatial neighborhood information into the FCM clustering algorithm. A standard diabetic retinopathy database was used in this study to test the proposed algorithm. This methodology showed improved sensitivity and accuracy of the segmented result. The proposed method seems to be promising as it can also detect the very small areas of exudates. Such an image processing technique can reduce the work of ophthalmologists and help in patient screening, treatment and clinical studies.

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KEY WORDS

Diabetic retinopathy; Fuzzy c-Means; digital fundus image; exudates

***Corresponding author:** **Email:** adalbiotech@gmail.com, **Tel.:** +91-9965718013; **Fax:** +91-451-2554249

INTRODUCTION

Diabetic retinopathy is an emerging cause of vision loss in both developed and developing countries. The World Health Organization (WHO) has projected the number of adults with diabetes in the world would increase exceptionally: from 135million in 1995 to 300 million in 2025. In India, this condition is expected to be the greater; (i.e.) nearly 195% from 18 million in 1995 to 54 million in 2025 [1-3].

Diabetic retinopathy is a chronic disorder which is considered as a major source in patients suffering from diabetes [4]. It is characterized by the destructive of blood vessels that nourish the retina. It is of two categories: category 1 primarily initiated by autoimmune pancreatic b-cell damage and described by absolute insulin deficiency, and category 2 described by insulin conflict and relative insulin deficiency [5]. For example, in the USA; it was estimated that nearly 7% of the US population achieved the diagnostic criteria for diabetes [6]. In Saudi Arabia the occurrence of diabetes mellitus was estimated at around 31% and it grows with age [7]. It is the general cause of vision loss between the age-group of 20 and 65 years. Recently an extensive study had been performed in various aspects of diabetic retinopathy.

The most effective treatment is detecting the condition in premature stage through regular screenings [8, 9]. During the screenings, color fundus images are obtained using fundus camera. However, as a result large number of fundus images are produced which requires physical investigation and diagnosis. Moreover, medical experts like ophthalmologists need to spend their time and energy to analysis these images. It would be more affordable if the initial process of analyzing the images can be done automatic so that merely the abnormal fundus images need to be diagnosed by the ophthalmologists [8, 10].

On the other hand, diabetic retinopathy which consequences from long-term diabetes mellitus, it is a common disease that clues to choroidal neo-vascularization [2]. The choroidal neo-vascularization is a significant stage that leads to vision loss. It decreases the amount of blood supplied to the retina. One of the treatment strategies is that

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the affected areas of the retina are photocoagulated with the help of lasers. To achieve satisfactory results, the expert has to identify the choroidal neo-vascularization and cauterize it completely. Optic disc and blood vessels should be carefully avoided while radiating the area of acute vision.

Retina is a thin clear structure including of several layers. The cells within the retina includes three major components: (1) neuronal component which contribute the retina its visual function by converting light to electrical signals; (2) Glial components are the supporting column of the retina; and (3) Vascular components which delivers the inner retina while the outer retinal is being delivered by diffusion from choroidal circulation [5]. Diabetes will produce its result on both neuronal and vascular components of the retina.

Several issues were found to influence diabetic retinopathy including chronic characteristics of the disease, age, pregnancy, blood pressure, hyper-viscosity, kidney failure and anemia. Hyper-viscosity of the blood [11] influences the diabetic retinopathy.

More accurate and reliable solution through image processing and artificial intelligence tools included Genetic Algorithm (GA) and Artificial Neural Network (ANN) [12, 13]. Currently numerous clustering algorithms have been developed for image segmentation. Artificial intelligence and fuzzy based method such as Adaptive Neuro-Fuzzy Inference System (ANFIS), K-Means, Fuzzy c-Means (FCM) [14-17] are considered to be effective in image segmentation. Khalida et al. [18] suggested FCM as a clustering technique for segmentation of color image based on the elementary region developing method and used membership grades of pixels to categorize pixels into suitable segments.

The research framework of this paper is to perform FCM algorithm on fundus image to extract the exudates within blood vessels. The organization of the rest of this paper is as follows: Section 2 presents our methods, including the overview of the methodology, detection, filtering, template matching and descriptions of clustering algorithm's structure. Section 3 discusses the results and discussions. Finally, the paper ends with a short summary in Section 4.

MATERIALS AND METHODS

The proposed research framework starts with pre-processing which is mainly to enhance the image quality for the stages that follows. The image pixel values were permanently altered and enhanced data was used for further analysis. Pre-processing suppressed the undesired information and enhances the desired features. Pre-processing involved brightness correction, detection of edges, histogram equalization and so on.

Detection

Diabetic patients require routine eye examinations so that interrelated eye problems can be identified and treated efficiently. Most diabetic patients are normally observed by an endocrinologist who works closely with the ophthalmologist.

Filtering

A fundus camera delivers fundus image in digital form which can be effectually used for the computer based automated detection of diabetic retinopathy. The performance on one of the normal fundus image is shown in **Figure– 1**.

One of the most important components of our system is the filters, which extracts the ideal data for the diagnosis. Matched filter was used for vessel segmentation that acquires more computational time than other edge detector for the same purpose [1, 19].

Unfortunately due to uneven illumination it may appear darker because macula centered fundus images are often captured on both right and left eye [9]. To rectify this problem we have to use illumination equalization to normalize the luminosity across the image. Adaptive histogram equalization enhances the blood vessels in vessel segmentation [21]. Since blood vessels usually have lower reflectance when compared with the background, these types of contrast enhancement improve the vessel segmentation.

Template matching

The normal and healthy fundus images were taken and kept as standard to separate the abnormalities in the test image. This standard image acted as the template. Both the standard image and test images were transformed from RGB to gray levels and later by point processing (pixel by pixel) both the images were assessed.

During assessment, the further objects present in the test image got separated and made clearly visible in the result. While comparing, if the test image matches with a normal one, then it gets cancelled as there is no difference in pixel values between

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the two images. The basic requirement of the proposed method is that, the references of the normal fundus image and the test images must be taken in the same orientation with same lighting, background and so on [21, 22].

Proposed methodology

The proposed methodology is composed of four steps. Since blood vessels usually have lower reflectance compared with the background, a green component of fundus image will be separated. It was preprocessed to reduce the noise. Then we applied the matched filter to enhance blood vessels. The spatially weighted Fuzzy c-Means (FCM) clustering algorithm is used to distinguish between vessel segments and the background of the matched filter response (MFR) image [3]. A label filtering technique is used to remove the misclassified pixels.

Fig: 1. Vessel segmentation of original fundus image.

In order to extract the enhanced segments in the matched filter response images, an effective thresholding scheme is necessary to avoid complicated relationships or overlap between foreground and background. Hence thresholding based on spatially weighted FCM clustering algorithm was implemented.

The spatially weighted FCM clustering algorithm was formulated by combining the information of spatial neighboring into the FCM algorithm [3]. The weight in the algorithm was modified by bearing in mind the neighborhood influence on the central pixel to improve the performance of image thresholding.

The computation time of the proposed method is very fast as compared to the conventional techniques since the gray level histogram of image was used as an alternative of the whole data of image to compute the parameter for the FCM algorithm [22]. Due to the concern of the neighborhood information, the proposed method seemed to be noise resistant.

Clustering algorithm

In this paper, a prior knowledge about spectral information for certain land cover classes is preferred, in order to classify image in fuzzy logic manner. Steps to implement the algorithm are given below.

Step 1: Assign the number of clusters.
Step 2: Randomly allocate input vector to the cluster. Create partition.
Step 3: Compute a cluster as center, the mean of each vector component of all vectors assigned to that cluster. Repeat for all clusters.

Step 4: Estimate the distance between each and every center and input vector.
Step 5: Update partition by assigning each input vector to its nearest cluster center.
Step 6: Stop if center do not move any more otherwise loop to Step 4.

The proposed method uses an iterative clustering method that yields a best c partition, Since FCM algorithm is iterative and time consuming, the gray level histogram of image was used to the algorithm [23].

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RESULTS AND DISCUSSIONS

In order to evaluate the performance, we compare our simulation results with the state-of-the-art results obtained from piecewise threshold probing, local entropy thresholding, well known Otsu thresholding and hand-labeled ground truth segmentations [1, 24]. The vessel detection from Otsu thresholding is depicted in **Figure– 2**.

In this section, the results obtained from our proposed algorithm are presented. Results are compared with the well-known Otsu thresholding. Moreover, since the algorithm behavior should be image size independent, a statistical study of the measures variation was performed out. The study was based on the processing of 20 normal retinal images of each class and on three sets of measurements: one for the original images, one associated to halved area versions of the original images, and another for doubled area versions of the original images. The results of the present study revealed that the proposed algorithm is robust to differences in resolution of the image.

Fig: 2. Vessel detection from Otsu thresholding.

The proposed method preserves the computational ease and also can achieve accurate segmentation results in the case of normal fundus images and abnormal images with obscure blood vessel appearance. Blood vessel width is deliberated by interpolation technique and award elevated disparity among normal and abnormal images.

The algorithm was implemented in MATLAB version 2009b and is run on a 1.7GHz Core 2 Duo personal computer with a memory of 8 GB. Test fundus images are taken from the stare database. Normal retinal images and affected images are used for the experiment. The computational time for the complete procedure of the proposed algorithm just takes about one minute for each fundus image. Among the 30 images of standard diabetic retinopathy Database, 20 normal images with no pathology (normal) and 10 abnormal images including pathology that obscures or even confuses the blood vessel appearance in varying positions of the image (abnormal) are taken for analysis.

Detection of vessel in fundus images produces unconnected parallel edges to let extraction of blood vessels using spatial weighted FCM **[Figure– 3]**. The edge detection techniques produce better results only when the edges are distinct and sharp. The proposed methodology performs better by segmenting even the smaller blood vessels. The proposed methodology segments the blood vessels very well from the background and extracts the exudates to classify fundus images. The proposed method has achieved 94.5% accuracy in identifying all the retinal images with exudates, and 86% accuracy in classifying normal retinal images as normal. But it shows that the major obstacle of this approach is the presence of lesions in the abnormal Images. From the above experimentation it is found that Global Otsu thresholding algorithm for vessels segmentation is best suited because it is compatible with template matching algorithm.

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Early diagnosis of diabetic retinopathy was suggested based on decision support system by Kahai et al. [25]. Normal and prolific diabetic retinopathy phases were automatically classified with the help of dimensions of the RGB components of the blood vessels coupled with a neural network technique. Nayak et al. [26] have investigated exudates and blood vessel area along with texture parameters together with neural network to classify fundus images into normal and diabetic retinopathy. Recently, Acharya et al. [27] used support vector machine (SVM) classifier to categorize the fundus image into normal and prolific diabetic retinopathy phases. They have established an average accuracy of 82%. Larsen et al. [28] have developed an automated system, which identified around 90% of patients with diabetic retinopathy and around 82% of patients without diabetic retinopathy, when implemented in a screening population involving of patients with untreated diabetic retinopathy.

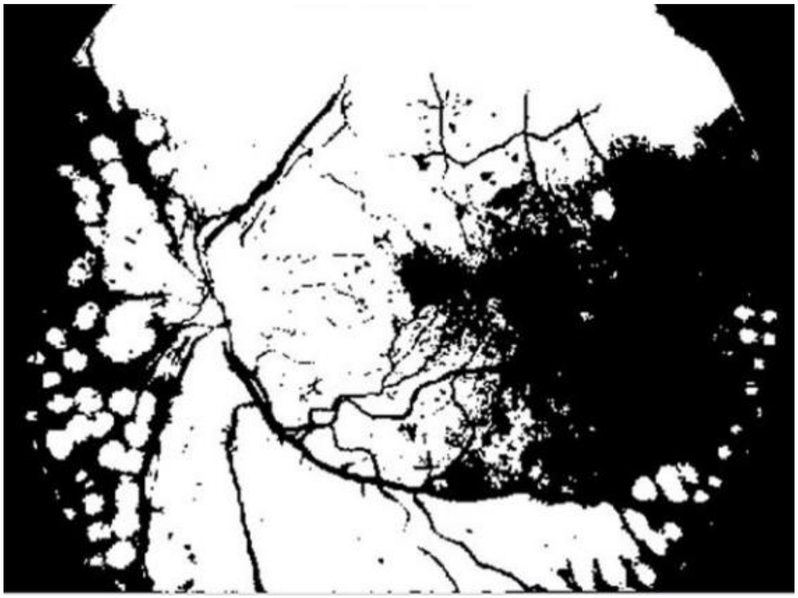

Fig: 3. Vessel detection from spatial weighted Fuzzy c-Means clustering algorithm.

With the proposed method, automatic detection of exudates due to diabetic retinopathy is achieved within short computational period. The accuracy is seemed to be increased using Fuzzy c-Means compared to the results from existing literatures. In order to support the sophisticated operations imposed in the automated image diagnosis by sophisticated embedded systems can be used. These automated systems can be attached with an ophthalmoscope from which the fundus image is entered and a separate visual device can be used to display the output in terms of the normal and abnormal conditions of the disease. Further the above algorithms can be enhanced to produce results including the grade and severity of the disease.

CONCLUSION AND FUTURE WORK

In the present study, a spatially weighted Fuzzy c-Means clustering algorithm for vessel detection in ocular fundus images is proposed. The proposed method not only considered the advantage of the fuzzy system, but also deliberates the spatial neighborhood relation among pixels. The way the weight in the algorithm used plays a key role in improving the performance of the clustering algorithm. The proposed method maintains the computational simplicity and also achieves accurate segmentation results in the case of normal fundus images and images with obscure blood vessel appearance. The proposed method can be further amended by considering the optic disc region, vessel curving and crossings of the retinal image. However, obtained results of proposed method show that the method is able to perform the optic cup and disc detection, but it involves further improvement and parameter tuning to be incorporated to this specific purpose. The future work also aims at applying the shape analysis and classification strategies to the segmented vessels produced by method described in this study. Because of its simplicity and general nature the proposed algorithm seems to be applicable to a variety of other applications. An automated process for the early diagnoses and intervention can hence be of great aid to the patient and ophthalmologist alike in the appropriate supervision of this widespread disease.

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CONFLICT OF INTERESTS

We declare that we have no conflict of interest with any of the suggested reviewers and that the paper has not been supported by any grant to declare and have no personal relationships with other people or organizations that could inappropriately influence (bias) their work.

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ABOUT AUTHORS

Dr. M. Jagannath *is an Associate Professor in the School of Electronics Engineering at VIT University, Chennai, India. Prior to joining VIT University, he was heading the Department of Biomedical Engineering at SMK Fomra Institute of Technology, Chennai, India. He obtained his Ph.D. from IIT Madras, Chennai in the year 2012. He has served the position of Senior Project Officer at Indian Institute of Technology Madras, Chennai, India. He has taught at Sri Sai Ram Engineering College, Chennai; Madras Medical Mission, Chennai; Vellore Institute of Technology, Vellore. He received IndiraGandhi Sadbhavna Gold Medal Award for Individual Achievement and Service to the Nation from Global Economic Progress and Research Association, India, 2014. He has more than 50 research articles published in various reputed conferences and journals. His research interests are ergonomics, biomedical instrumentation systems, biomechanics, control systems, mechatronic systems and robotics.*

Dr. K. Adalarasu *received the B.E. degree in Electronics and Instrumentation Engineering from University of Madras, Tamilnadu, India, in 1998 and the Ph.D. degree in driver fatigue measurements from Indian Institute of Technology Madras, India, in 2010. At present, he is a Professor in the Department of Electronics and Communication Engineering at PSNA College of Engineering and Technology, Dindigul, Tamilnadu, India. He has published his research work in number of national and international journals and conferences.His research interests include cognitive neuroscience, industrial human safety and ergonomics testing of vehicles.*