

## **AUTOMATIC EXUDATES DETECTION FROM NON-DILATED DIABETIC RETINOPATHY RETINAL IMAGE USING FUZZY C-MEANS CLUSTERING**

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Exudates are the primary signs of diabetic retinopathy which are mainly cause of blindness. It could be prevented with an early screening process. Pupil dilation is required in the normal screening process but this affects patients' vision. Automatic computerized screening should facilitate screening process, reduce inspection time and increase accuracy. In this paper we proposed an automatic method to detect exudates from low-contrast digital images of retinopathy patients with non-dilated pupils using a Fuzzy C-Means (FCM) clustering technique. Intensity, standard deviation on intensity, hue and a number of edge pixels, were selected as main features to supply to FCM method. The number of cluster optimization was based on sensitivity and specificity which were calculated by comparison of the detected results and hand-drawn ground-truths from expert ophthalmologists. From the result, it is found that the proposed method detected exudates successfully with high accuracy of 92.18 % and 91.52 % for sensitivity and specificity respectively.

### **INTRODUCTION**

Blindness is an outcome of diabetic retinopathy and its prevalence is set to continue rising. An estimated 50-65 new case of blindness per 100,000 occurs every year [1]. The screening of diabetic patients for the development of diabetic retinopathy can potentially reduce the risk of blindness in these patients by 50% [2-4]. Current methods of detection and assessment of diabetic retinopathy are manual, expensive and require trained ophthalmologists. Fuzzy C-Means (FCM) clustering is well-known clustering technique for image segmentation [5]. It has also been used in retinal image segmentation [6-8]. Osareh *et al.* [6] used colour normalization and a local contrast enhancement in a pre-processing step. The colour retinal images were segmented using Fuzzy C-Means (FCM) clustering and the segmented regions were classified using a neural network. Xiaohui Zhang and Chutatape O. [7] used local contrast enhancement preprocessing and Improved FCM (IFCM) in Luv color space to segment candidate bright lesion areas. Most of techniques mentioned above worked on images taken when the patient had dilated pupils in which exudates and other retinal features are clearly visible. In this paper, we present an automatic method to detect exudates from low quality retinal images taken from non-dilated pupils from diabetic retinopathy patients using Fuzzy C-Means (FCM) clustering algorithm.

### **METHODOLOGY**

#### **Exudates detection**

The exudates can be identified on the ophthalmoscope as areas with hard white or yellowish colours with varying sizes, shapes and locations. They normally appear near the leaking capillaries within the retina. This part of the paper describes how features were selected in a segmentation process using FCM clustering and also explains how the number of clusters was optimized.

### Feature selection

Four features, namely, the intensity value after pre-processing, the standard deviation of intensity, hue and number of edge pixels from an edge image were selected as described as follow:

1. Intensity image after pre-processing ( $I_{CLAHE}$ ) is selected as one of the classification features because exudates pixels can usually be distinguished from normal pixels by their intensity. A median filtering operation was applied on the I band to reduce noise before a Contrast-Limited Adaptive Histogram Equalization (CLAHE) was applied for contrast enhancement.
2. Standard deviation of  $I_{CLAHE}$  was also chosen because the distribution measurement of the pixel values would differentiate the exudates area from the others since standard deviation shows the main characterization of the closely distributed cluster of exudates.
3. Hue, also extracted from HSI space, was the third feature selected because hue components make up chrominance information. From visual inspection, exudates appear differently in a yellowish or white colour.
4. Normally exudates gather together in small clusters so they tend to have many edge pixels around the area. However, during this feature extraction, we removed some irrelevant edge pixels, as described:
  - 4.1 For fast edge detection, a Sobel edge operator was used to compute the gradient magnitude.
  - 4.2 The result from the previous step was then thresholded in order to get most of the edge pixels.
  - 4.3 Some of the results are part of vessel's edge and these vessel edge pixels need to be removed before proceeding to the next step. Quick and approximate blood vessel detection was achieved by using a decorrelation stretch on the Red band. High-value red pixels selected from the decorrelation stretch image were chosen and added to the result from the previous step because the soft exudates normally appear red. However, red pixels which belong to the optic disc, which also appear red, have to be removed first. The optic disc was quickly detected by using an entropy feature on  $I_{CLAHE}$ .
  - 4.4 A number of neighboring white pixels of the resulting image from the process 4.1 – 4.3 was counted using a window size of 17 x 17 to form our final feature, namely an image of the number of edge pixels

Image of four features are shown in Figure 1. These four features were used to segmentation using Fuzzy C-Means clustering in next step.

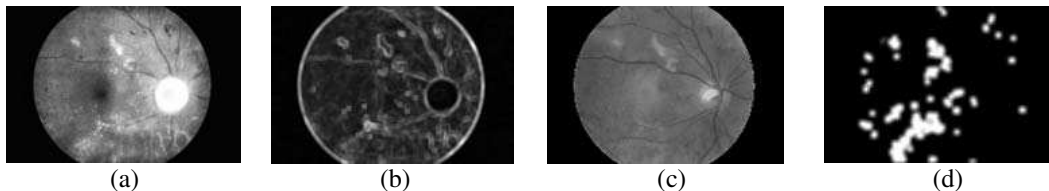


Figure 1. Input features for FCM clustering of image1. (a) Intensity image after pre-processing, (b) Standard deviation of intensity image, (c) Hue image, (d) Image of edge pixels.

### Segmentation using Fuzzy C-Means clustering

The FCM clustering algorithm was applied to 40 test images to get a result of two to eight numbers of clusters for each image. The accuracy of the output from this step will be calculated by

comparing with ophthalmologists' hand-drawn ground truth and the performance measurement of each parameter will be discussed in the following section.

### Performance measurement

The performance of each parameter was measured by comparing the detection result with ophthalmologists' hand-drawn ground truth and eight performance measurements, namely, True Positive (TP), False Positive (FP), False Negative (FN), True Negative (TN), sensitivity, specificity, positive predictive value (PPV) and positive likelihood ratio (PLR) were calculated [8,9]. The sensitivity was computed by  $TP/TP+FN$ , specificity was computed by  $TN/TN+FP$ , PPV was computed by  $TP/TP+FP$  and PLR was computed by  $(TP/TP+FN)/(FP/FP+TN)$ .

## RESULTS

The first candidate is the first cluster of clustering, displayed in Figure 2 (a). This cluster contains most of the original image information but all exudates are missing. For this case, the exudates pixels can be obtained by subtracting this first cluster with the original intensity image. The term Subtracted cluster will be used throughout the text to represent this result. The result is displayed in Figure 2 (b). The result might yield a very high true positive value; however, the false positive value would also be very high too due to misclassified non-exudates pixels. The second important candidate cluster is a second cluster of the classification result (referred as Second Cluster) as displayed in Figure 2 (c). This result has mostly exudates pixels. Even though this cluster contains fewer pixels, most of them are true exudates pixels which may give a smaller true positive value; however, it also reduces the false positive value because misclassification of non-exudates pixels is also lower. The average values of sensitivity, specificity, PPV and PLR of validation results on both Subtracted cluster and Second cluster are shown in Table 1.

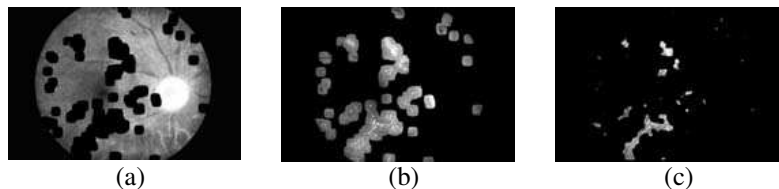


Figure 2. Candidate clusters  $n=8$ . (a) First cluster, (b) Subtracted cluster, (c) Second cluster.

## CONCLUSION AND DISCUSSION

In this paper, we have investigated and proposed methods to extract exudates from images taken from diabetic patients with non-dilated pupils. The work is based on the Fuzzy C-Mean (FCM) clustering segmentation technique. Four input features based on characteristics of exudates, namely intensity, standard deviation, hue and number of edge pixels, were selected. The performance of the algorithm was measured against ophthalmologists' hand-drawn ground-truth. Two main measurement values, namely, PPV and PLR were used as the performance measurement of exudates detection because they combine the true positive and false positive rates. The results indicate that the system can facilitate the ophthalmologist to detect the exudates in the screening process, however, the suitable number of clusters that the system need to segment the given input to is depending on ophthalmologist's requirement and application. If the applications require high accuracy Second cluster with  $n=8$  should be chosen because it gives a higher accuracy

with low false positive value. However, if the applications need to detect more exudates pixels or need to run faster, then Subtracted or Second cluster with  $n=2$  are recommended parameters.

Table 1. The average exudates performance evaluation results.

Number of cluster	Subtracted cluster				Second cluster			
	Average sensitivity (%)	Average specificity (%)	Average PPV (%)	Average PLR	Average sensitivity (%)	Average specificity (%)	Average PPV (%)	Average PLR
2	92.18	91.52	8.86	13.37	92.18	91.52	8.86	13.37
3	95.45	88.72	7.23	10.26	82.87	94.96	12.22	21.00
4	96.39	87.37	6.64	9.20	76.89	96.24	14.52	27.07
5	96.94	86.55	6.33	8.63	72.51	96.94	16.15	32.59
6	97.07	86.03	6.14	8.32	69.16	97.36	17.41	37.11
7	97.13	85.72	6.03	8.12	66.63	97.65	18.40	40.82
8	97.29	85.43	5.94	7.96	64.27	97.85	19.21	44.06

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