Detection of Hard Exudates using K-Mean Clustering for Screening of Diabetic Retinopathy

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Abstract

Diabetic Retinopathy (DR) is the prolong complication of Diabetes and is widely spread all over the world. Prolongation DR may lead to blindness, hence prevention at early stage of DR should be taken. Exudates are the primary sign of DR. Thus early detection of exudates may help in diagnosis of DR. In this paper, we have used k-mean clustering for detection of hard exudates with the optic disc, followed by mathematical morphological operation to eliminate the optic disc. A set of 30 digital retinal fundus images were used in this experiment. The performance parameter such as sensitivity, specificity and accuracy obtained as 84.7%, 99.62% and 99.57% respectively. The proposed method takes 34 seconds to automatically detect the hard exudates and thus reducing the time consumption of screening process by ophthalmologists.

Keywords: Diabetic Retinopathy, Hard Exudates, k-means clustering, morphology.

1. Introduction

Diabetes is a metabolic disorder. It occurs due to hyperglycemia i.e. constant increase of glucose level in the blood. It has been recognized and accepted by International Diabetes Federation (IDF) [1] that Diabetes is becoming a rapidly increasing health threat worldwide. Also it has been reported by IDF that worldwide 371 million people are suffering from diabetes, out of which 63 million people are suffering in India only. IDF also reveals that in India, 36 million cases are undiagnosed which leads to retinal disease, called as Diabetic Retinopathy (DR). Diabetic retinopathy may eventually lead to loss in vision or potentially blindness with increase in the time. Hence regular screening at early stage is recommended to reduce the visual symptoms of DR.

One of the primary sign of the DR is exudates. Exudates are an abnormality observed in the first phase of DR. Exudates typically is in cluster forms. These clusters may be adjacent to group of microaneurysms or around fovea. Exudates are yellowish intra-retinal deposits which are normally located in the posterior pole of the fundus [2]. The analysis and diagnosis of the disease from detection of exudates by ophthalmologists demands the use of chemicals for dilation of pupils, which may have a side effect on patients and requires great deal of time, this becomes laborious for ophthalmologists and inconvenient for the patients. Hence various digital image processing techniques are used for detection of exudates. A reliable method for automated assessment of the presence of lesions in fundus images will be a valuable tool in assisting the limited number of professional and reducing the examination time [6]. Thus it saves costs, time and labour. Figure 1 shows the Retinal image with Hard exudates and showing typical components of retina such as optic disc and main blood vessel.

We have concentrated on detecting exudates as these are primary indicator of DR disease, detecting retinal exudates in a large number of images that are generated by screening programmes is very expensive in terms of time and may lead to human error. With this motivation we proposed an automated method to detect the hard exudates using a

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combination of k-mean clustering algorithm and morphological operations. In the rest of the paper, section 2 presents some of existing methods to detect the exudates; Section 3 presents the methodology and outlines the main techniques used, while results and conclusions are presented in Section 4.

![Retinal image with Hard Exudates](Image)

**Fig 1: Retinal image with Hard Exudates**

### 2. Related Work

Various methods were used by several people for exudates detection. Few of them are described below in accordance with their proposed method and performance parameters.

JayaKumari et al [3] proposed a method for detection of exudates using contextual clustering technique. This technique is used for the segmentation of hard exudates from the pre-processed image. An Echo State Neural Network (ESNN) was designed for the classification of hard exudates. This method produces sensitivity as 93% and specificity as 100% regarding the exudates based classification.

Osareh et al [4] proposed a system for Hard exudates detection using Fuzzy C-mean (FCM) clustering technique for the segmentation. The segmentation process is carried out on a normalized, contrast enhanced image obtained from the colour retinal image. Classification of segmented region as exudates or non-exudates was fulfilled by an artificial neural network classifier. It provides 93.0% sensitivity and 94.1% specificity in terms of exudates based classification.

Hussain et al [5] reported an automated method for detection of, hard as well as soft exudates, using a split and merge technique. This method is based on coarse to fine segmentation principle. In this algorithm, the green channel is used for pre-processing and elimination of optic disc. Coarse exudates detection is based on local variation operator whereas adaptive thresholding technique is used for fine exudates detection. This combination of fine and coarse exudates is used for the improvements in the results. This method provides the performance measure as 89.7% sensitivity and 99.3% specificity.

C.Sinhanayothin et al [7] reports a system of automated detection of Diabetic Retinopathy by detection of exudates, haemorrhages and microaneurysms. The author introduced Recursive Region Growing Segmentation (RRGS), used on 10x10 window with selected threshold value, for detection of exudates. The author also proposed the detection of anatomical component of retina. The sensitivity and specificity for exudates detection were 88.5% and 99.7% respectively.

Akara et al [8] used a mathematical morphological technique on non-dilated pupil retinal images. In this paper the optic disc was eliminated prior to the detection of hard exudates. The author implemented a set of optimally adjusted morphological steps to automatically detect the exudates. The process time for this algorithm is 3 min. approximately, out of which it took 1 min to eliminate the optic disc. The algorithm provides the sensitivity and specificity as 80% and 99.46% respectively.

Akara et al [9] detected the exudates for Diabetic Retinopathy using a Fuzzy C-Mean (FCM) clustering technique. Optimal selection of number of cluster was done using FCM algorithm. The number of clusters varied from 2 to 8 clusters and the processing time varied respectively from 1.5mins to 18 mins. With 2 clusters the sensitivity and specificity was 92.18% and 91.52% respectively.

The comparative study of automated techniques for exudates detection [10] has shown that specificity and accuracy of k-means clustering technique are higher than other techniques. The processing time required is also very low (seconds) as compared to FCM techniques (mins)[8,9]. Thus the combination of morphological and k-mean clustering method provides a technique to detect hard exudates that consumes less time duration for processing and with better performance parameters.

### 3. Methodology

We have used the digital retinal images from the MESSIDOR database. These images were captured using a colour video 3CCD camera on a Topcon TRC NW6 non-mydriatic retinograph with a 45 degree field of view. The images were captured using 8 bits per colour plane at 1440x960 pixels. The images were stored in TIFF(.tif) format[11]. The flowchart of the proposed method to detect hard exudates from the digital retinal images is shown in Fig.2.

The proposed method is divided into two parts. The first part is pre-processing of the raw image which is described in section 3.1. Second part consists of detection of hard exudates using the k-means clustering included in section 3.2.

#### 3.1 Pre-processing

At first the Red, Green and Blue colour space is converted into Hue, Saturation and Intensity space. Intensity is one of the classification feature to distinguish the exudates pixels. The intensity component from HSI
space is preferred as it allows the other two colour components to be separated from it. The retinal images obtained may be noisy and with non-uniform illumination due to various reasons. Sometimes, the contrast of the images might be low. Hence Contrast Limited Adaptive Histogram Equalization (CLAHE) is used for contrast enhancement, thus making the visual appearance of hard exudates distinguishable. But with this enhancement, noise in the image also get enhanced which is undesired. Hence Median filter is applied prior to CLAHE. After the pre-processing the clubbed HSI image is converted back to RGB colour space for further processing. Fig 3 shows the original image, the extracted I-channel from HSI color space, the contrast enhanced I-channel image and the completely pre-processed RGB image.

![Fig. 2. Procedure of proposed detection method](image)

### 3.2 Detection of Hard Exudates

In this proposed method the segmentation of the objects is based on their colour features, as hard exudates are the bright lesions in the retinal image with distinct boundaries. Here we have used the CIELab colour space. This colour space is the second of two systems adopted by CIE in 1976 as models that better showed uniform colour spacing in their values [12]. In L*a*b* colour space, L indicates the Luminosity layer, a* consists of the chromaticity layer which indicates the colour value on red-green axis whereas the chromaticity layer of b* indicates the colour value along yellow-blue axis.

Firstly we have transformed the colour enhanced RGB image to Lab colour space. The chromaticity layer of a and b are extracted from Lab colour space for colour separation. This matrix containing only colour information is used for k-means clustering algorithm.

In k-means clustering algorithm, a certain number of clusters(k) should be fixed. The k-means algorithm steps are as follows:

- Assign each object to the group that has the closest centroid.
- Repeat till the centroid values remains unchanged

This algorithm assigns each object to the group that has closest centroid, thus providing us with k (here k=6) different images containing each cluster. The objects are partitioned in such a way that they are close to each other as possible and as far from other objects in other clusters. To separate the image with exudates and optic disc, we have used the Euclidian distance factor. A manually defined centroid(p) was compared with all the centroid obtained by k-means algorithm. The cluster having the centroid with minimum difference from that of manually defined centroid(p) was selected. Thus finally, we obtained an image containing exudates and optic disc, as optic disc is similar in terms of intensity, colour and contrast to that of exudates.

Next step consist of elimination of optic disc. This is done using morphological closing operations. The optic disc appears as a bright yellowish, circular form. It has maximum cross sectional area. The optic disc size varies from one person to another occupying about 1/10 to 1/5 of the image [12]. Firstly, a circular structuring element is used for carrying out a morphological closing operation.
on the extracted cluster image. Then the object with maximum area is subtracted from the main cluster image. Thus we obtain an image only with hard exudates. The results of proposed method of hard exudates detection are shown in Fig.4.

3. Results and Discussion

Experiments have been carried out to test the proposed method. The results of this experiment are verified using the expert ophthalmologist hand-drawn ground-truth. Here, we have used a set of 30 images which are abnormal images containing bright lesions of various intensity, size and numbers. These images were randomly chosen from standard MESSIDOR database. The proposed method was evaluated using the performance parameters namely - Sensitivity, Specificity and Accuracy. To obtain these parameters four types of pixels are considered; True positive (TP), True negative (TN), False positive (FP), false negative (FN). Equations below shows the calculation of performance parameters

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\text{Sensitivity} = \frac{TP}{TP+FN} \times 100
\]

\[
\text{Specificity} = \frac{TN}{TN+FP} \times 100
\]

\[
\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \times 100
\]

Using this, the sensitivity, specificity and accuracy obtained in our proposed method are 84.74%, 99.62% and 99.57% respectively. The number of non exudates pixel that are falsely detected as exudates (FP) is comparatively high, hence the specificity is almost close to 100%.

The proposed technique may ease the diabetic retinopathy screening process of ophthalmologist on a wide scale. This technique can be further developing to detect Microaneurysms and haemorrhages. In future a combined system that can detect all the abnormalities present in fundus image can be developed which will help to decide the degree of diabetic retinopathy.

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References