Effective contrast enhancement techniques for Fundus images

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Abstract: Type-I and Type-II diabetes is an ever increasing condition booming nowadays in this era. Diabetic Retinopathy (DR) is an eye condition which is targeted on such patients. The characteristic of this DR is basically aimed at the minute blood vessels present in the eye. A feature known as "Exudates" starts to appear while examination of the eye. The cause of such features in the fundus of the eye is actually the presence of fluid that would eventually ooze from the vessels. Neglecting this situation would result in blindness too. A detailed analysis is necessary for us to improve the patient's health. Examining the fundus of the eye and analysing it accurately would help in avoiding the severity of the disease. Image processing technique allows one to capture an RGB model of our fundus wherein all the features of the eye, that might include blood vessels, exudates, and haemorrhage if any. With the obtained image, the major job is to now analyse the data thoroughly and provide an appropriate treatment. In order to distinguish between the exudates and the other features, we first choose an effective colour model to observe a better contrast of the exudates. Further, we perform a unique segmentation technique wherein we automatically detect the adversity of the exudates population in the fundus image of the eye by which we would be a guide for suggestive treatments.

Keywords: Optic Disc; Fundus; Exudates; Diabetic Retinopathy (DR); Threshold; Segmentation; Threshold

I. INTRODUCTION

In the era we are living in today, most of the individual living dwells on a non-active society wherein physically being active and physical and mental fitness is highly questionable. With the existing lifestyle of our environment, we have contributed to building a way for quite a few unhealthy situations, in other words, a house for a variety of medical conditions to rest upon human-kind. There is a list of common diseases that pop up one's mind, however, we will highlight on the most popular condition existing especially among the senior population, which is diabetes.

Type-II diabetes is a situation of a complete imbalance of sugar levels in the body. This causes a room for a variety of health disorders, one among which is the Diabetes Retinopathy.

This is a disorder associated directly with the eye causing severe blindness also when left untreated. Fig. 1 shows an image of a normal healthy eye and a DR affected eye [1].

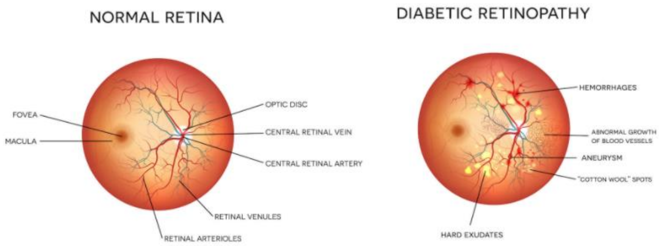

Fig 1. (a) Normal Healthy Image of an Eye; (b) Unhealthy Eye with a DR disorder

A healthy fundus image of the eye may consist of optic disc and blood vessels only. Whereas an unhealthy DR fundus image will constitute various other abnormal features such as exudates, which may be a "cotton-wool" like appearance, hemorrhage, or even any extra vessel growth.

There are two kinds of DR conditions – Proliferative Diabetic Retinopathy (PDR) and Non-Proliferative Diabetic Retinopathy (NPDR) or early diabetic retinopathy, as shown in Fig. 2 [2].

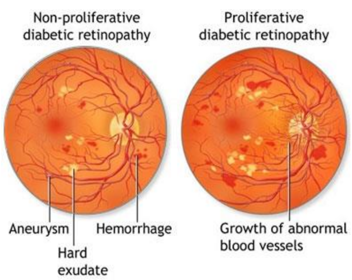

Fig 2. (a) NPDR condition (b) PDR condition

The NPDR affect may be of different levels of intensity. It can be mild, moderate or severe increasing the damage to the blood vessels of the retina gradually. A PDR on the other hand affects the newly growing blood vessels leading to even a retinal detachment [3].

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Performing and examining the condition of the fundus is of great importance to provide a suitable diagnostic treatment. The captured images of the eye is subjected to a series of analytical methods using the image processing technology so as derive on a better resultant image for the detection of the disease and the influence of the same.

The first step to be performed on the pathological image obtained in order to achieve an appropriate exudate detection of the fundus is to convert the image with a better level of contrast. Consider Fig. 2 which shows an example of a few fundus images.

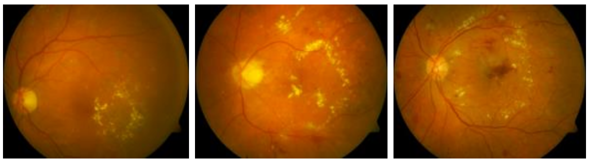


Fig 3. Different fundus images obtained in the RGB model

It is evident from the Fig. 3 that the exudate as well as the optic disc is of the same colour tone. Hence differentiating these two features is a critical step. The images are usually found in the RGB model. In the process of extraction, we first use the true colour analysis, wherein we choose the best possible colour mode suitable for further processing.

Following this step, we move on to correcting the contrast of the image. We do have a number of methods already existing in performing the colour enhancement regime, which we will discuss in this paper. Among the available techniques, we choose the best fit. The resultant image would give us a feature enhanced output with salient features amplified with a distinguishable edge definition.

The highly contrast adjusted image is then subjected to process known as Segmentation. This is an important process of exudates extraction as this is the step where we try to bifurcate the affected areas from that of the existing features that will normally exist in the eye. Our aim while segmenting the exudates will be to develop an automated fashion to increase the accuracy of the prescribed treatment. Hence, a versatile algorithm for the same is derived to exclusively eliminate the optic disc, which is mainly the feature that would camouflage the infection. Having the final image with only the infected area of fundus, we will apply Content Based Image Retrieval for therapeutic suggestions.

II. METHODOLOGY

The basis of our paper is to develop a novel methodology to differentiate between the exudates of the fundus from that of the optic disc, which is the major part of the eye that is observed to cause a similar pictorial impression at the RGB level.

The basic process outline of the methodology is shown in Fig. 4. Each step is sequential, bearing its own purpose in the automated algorithm.

1. The processor is fed with fundus images obtained by pathological examination of the eye.
2. The entire algorithm is loaded within this processor for automatic segmentation and CBIR.
3. Following are the contents present within the algorithm:
   a) Acquisition of fundus image.
   b) Colour model selection
   c) Performing contrast adjustment
   d) Segmentation to get a black and white fundus image
   e) Modify the morphological of the optic disc
   f) Detect and nullify the optic disc
   g) Exudate's area is retrieved

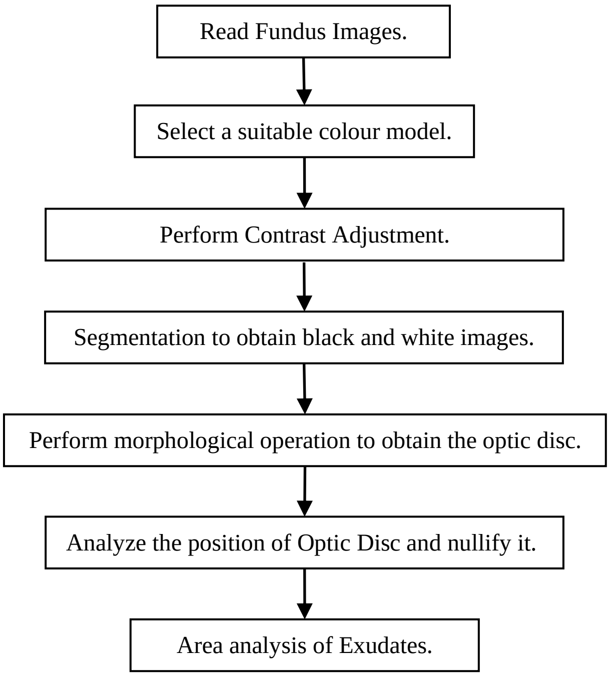


Fig 4. Process Flow of Exudate Extraction

III. PRE-PROCESSING

An image obtained post the lab examination will have to undergo few pre-processing operations before the commencement of segmentation as shown in Fig. 5. There are two main processes in this regime. Initially, we choose a good colour model from the RGB image, i.e. either Red, Blue or Green. Following this, we do the colour enhancement procedure wherein the exudates are significantly visible from that of the background data present.

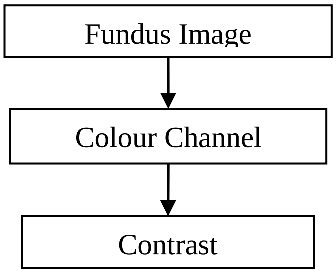


Fig 5. Process Flow for Pre-Processing

A. Fundus Image Acquisition

DiaRetDB0 and DiaRetDB1 is a database of various fundus images which is open for public access. We use images from the dataset for our experiment.

For an ease of observation, we categorize the image database into 3 colour modes based on the intensity of the image, i.e., light, medium and dark mode, as shown in Fig. 6.

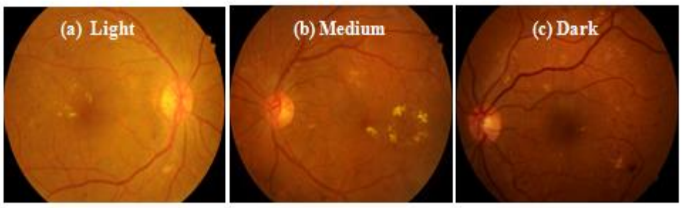
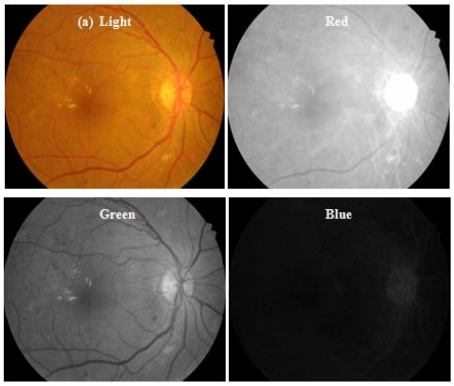


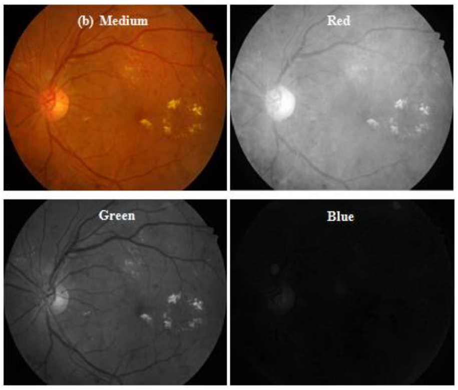
Fig 6. Fundus images with varying brightness levels

B. Colour Channel Selection

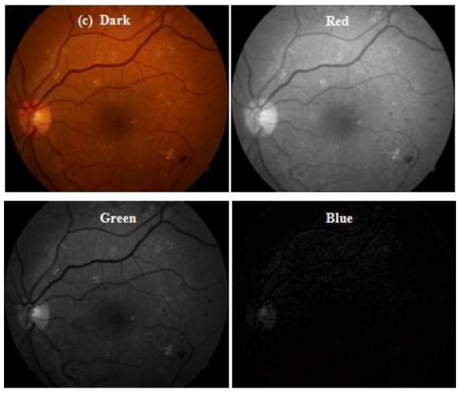
This is the initial step in our pre-processing flow. We know that the pathological is of the RGB model format. In order to perform segmentation, we have to convert the RGB image into a monochromatic one. The main point of consideration is to have a clear observation of the exudates and other features without any distortion or any other merging effect. Images are individually examined under every true colour to know the best image clarity. As said early, all the images segregate under three brightness levels are subjected and compared for a best fit.



(a) Light contrast fundus image



(b) Medium contrast fundus image



(c) Dark contrast fundus image

Fig 7. Fundus images with Red, Green and Blue channel models experimented on varying contrast dataset

From the above images as shown in Fig. 7, the green channel seems to produce a qualitative image that can be used for further segmentation. The image post green filter is observed to project the exudates as well as the blood vessels in the fundus of the eye [4].

C. Contrast Enhancement

The image with the green channel component now requires contrast enhancement. There are various ways to perform this process and obtain a good image. The most accurate out of all the other methods that are discussed in the following section, we find out that the Non-Linear Brightness Transformation (NLBT) produces the best output.

Let us have a brief discussion on few existing transformation methods that exist already.

a) Logarithmic Transform

In this method, each pixel is transformed to its logarithmic value.

The log transformations can be defined by this formula,

$$s = c \log(r + 1) \quad (1)$$

where 's' and 'r' are the pixel values of the output and the input image and 'c' is a constant [5].

The dark pixels of the image are basically expanded while the higher pixel values are compressed. The minimum pixel value is kept to at least 1 even if a log(0) exists. The gray levels are expanded or compressed based on the amplitude, whether low or high [5].

b) Non-Linear Brightness Transformation

In this image processing transform, each output pixel's value depends on the brightness of an image. This algorithm basically plays around with the brightness and contrast of the image. Here, the brighter regions become more bright, and the dark regions become more dark.

c) Histogram Equalization

Histogram equalization is a method to modify the intensity distribution of a histogram to obtain an adjusted contrast image. Histogram equalization is one of the forms of nonlinear contrast enhancement that is put mostly to use. An equalized histogram will have all pixel values redistributed so that each user defined / specific output gray scale will have an equal number of pixel approximately. The regions bearing the utmost population of brightness values in the histogram will experience and increased contrast. There will be automatic reduction of the contrast too in light or dark regions of the fundus image [6].

d) Adaptive Histogram Equalization

It differs from ordinary histogram equalization in the respect that the adaptive method computes several histograms, each corresponding to a distinct section of the image, and uses them to redistribute the lightness values of the image. It is therefore suitable for improving the local contrast and enhancing the definitions of edges in each region of an image [6].

e) Contrast Adaptive Histogram Equalization

Contrast Limited AHE (CLAHE) differs from adaptive histogram equalization in its contrast limiting. In the case of CLAHE, the contrast limiting procedure is applied to each neighborhood from which a transformation function is derived. CLAHE was developed to prevent the over amplification of noise that adaptive histogram equalization can give rise to [7].

Table 1 shows a comparison of all the images of the various transformation methods performed for the three different brightness modes.

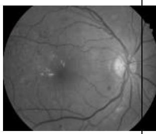
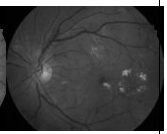
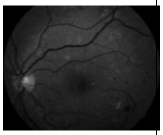
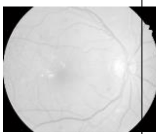
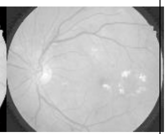
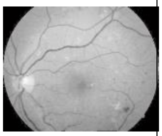
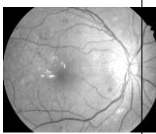
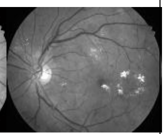
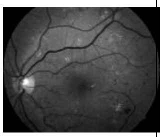
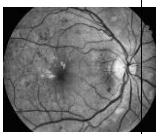
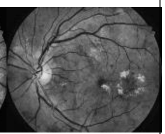
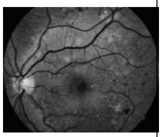
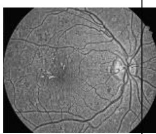
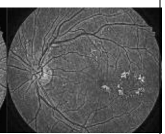
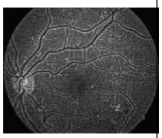
Type of Transformation	**Original Colour Contrast of Image**		
	Light	***Medium***	***Dark***
Original Image			
Logarithmic Transformation			
Non-Linear Brightness Transformation			
Adaptive Histogram Equalization			
Contrast Adaptive Histogram Equalization			

Table 1. A comparative table of different transformation methods

IV. SEGMENTATION

This is a process of partitioning the fundus image into various portions so as to isolate the different features present in the image. The necessity of dividing the image into different segments is due to the fact that the optic disc, which is a major icon of the eye, has a similarity in appearance with that of the exudates. To avoid this confusion, appropriate segmentation technique is of great importance.

Choice of segmentation method would be to target on an easy, robust, accurate and automatic algorithm.

In our previous sections, we have discussed that the NLBT technique suits best for a transformed image. Let us move forward into the details of the image segmentation process.

Before we look at a brief of the two methods, let us have an overview of the importance of Threshold of an image. We know that each fundus image is composed of a collection of a number of pixels. Every pixel will have a unique value corresponding to the brightness of that particular image grid. In segmentation, we chose a way to isolate the exudates alone by using the appropriate pixel value.

A. Existing Methodologies

There are a few existing algorithms by which can perform segmentation. Few of them are as follows:

a) Watershed Algorithm

This method is proposed using the morphological information of the fundus image. The idea of this algorithm is to consider the entire fundus image as a mountain consisting of hills and valleys and flood the entire model by punching a hole at the base of the valley.

As a rescue solution, a dam is built. The flooding will lead to a model where aerial view will provide only the dam boundaries, which is nothing but the watershed divided lines [8].

The whole image is divided into small non-overlapping segments. Here, there is a possibility over segmentation. To solve this, an enhanced version of this algorithm was re-modeled to highlight only the watershed marks. This way, the reconstructed grey image conveyed better information of the actual image [9].

b) Using Histogram of Contrast Adjustment Image

Exudate and background pixel intensities are bifurcated into two data sets, wherein, the pixel value of each grid changes to 1 or 0 depending on the average of the two datasets [9].

c) SWFCM Clustering algorithm

Spatially Weighted Fuzzy c-means clustering method is used which is a more speedy process compared to the existing FCM. Considering the grey image of histogram, the equation of FCM is extended by weighing the neighboring pixels also [9].

d) Saliency Method

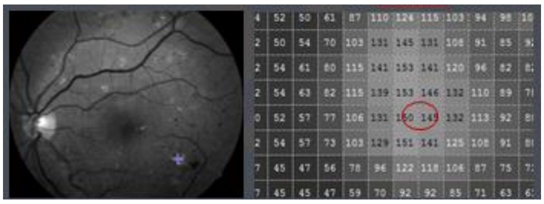
This method determines a threshold value in order to perform the last step of the segmentation. Unique colors in the original fundus images are captured so as to highlight the exudates bearing a greater pixel weight [10].

B. Proposed Segmentation Method

a) Manual Selection of Threshold

The method that is proposed in this paper is to set the threshold value of the fundus image in a robust and efficient way, such that all the bright areas of the fundus become white, while the rest become dark. Considering all the images in the dataset, the average all the minima intensities of the exudates is considered to be the threshold. Upon application of this threshold, a binary image is finally obtained that highlights the exudates and the optic disc [11]. Furthermore, the obtained optic disc must be eliminated so that only exudates can be further analyzed [12].

(a)



(b)

Fig 8. (a) shows an RGB DR image after the green channel filter and NLBT (b) shows the pixel grid of a particular area of the exudates pointing out how to spot the minimum pixel value manually

Table 2 shows an image comparison consisting of all the pre-processing steps performed so far.

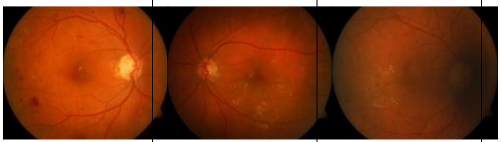
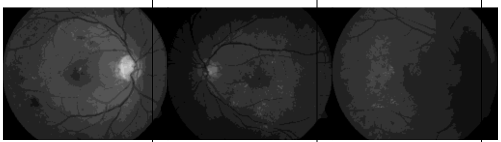
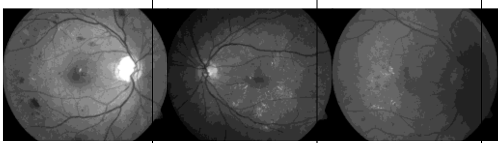
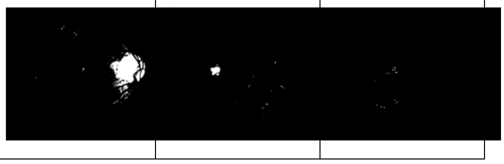
Type of Transformation	**Original Colour Contrast of Image**		
	Light	***Medium***	***Dark***
Original Image in RGB Model			
Green Channel Model			
Non-Linear Brightness Transformation			
Manual Segmentation			

Table 2. A comparative table of the proposed algorithm segmenting the fundus image manually

The limitation of this technique is that intensities must be manually fixed, which may not be accurate enough to satisfy all the image intensity modes.

b) Automated Threshold Selection

- Method: Calculate the average pixel value i.e Average Brightness of the entire NLBT image. Find the Threshold of all the images by Curve fitting method on brightness vs threshold plot.
- Advantage: This approach is more robust as it serves the condition best for an image with any contrast level. The ease of this algorithm showcases an effective way of exudates segmentation compared to the existing techniques, refer Table 3. Also, the yield of the resultant image is high. This makes this method more reliable too.

Type of Transformation	Original Colour Contrast of Image		
	Light	*Medium*	*Dark*
Manual Segmentation			
Automated Segmentation			

Table 3. A comparative table of the proposed algorithm segmenting the fundus image automatically

C. Binarization

The next process, as part of the segmentation process is known as binarization wherein we identify the optic disc and nullify the same in the image area. As mentioned earlier in our paper, since the optic disc and exudates within the fundus image might mislead the accurate detection of the infected regions, we have to eliminate the same using image processing.

From the available dataset, we can conclude that the exudates, in general, are not associated with the optic disc. In other words, the area of infection is spread across the fundus rather than being attached to or present along with the optic disc regime. Taking into account this observation, we use the dilation function to enhance all the white regions of the post segmented image.

As a result of dilation, as shown in Table 4, the optic disc region along with few associated features gets expanded. This way, we will be able to get a huge white blob of the disc which now can be easily distinguished from other exudates that are spread out on the fundus. Thus, eliminating this blob becomes much easier.

Type of Transformation	Original Colour Contrast of Image		
	Light	*Medium*	*Dark*
Automated Segmentation			
Dialation			
Optic Disc Elimination			

Table 4. An example of binarization process of nullifying the optic disc presence

V. CONCLUSION

This paper provides an overview of diabetic retinopathy, its different forms, the severity it can create on mankind when left untreated. Hence, here we have discussed a novel method of approaching this medical condition through image processing technology. We have briefly discussed on two different aspects of this technique wherein we play with the image contrast for a better clarity and further segment it in an automatic way to provide accurate results.

We have seen that, from the existing finding, the NLBT serves us the purpose of producing the best colour channeled image good enough for segmentation. Also, we have proposed an effective, robust, automated algorithm comparing in detail on other algorithms that have been implemented before.

We have gone further to perform the binarization also, where we have been able to nullify the presence of optic disc in the fundus. As a result, the end image would be only that of the exudates present in the fundus. Hence, the extraction of exudates from the fundus image was achieved successfully.

As a future work, we will continue with the segmented image to provide CBIR to patients. This would also be implemented in an auto-mode where we plan on creating a database for the treatment too, based on the adversity of the exudates percentage on the fundus. By having an accurate estimate of the area affected by DR, we will proceed to subscribing medication also to the patients.

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