Exudates Detection in Fundus Image using Image Processing and Linear Regression Algorithm

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***Abstract*: Diabetes disease is the fastest growing disease in India, which will affect our eye indirectly and it is called as diabetic retinopathy which will lead to vision loss where exudates formation is the prominent early sign of DR. So our propose method is to successfully detect the exudates with 94% accuracy by nullifying the optic disc because the OD and exudates are of same intensity. Image processing and linear regression, a machine learning technique is involved, which is used to train machine to differentiate between OD and exudates. This helps ophthalmologist's life easy to treat patients in early stage.**

***Index Terms*: Diabetes, diabetic retinopathy, linear regression, machine learning, image processing**

I. INTRODUCTION

In this era of 2020, as we all know, increased urbanization, intake of unwholesome food, desk- bounded lifestyle that is probably leading to obesity, impart to the rise in diabetes. Diabetes is much prevalent in low-resource countries. According to a research conducted, India is second on the list of countries suffering from diabetes with age ranging from 20 to 79 [1]. Diabetes is associated with multiple disorders in the body. It may cause many complications in an eye. One of them is the diabetic retinopathy (DR). It may increase the threat of blindness, if it is not treated early. Usually DR is seen in the people having high blood sugar, high blood pressure and cholesterol. The glucose levels in blood changes in retinal blood vessels. Initially DR may be seen with no symptoms or only humane vision problems. Eventually it may cause blindness.

Diabetic Retinopathy is caused when excessive sugar is present in body lead to blockage of small blood vessels that feed retina the essential nutrients by stopping blood supply. As a result, the eye starts to grow new blood vessels as replacement in areas where the blood vessels are not to be found. This condition is called revascularization [2]. These blood vessels that grow hastily can sometime disintegrate and leak essential lipids in the retinal area. This condition of deterioration is called Diabetic Retinopathy [3]. The yellow fatty lipid deposits formed are known as exudates. Due to their high intensity values, they are often called as bright lesions. There are two types of DR, one is Early DR and the other one is advanced DR [4].

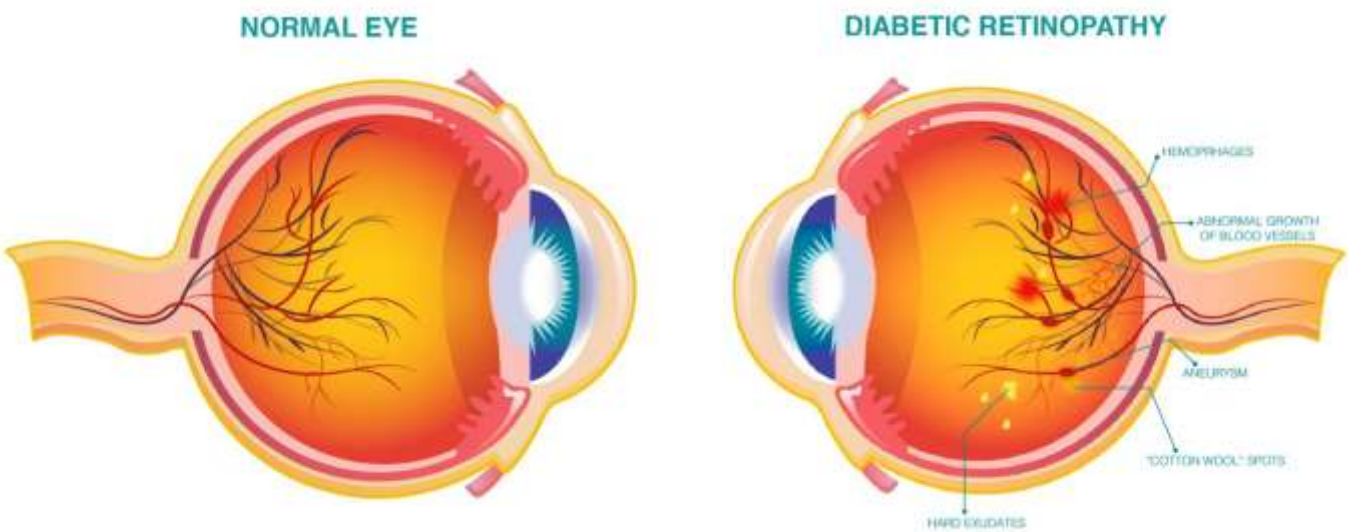


Fig. 1.Normal and DR retinal image

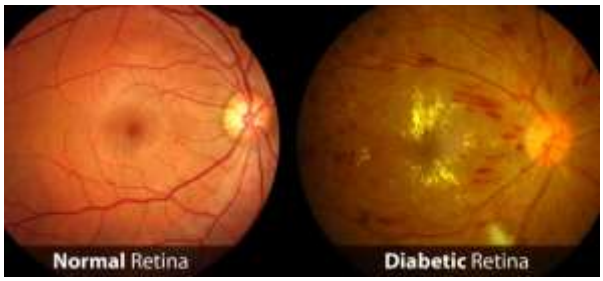


Fig. 2.Fundus image in both normal and DR

In early DR, often known as NPDR (Non-Proliferative DR), walls of blood vessels in retinal area become delicate, tiny lumps protrude from the vessel walls and start leaking fluid and blood into retinal area. This is very common in many patients. The other type is advanced DR, well known as PDR (Proliferative DR), where the blood vessels injured close off, which causes growth of new, unusual blood vessels in retinal area and leak into plain, gelatin like substance that fills center of eye. These two types range from mild to severe cases. Early signs of DR include formation of exudates, micro aneurysms (MA), cotton wool spots, hemorrhages (HE), which correspond to NPDR. If left untreated, this disorder enters PDR stage, where vision loss cannot be
Prevented due to Revascularization. The difference between normal retina and DR retina is shown in Figure 1.
Usually Ophthalmologists are the one who treats the eye disease. The images of retina are taken from a fundus camera, which are known as fundus image, shown in figure 2. With respect to anatomic nomenclature, a fundus means a part of a hollow organ; the organ being eye here. The ophthalmologists examine these images and identify the presence NPDR or PDR. Over past two decades, several attempts are being made to make the process of exudates detection automated, with intentions of making doctors' lives easy [5] and also reducing human errors in diagnosis. But the major problem that lies with respect to algorithm development is the fact that the optic disk (OD) of the eye has similar intensity values as that of the exudates. Hence, many times, parts of OD are misdiagnosed to be exudates, thus leading to false analysis.

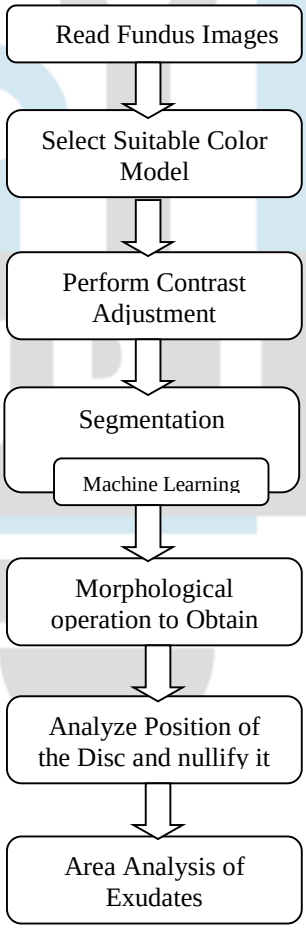


Fig. 3.Flow diagram of proposed method

The most popular techniques used for exudates detection are Support Vector Machine (SVM), morphology mean shift algorithm (MMS), mathematical morphology and entropy threshold, delta rank transform and so on. The authors in [6] propose the use of gamma correction technique to detect exudates, which yields a low accuracy.

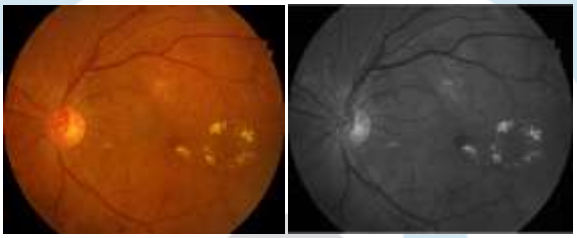
In [7], MMS is used. According to the method, the morphology mean is found by considering some window size manually which is not trivial. In [8], the authors use a classification-based machine learning technique called SVM, where choosing its kernel function is complex and the processing speed is very low. In [9] the delta rank transform was used, where it was robustness against the noise and accuracy was less. A detailed survey has been carried out in [10]. In this paper we propose an algorithm for automatic detection of hard exudates using linear regression.

II. Proposed Method

The main objective of the work carried out in this paper is to detect the exudates from fundus image. A supervised learning technique called linear regression is used for this work. The flow of the project is shown in Figure 3. Each step in explained in detail in this section.

Acquire fundus image

The initial step is acquiring Fundus images from database. The database used are DiaRetDB0 [11], DiaRetDB1 [12], MESSIDOR [13] and IDRiD [14]. A total of 60 images with both healthy and unhealthy retinal images are considered. The green component from the color fundus images is extracted, as shown in Fig. 4. This component is chosen as it shows lesser variation than other color components.



(a) (b)

Fig.4. (a) RGB image, (b) Green extracted image

Contrast enhancement

Once the images are read and color model is chosen, the next step is to enhance the image so that the exudates and OD stand out from the background. In order to do so, a special statistical technique based on histogram is utilized. It is termed as Mean by Histogram Approximation Technique (MbHAT). According to this method, the first peak that occurs at lower bins of histogram, as shown in figure. 5 correspond to the black background around the fundus area. This has to be eliminated.

After removing the background, next step is to find the mean of fundus image. As we can see in figure 5 the histogram has bins (x axis) which range from 0-255 and counts (y axis) that depicts the light intensity variations in fundus image. Using these two axes we find the mean value. Initially the maximum and minimum difference is found using the counts corresponding to bins.

Finally mean is found using equation1.

$$\text{Mean} = \sum_{i=min}^{max} (\text{counts}(i) * \text{bins}(i)) / \text{counts}(i) \text{ ----------Equation 1}$$

Once the mean is found that is nothing but threshold value which is found automatically. It is further used for segmentation.

Machine learning

In our work the next step is segmentation where machine learning technique is used. Here we use linear regression. It is the statistical modeling used for analyzing for estimating the relationships between a dependent variable and one or more independent variables [15]. It is based on supervised learning to predict a dependent variable based on given independent variable. So this is called linear relationship between x and y.

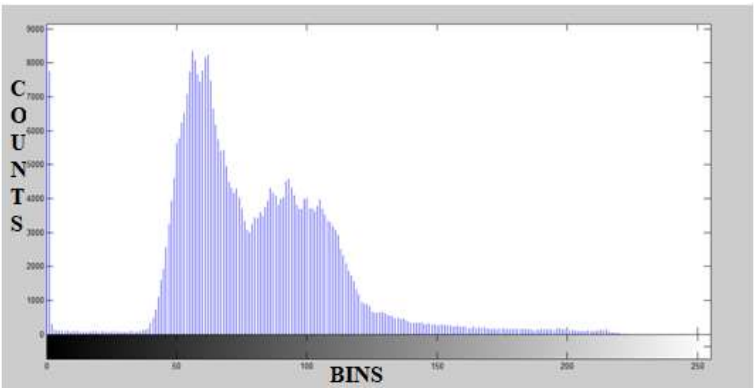


Fig.5. Histogram of fundus image

(a) (b)

Fig.6. (a) RGB image, (b) Segmented image

In this step we considered 30 images from database for training purpose. Hence we trained the machine with some set of images, and rests are used for testing. So therefore, in this step we give training to machine to extract the exudates from the whole image. Once the mean is found it was used as threshold which is found automatically and used in quadratic model equation which was found. The quadratic model equation is shown in equation2.

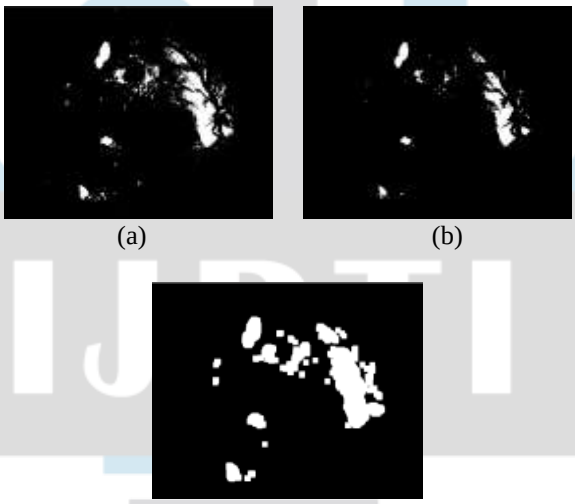
$$Equ = a * mean^2 + b * mean + c$$ ----------Equation (2)

Using this equation, the image will be segmented, where it turns to black and white image. The OD and exudates are made white others to black as shown in figure6.

After the segmentation is done, to only extract exudates, we performed Morphological operation to process image based on shapes. The two imporatant operaion is used erosion and dilation [16]. Initially erosion is done on image considering square shaped structuring element to takeout the small blobs close to OD as shown in figure 7(b). Dilation with disc shaped structuring element is carried out that makes sure that any split blobs are merged into one unit, as shown in figure 7(c).

Detection of exudates

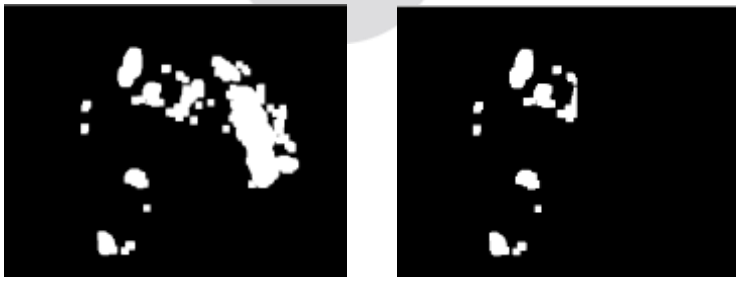
After the Morphological operation is done, we need to find area of blob that is the area covered by white pixel. Blob is nothing but the class of connected regions in segmented image. This blob is called contour. So this is used to find the size of object to be examined. Using this we find the maximum area. Once the max area is found, the OD will be masked so that only exudates are seen in the image as shown in figure 8(b).



(a) (b)

(c)

Fig.7. (a) Segmented image, (b) Eroded image, (c) Dilated image



(a) (b)

Fig.8. (a) Dilated image, (b) Masking using contours

Once the Masking is done, It is still in dilated image form, we need to convert it back to the normal form so now we use

the following to convert. equation(3).

$$\text{dilation} != 0 \,\&\&\, \text{segmentation} = 1 = \begin{cases} \text{dilation} = 1 \\ \text{else} \\ \text{dilation} = 0 \end{cases} \text{----------Equation 3}$$

After using this equation 3, we get the normal image with only exudates seen in figure9. Using this way we get the exudate detected. Next process is to find the area of exudates so that it is easy to get to know the amount of spread in retina. Using that the opthalmologists can treat accordingly.

The algorithm is given below which describe in brief about the linear regression used in segmentation. Here the input is taken as green extracted image, then we found the histogram of the image to get counts and bins. Later mean was found using histogram to remove the background and enhance the image. Finally the slope was found and performed segmentation using the slope .

finally the output image was in the form of binary image as shown in figure 6b.

Algorithm used for segmentation using linear regression

Input: Green component extracted from RGB retinal Image.

Step 1: Find the histogram of an input image, which consists of counts and bins

Step 2: Compute the mean value using MbHAT

- Compute the min and max value
- Mean = sum (counts(i*bin(i)) / sum(count(i)), where i belongs to minbin and maxbin

  Step 3: Compute segmentation using linear regression.
- Do slope calculation

$$Equ = a * mean^2 + b * mean + c$$

- for all rows and columns

  If (pxl > equ)

  Seg = white

  else

  Seg = black
- Print the segmented output

  Output: The binary segmented output of an image.

III. Results And Analysis

In our work we used standard diabetic retinopathy databse level 0 and 1 (DiaRetDB0, DiaRetDB1), Methods to evaluate segmentation and indexing techniques in the field of retinal ophthalmology (MESSIDOR) and IDRiD (Indian diabetic retinopathy image dataset) datasets are used for detection. Out of these datasets fundus images 60 images were selected which consists of hard exudates.

Exudates sign in it which had healthy and unhealthy retinal images. Till date as many research is done on automatically detecting exudates, were SVM, and CNN and so on technique used to extract the exudates but here in our project we are using supervised learning technique called linear regression which could overcome some of the disadvantages which had occurred in SVM,CNN,KNN and so on.

The Python 2.7.5 tool is used as code editor to do the development, where OpenCV (Open Source Computer Vision Library) is the library used for solving computer vision problems which makes use of Numpy for arithmetic operations and to work with images to detect the shapes. Therefore system should have the configuration of 2GB RAM, 120GB of disk space and dual core processor.

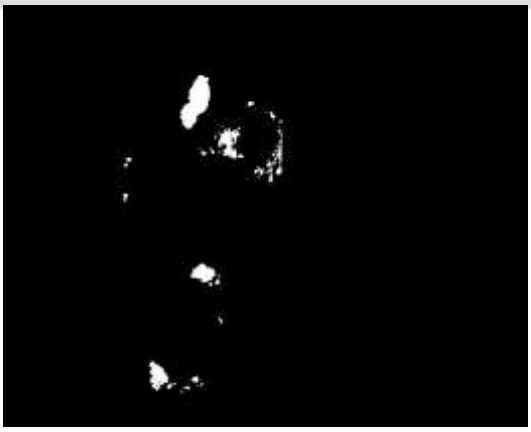


Fig. 9. Exudate detection image

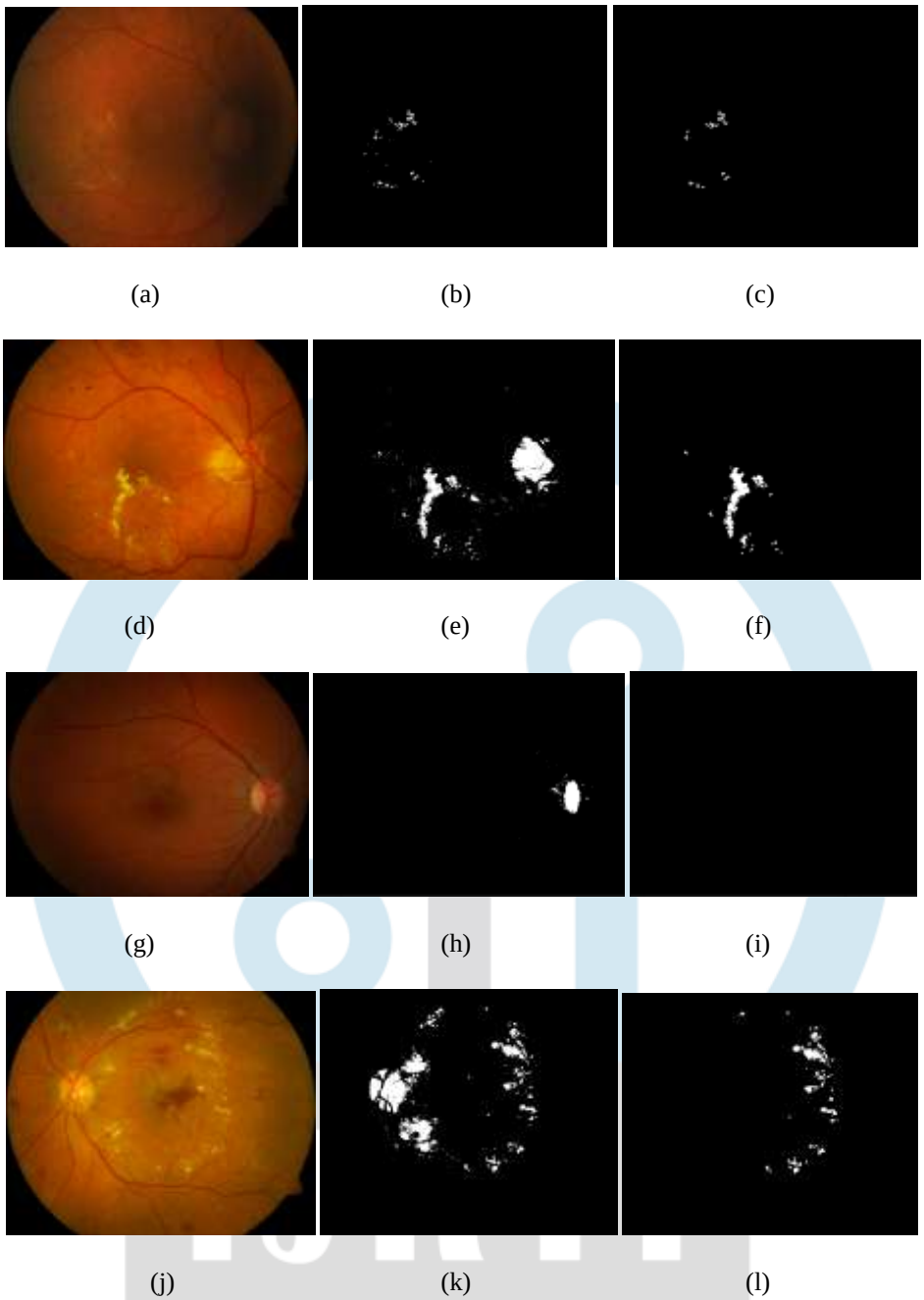


Fig.10. Results of proposed method (a) OD not seen, (b) segmented image. (c) output image, (d) image with high intensity, (e) segmented image, (f) output image, (g) No exudates, (h) segmented image, (i) output image, (j) uniform intensity image, (k) segmented image and (l) output image.

The technique which we used will check the images linearly based on intensity and mean value found, in machine learning to detect the exudates automatically without depending on pattern matching. As SVM uses template for all the images then depending on some parameters selected should find score and pattern matching done for all images which is finally time consuming and high memory intake. But in our method there will be no pattern matching used so we overcome the disadvantage of SVM and found the exudates by nullifying the OD. An accuracy of 94% is obtained from this method.

The outputs of this method is shown in figure 10. Where there is different cases which are handled by this method like in figure 10(a) the OD is not seen, the exudates are properly extracted and shown in figure 10(c). In 10(d) shows the case where intensity is more both in OD and exudate, and the output figure 10(f) exudates are extracted properly by removing the OD. In figure 10(g) shows where there is no exudates in it and the output is perfectly seen in figure 10(i). In figure 10(j) the image with higher intensity and output as we can see in figure 10(l) the output is extracted with good accuracy.

IV. Conclusion

The diabetes is considered as fastest growing disease in India, which will affect our eye indirectly and it is called as diabetic retinopathy which will lead to vision loss. As hard exudates are one of the prominent early sign, our work is to successfully detect exudates by nullifying the OD in fundus images of the eye with 94% accuracy. The difference from that of using SVM and CNN is

that they had disadvantage of low processing speed and high memory consumption but by using linear regression it has overcome those disadvantage. And therefore helping our ophthalmologists to easily detect the exudates and treat patients in early stage. Hence in turn helping the medical field. Therefore making ophthalmologists work stress less and improving the efficiency of DR screening.

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