ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Automatic Identification and Segmentation of Exudates and Optic Disc in Color Fundus Images of the Diabetic Retinopathy Human Retina.

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ABSTRACT

In this paper, a new approach for the automatic detection and segmentation of exudates in color fundus images of the Diabetic Retinopathy (DR) is proposed. DR is a diabetic disease which leads to blindness. The damage of retina blood vessels is the main reason for diabetic retinopathy. The near the beginning detection of diabetic retinopathy enables laser treatment to the affected eye to delay or stop the visual loss. The exudates are the main symptoms of diabetic retinopathy. So the near the beginning phase of diabetic retinopathy can easily be detected by the exudates. However the manual accurate detection of exudates by ophthalmologists will take more time. Moreover the number of ophthalmologists or experts is also not sufficient. For these reasons, the automatic detection of exudates is necessary for the efficient detection of diabetic retinopathy in retina. In this work, the automatic identification of optical disc and exudates using k-means and fuzzy c-means clustering is compared with the proposed approach which based on the principal component analysis. The superiority of the proposed approach had evaluated using some performance measures such as sensitivity, mean square error (MSE), specificity, and peak signal to noise ratio (PSNR).
Keywords: Exudates, Optical Disc, Diabetic Retinopathy, Segmentation, Principal Component Analysis.

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INTRODUCTION

Diabetic retinopathy (DR) is one of the common diabetic disease which leads to blindness in human beings in middle and old age groups. This may be caused by the variations in the blood vessels. The early detection of diabetic retinopathy needs laser treatment to prevent or control the visual loss. DR can be classified into two types as non proliferative (NPDR) and proliferative (PDR) type. NPDR is the initial stage of the disease in which new blood vessels are formed in the retina and the retina is destitute of oxygen. In proliferative diabetic retinopathy (PDR) stage, there is a deficient of oxygen in the human retina and also new blood vessels will grow along the retina.

Exudates and hemorrhages are the most important abnormal features which lead to blindness. The accumulation of lipids and proteins occur in the form of exudates. The exudates may appear either as white or yellow color of varying brightness, shape, size and location. Exudates can be classified as either hard (clear boundaries) or soft exudates (unclear boundaries). The optic disk, blood vessels and fovea are some features of fundus images. In diabetic patient's retinal image, exudates also present along with the normal features. In severe case of diabetics, hemorrhages and micro aneurysms also appear in the retinal image. In few cases, both optical disk and exudates can be appearing in similar color, contrast and brightness. So it is necessary to differentiate them for the accurate and efficient analysis of the fundus images. So in the exudates detection, the initial step is the identification and masking of the optical disk. Many eye diseases can be identified with the proper analysis of retinal images.

LITERATURE SURVEY

The combined approach of support vector machine (SVM) classifier and morphological process for the identification and classification of diabetic retinopathy images into different cases like moderate or severe had reported in [10]. The identification of both bright and red lesions in diabetic retinopathy images without any pre or post processing to allow the specialist to evaluate the image is reported by [1].

LI Yafen et al have proposed an approach for the automatic detection of Diabetic Retinopathy using image processing techniques such as image enhancement and texture analysis [9]. The segmentation and extraction of optical disc and exudates in retinal images using Spatially Weighted Fuzzy C-Means clustering algorithm had proposed by [7]. This method is based on the traditional Fuzzy C- Means (FCM) clustering algorithm on which the spatial neighborhood information is incorporated.

The detection of the contours of exudates in color retinal image based on grey level variation using watershed transformation and morphological filtering techniques had suggested by [19]. It is very difficult to detect the blood vessels using manual processes because these vessels in the retinal images are more complex and have low level of contrast. So it very difficult to collect the information (length, width and pattern) of blood vessels and also to detect the symptoms of diabetic retinopathy. So it is essential to build up computerized automated system for the efficient extraction and segmentation for the detection of exudates and optical disc to reduce the workload and assist the ophthalmologists to identify the true and false positives [12][21].

The retina vessel extraction using single and multi-scale matched filter had proposed by [17][23]. The Gabor filter based segmentation of blood vessel had recommended by [15]. The combined approach of matched filter and ant colony optimization had proposed by [2] for the detection of blood vessels in human eye. The morphology based segmentation of blood vessels had explained by [11][22]. Adaptive local thresholding for the efficient detection of the blood vessels in retinal images had proposed by [6].

The soft computing based exudates detection in fundus reinal image had proposed by [20]. In this work, Fuzzy k-means and and neural network is utilized for the detection of abnormalities in diabetic retinopathy images. Automatic detection of exudates from diabetic retinopathy retinal images using fuzzy based clustering had proposed by [18]. The identification and classification of hard and soft exudates using k-means clustering technique had explained by [13]. In this work, Hough transform had applied to eliminate the optic disc in retinal image.

MATERIAL AND METHODS

K –Means Clustering Algorithm

K-means clustering algorithm aims at minimizing an *objective function,* in this case a squared error function which is given by

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(j)} - c_j \right\|^2 \qquad (1)$$

where $\left\| x_i^{(j)} - c_j \right\|^2$ is the distance measure between a data point $x_i^{(j)}$ and the cluster centre c_j , is an indicator of the distance of the *n* data points from their respective cluster centers.

Step 1: Find out the number of clusters, K, and assume the center of these clusters (centroid)
Step 2: Choose the first K objects or any random objects as the initial centroids
Step 3: Compute the distance of each object to the centroids by squared Euclidean distance measure.
Step 4: Allocate every object to the group that has the closest centroid.
Step 5: After all objects were assigned, recalculate the positions of the K centroids

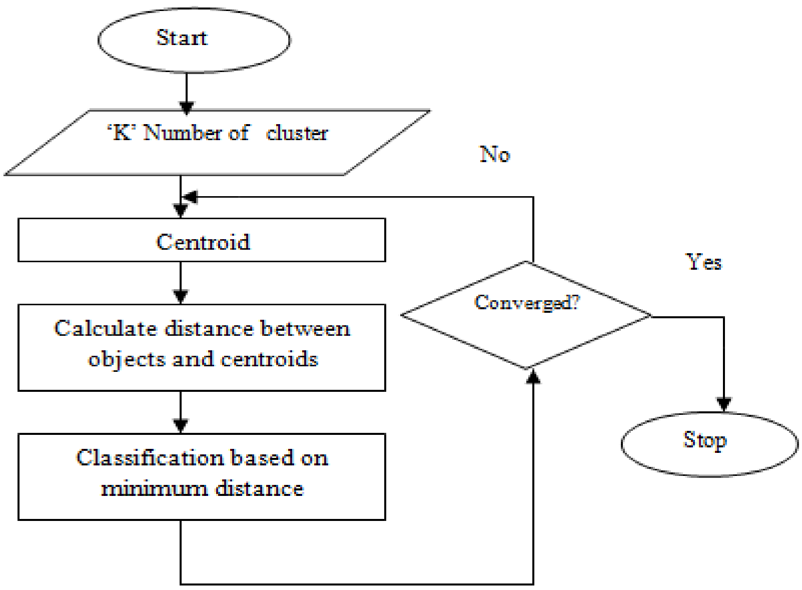


Figure 1. Flow chart for K-means clustering algorithm

Fuzzy C –Means Clustering Algorithm

The Fuzzy C-Means Clustering algorithm is based on minimizing its objective function [3]. FCM clustering algorithm for exudates detection is given below

1. Receive the image in the form of data matrix *X*
2. Fix the number of clusters, *c* ($2 \le c \le n$), *n* is the length of the image data [4][5]
3. Assume the partition matrix, ***U***
4. Calculate the cluster centers, V_i, i = 1**… c** using equation (2)

$$V_i = \frac{\sum_{j=1}^{n} (u_{ij})^m x_j}{\sum_{j=1}^{n} (u_{ij})^m} \qquad (2)$$

5. Estimate the Euclidean distance matrix, ***D*** using (3)

$$d_{ij} = \left\| X_j - V_i \right\| \qquad (3)$$

6. Compute the cost or objective function according to Equation (4).

$$J(U, c_1, \ldots, c_c) = \sum_{i=1}^{c} \sum_{j=1}^{n} u_{ij}^{m} d_{ij}^{2} \quad (4)$$

7. Compute a new **U** using Equation (5). Go to step 2

$$U_{ij} = \sum_{k=1}^{c} \left\{ \frac{\|x_j - v_i\|}{\|x_j - v_k\|} \right\}^{-2/m-1} \quad (5)$$

Principal Component Analysis

Principal Component Analysis is a most popular tool in data analysis and information retrieval. Here, number of possible correlated variables is transformed into uncorrelated variables. PCA also known as Karhunen and Leove (KL) or Hotelling transform. PCA generally find applications in the pattern recognition. With the help of PCA, we can reduce the number of dimensions without much loss of information. The detailed algorithm for principal component analysis is explained as follows

Step 1: Transform the input image into data matrix. The size of the matrix depends on the complexity of the image.
Step 2: Consider one column of the data matrix and subtract from the mean value of all pixel in that particular column.

Step 3: Compute the covariance matrix

$$\mathrm{Covar}(X, Y) = \frac{\sum_{i=1}^{n} (X_i - \overline{X})(Y_i - \overline{Y})}{(n-1)} \quad (6)$$

Where X_i is the value in the i^{th} value and $\overline{X}$ is the mean of the column.
All these values are stored in a square matrix called the covariance matrix.
Step 4: From the covariance matrix, compute the eigenvectors and Eigen values
Step 5: Select the components form Eigen vectors and form a feature vector
Step 6: Acquire the new data set by a simple multiplication of Row Data adjust and Row Feature Vector

EXPERIMENTAL RESULTS AND DISCUSSION

The result obtained from K-means clustering, Fuzzy C-Means clustering and the proposed approach is compared with some image quality measures such as Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Specificity, Sensitivity and Accuracy.

Mean Squared Error (MSE) is the average squared difference between input and segmented output image. This is most frequently used image quality measure due to its mathematical tractability and straightforward to design systems.

$$MSE = \frac{1}{MN} \sum_{j=1}^{M} \sum_{k=1}^{N} [f(j,k) - g(j,k)]^2 \quad (7)$$

The PSNR represents a measure of the peak value of the error. The main advantage of PSNR is ease of computation but it does not reflect perceptual quality. High value of the PSNR provides a higher image quality.

$$PSNR = \frac{1}{MN} \sum_{j=1}^{M} \sum_{k=1}^{N} [f(j,k) - g(j,k)]^2 / \sum_{j=1}^{M} \sum_{k=1}^{N} Max\,[f(j,k)]^2 \quad (8)$$

ISSN: 0975-8585

The quality measures sensitivity, specificity and accuracy can be computed using equation (9) (10) and (11) respectively.

Specificity = TN (TP + FN) (9)

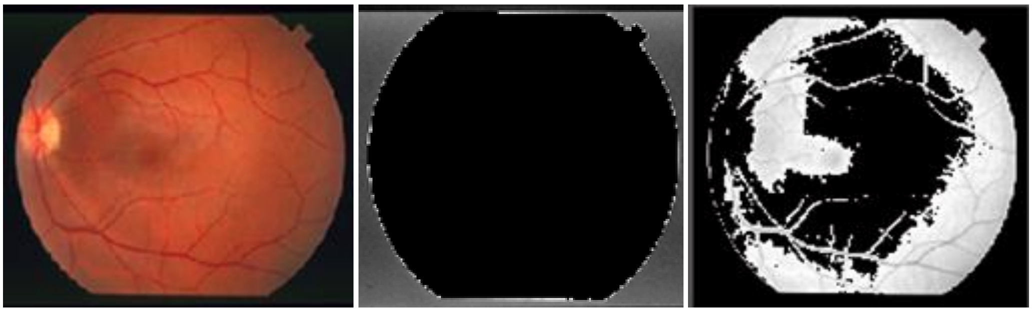
Sensitivity = TP/ (TP + FN) (10)

Accuracy = (TP + TN) / (TP+TN+FP+FN) (11)

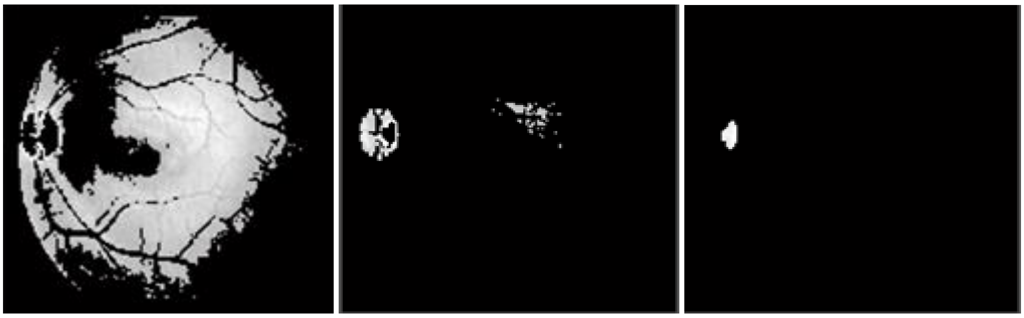
Table 1: Classification of exudates and non exudates pixels in retinal image

TP	True Positive	Number of exudates pixels correctly classified
FP	False Positive	Number of non exudates pixels incorrectly classified as exudates pixels
FN	False Negative	Number of exudates pixels not correctly classified i.e., not identified
TN	True Negative	Number of non exudates pixels correctly classified

Figure 2 shows the result of the exudates detection using k-means clustering method. The exudates detection using fuzzy c-means clustering and proposed approach is illustrated in fig 3 and 4 respectively.

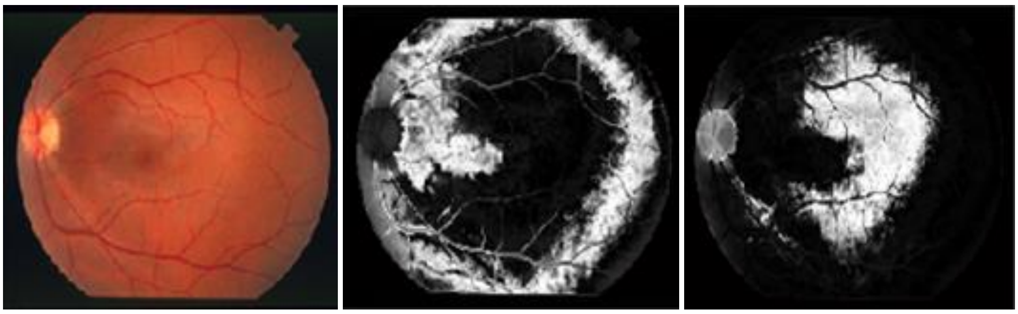


(a) Input Image (b) Region of Interest mask (c) Noise removal

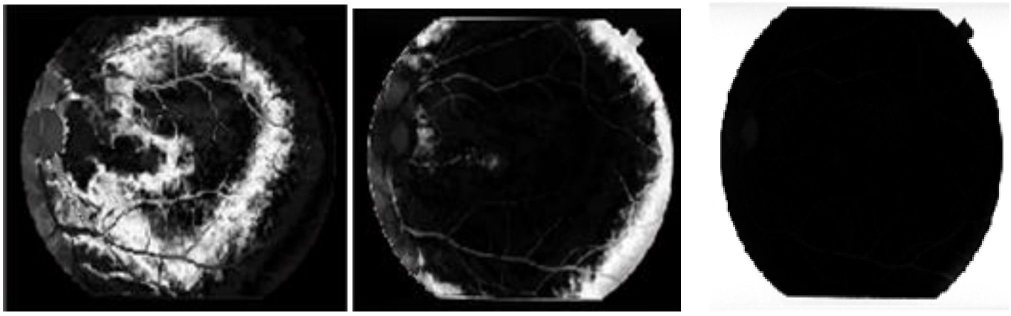


(d) K-means Clustering (e) Exudates Detection (f) Optical Disc

Figure 2. Exudates detection using k-means clustering method

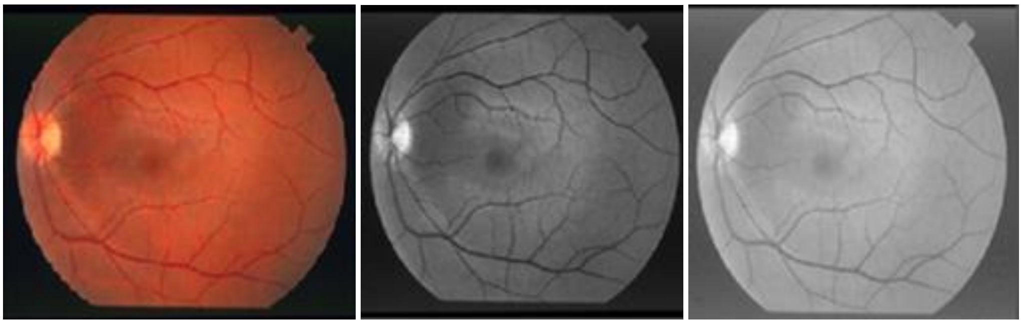


(a) Input Image (b) Region of Interest mask (c) Noise removal

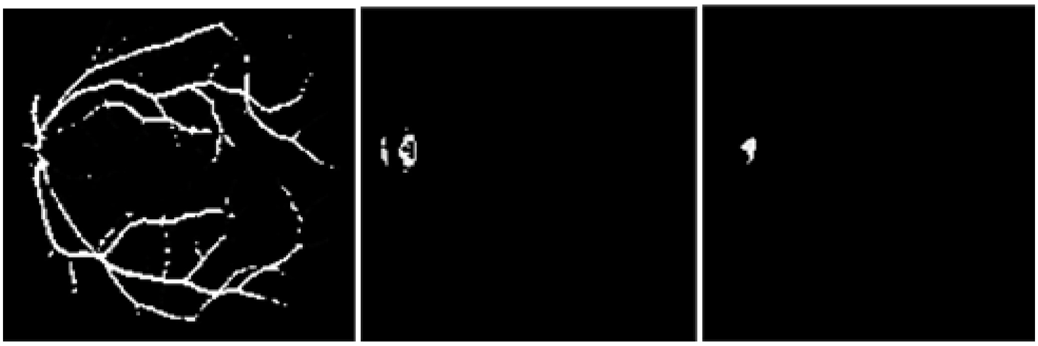


(d) Fuzzy C-Means Clustering (e) Exudates Detection (f) Optical Disc

Figure 3. Exudates detection using Fuzzy C-means clustering method



(a) Input Image (b) Intensity Image (c) Contrast Enhanced Image



(d) Retinal Vessel Segmentation (e) Exudates Detection (f) Optical Disc

Figure 4. Exudates detection using proposed method

Table 1 illustrates the comparative result of three methods (K-means, FCM and Proposed method) for the detection of exudates in retinopathy images.

Table 1: Effect of clustering method for the detection of exudates in retinal image

Sl. No	Parameter	K-Means	FCM	Proposed Method
1	MSE	31.49	0.2246	0.04684
2	PSNR	13.08	54.6158	71.4242
3	Noise Correction	0.6049	0.8543	0.9640
4	Sensitivity	78.9051	70.6244	95.2795
5	Specificity	84.6091	71.6086	99.8047
6	Accuracy	82.4003	78.382	98.9625

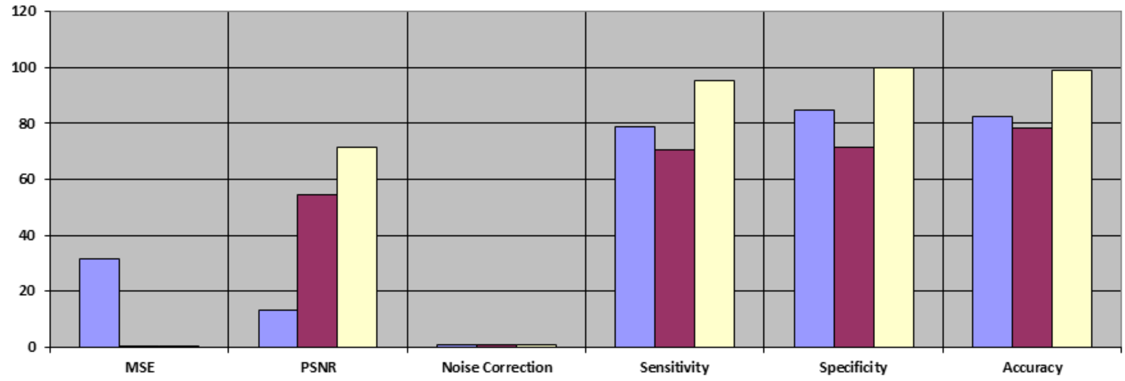


Figure 5. Evaluation of clustering method for the detection of exudates in retinal image

CONCLUSION

The automatic detection and segmentation of exudates in color fundus images of the diabetic retinopathy had explained. The detection of optical disc and exudates using k-means and fuzzy c-means clustering algorithm is compared with the proposed approach of principal component analysis. This comparison is based on the analysis of the resultant image produced by these methods using six image quality parameters. All six image quality parameters had supported the proposed approach of principal component analysis as compared to other two methods. The mean square error value is very low and the remaining parameters had produced high value for the proposed approach. So this paper easily concluded that the principal component analysis based detection of exudates and optical disc is more efficient as compared to either k-means or fuzzy c-means clustering.

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