Automated Diabetic Retinopathy Detection with Image Segmentation Techniques

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Abstract:

Diabetic Retinopathy is an eye disease that cause haemorrhage in retinal nerves of the eye which leads to blindness if not treated earlier with proper care. This disease is caused mainly for diabetic patients. About 80% of all patients have had diabetes for long years. But it could be reduced if there were proper and vigilant treatment and monitoring of the eyes. In earlier days also there were methods for detection of diabetic retinopathy. This work is mainly for computerized diagnosis of diabetic retinopathy from digital fundus images and fluorescein angiography images of eye retina. It has been an active research topic in medical image processing. In this study, the diabetic retinopathy is detected from the fundus images and fluorescein angiography images of the eye retina with image segmentation techniques.

Keywords:

Diabetic Retinopathy, Fundus images, Image Processing, Image Segmentation, Haemorrhage, Diabetes, Fluorescein Angiography .

Introduction:

Digital image processing is an area characterized by need for extensive experimental work to establish the viability of proposed solutions to a given problem. One part of the image processing is the image enhancement [3].Image Enhancement is the technique to improve the interpretability or perception of information in images for human viewers [3]. In our human senses eye is the most powerful sense. Obtaining and exploring images are forms a huge part of the habitual cerebral activity of human beings in their whole life time [7].

Medical image processing requires a comprehensive environment for data access, analysis, processing, visualization, and algorithm development [7]. Diabetic Retinopathy is found to be a leading cause of blindness due to the leakage of blood vessels of retina. The weakened blood vessels will leak blood to spread over retina, which in turn forms Micro aneurysms, haemorrhages, and cotton wool spots. Diabetic Retinopathy is a progressive disease which can advance from mild stage to proliferative stage. It was found that four stages such as Mild Non Proliferative Diabetic Retinopathy, Moderate Non Proliferative Diabetic Retinopathy, Severe Non Proliferative Diabetic Retinopathy, and Proliferative Diabetic Retinopathy can exist. Mild Non Proliferative Diabetic Retinopathy results due to the presence of at least one micro aneurysm. Micro aneurysms are small, round, and dark red dots with sharp margins and are the first detectable signs of retinopathy. Moderate Non Proliferative Diabetic Retinopathy results due to the presence of numerous Micro aneurysms, cotton wool spots and hard exudates [13]. The aim of the wok is to detect the early stages of bright lesions of Diabetic Retinopathy. This involves the processing of fundus images for the extraction of abnormal signs, such as hard exudates, cotton wool spots and haemorrhages and also the process of extraction the beading nerves from the fluorescein angiography images of the eye retina with image segmentation techniques[14].

Methodology :

I. Pre-processing Stage

Applying the filter is the initial pre-processing technique. Initially the medical image is subjected to the trigonometric function. Dividing the original image by a constant value of 2. The resultant image of the trigonometric function and by Step2 were fused together to give an enhanced image. [13]

II. Image Segmentation

Image segmentation is the process of partitioning a digital image into multiple segments. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain characteristics[14]. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Each of the pixels in a region are similar with respect to some characteristic or computed property, such as color, intensity, or texture[15].

THRESHOLDING

Thresholding is the simplest method of image segmentation. From a grayscale image, thresholding can be used to create binary images. The simplest thresholding methods replace each pixel in an image with a black pixel if the image intensity $I_{i,j}$ is less than some fixed constant T (that is, $I_{i,j} < T$), or a white pixel if the image intensity is greater than that constant. In the example image on the right, this results in the dark tree becoming completely black, and the white snow becoming complete white. Thresholding is used to extract an object from its background by assigning value T(threshold) for each pixel such that each pixel is either classified as a foreground or a background point[17].

GLOBAL THRESHOLDING

Threshold is a constant applicable over an entire image, is termed as global thresholding. The initial value of threshold in cases such as this is a value midway between maximum and minimum gray levels or only the maximum gray levels. The optimum threshold is near the midpoint between the modes , thus obtaining perfect segmentation[17].

MULTILEVEL THRESHOLDING

Multilevel image thresholds can be done using Otsu’s method. It returns threshold value thresh computed for image using Otsu’s method. We can use thresh argument to imquantize to convert an image into a two-level image. Otsu's method chooses the threshold to minimize the intraclass variance of the thresholded pixels[17].

OTSU'S METHOD

In Otsu's method we exhaustively search for the threshold that minimizes the intra-class variance (the variance within the class), defined as a weighted sum of variances of the two classes:

$$\sigma_w^2(t) = \omega_0(t)\sigma_0^2(t) + \omega_1(t)\sigma_1^2(t)$$

Weights $\omega_{0,1}$ are the probabilities of the two classes separated by a threshold t and $\sigma_{0,1}^2$ are variances of these two classes.

The class probability $\omega_{0,1}(t)$ is computed from the L histograms:

$$\omega_0(t) = \sum_{i=0}^{t-1} p(i)$$
$$\omega_1(t) = \sum_{i=t}^{L-1} p(i)$$

Otsu shows that minimizing the intra-class variance is the same as maximizing inter-class variance[17].

QUANTIZATION

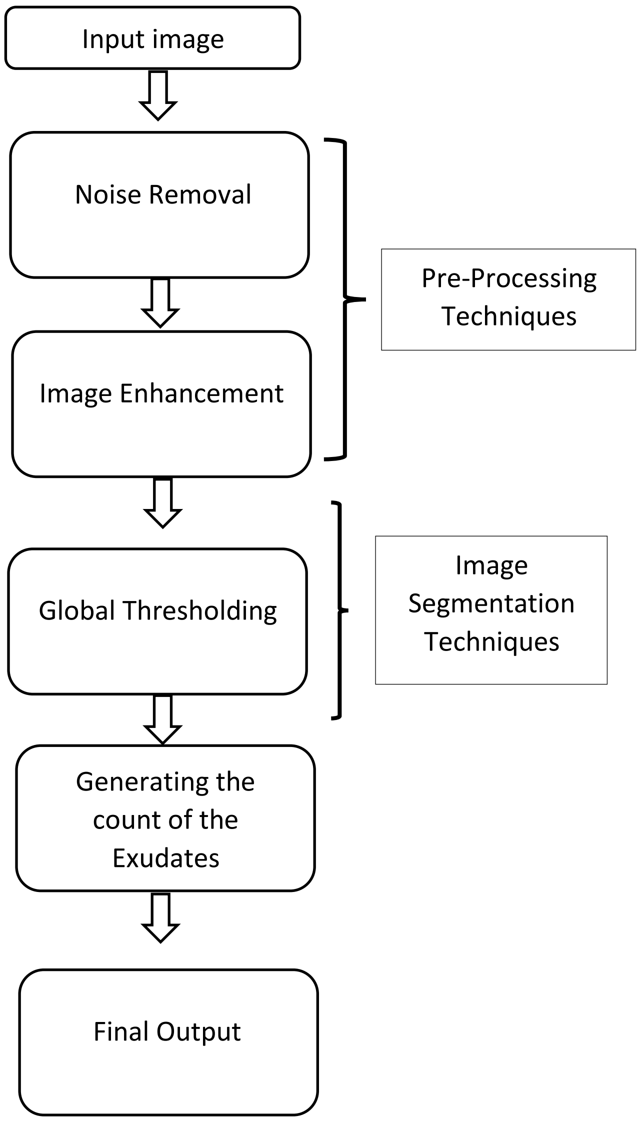
The image can be quantized using specified quantization levels and output values. This function determines the color to assign to each object based on the number of objects in the label matrix and range of colors in the colormap[17].

SEGMENTATION TECHNIQUES

Segmentation subdivides an image into its constituent regions or objects. The level to which the subdivision is carried depends on the problem being. The segmentation should stop when the objects of interest have been isolated. Segmentation of nontrivial images is one of the most difficult tasks in image processing. Segmentation algorithms for monochrome images generally are based on one of two properties of image intensity values: discontinuity and similarity. In the first category, the approach is to partition an image based on abrupt changes in intensity, such as edges. The principal approaches in the second category are based on partitioning an image into regions that are similar according to a set of predefined criteria[17].

Flowchart and Steps Involved

Extraction of Exudates



Step1: Acquire the input image

Step2: Convert the image to double class

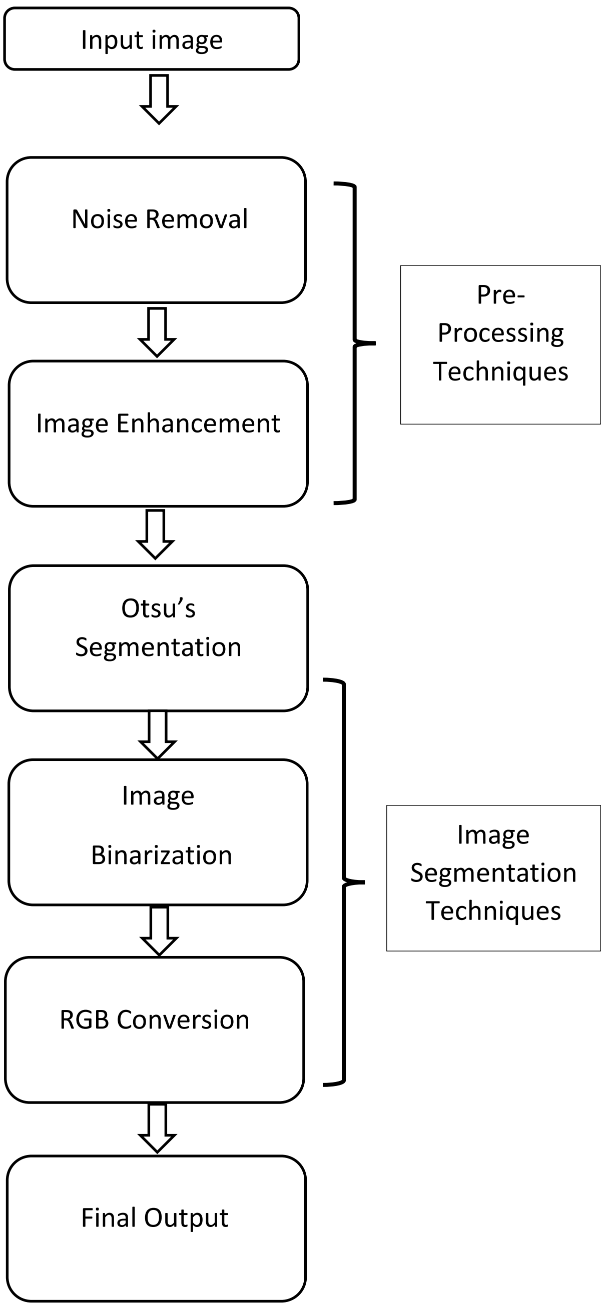
Step3: Apply image enhancement technique

Step4: Convert the image to gray scale

Step5: Apply Global thresholding to segment only the exudates

Step6: Generate the count of exudates to know the severity of the disease(the number of cotton wool spots present are calculated by labelling the components)

Segmenting the Haemorrhage



Step1: Acquire the input image

Step2: Convert the image to double class

Step3: Apply image enhancement technique

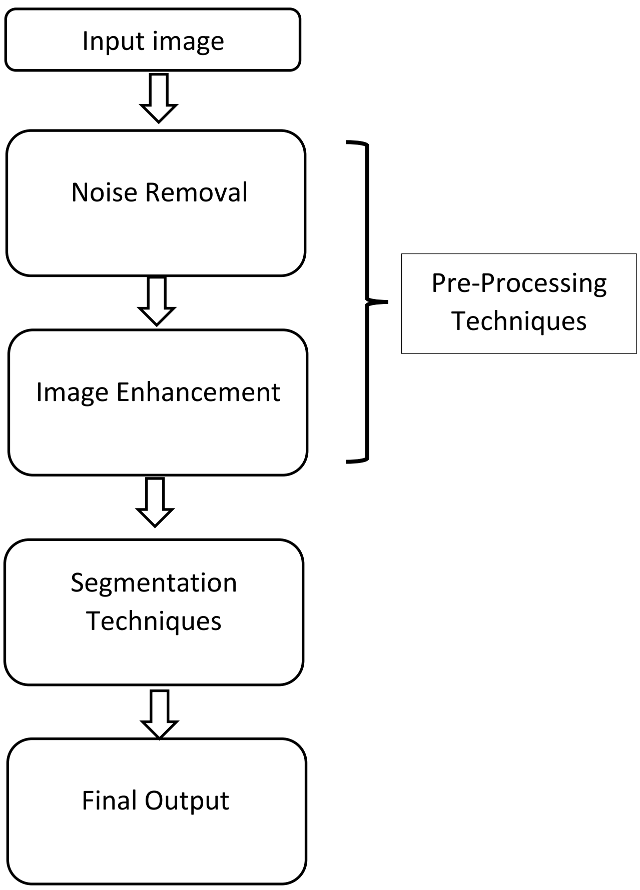
Step4: Convert the image to gray scale

Step5: Using Ostu's Multi thresholding and Quantization method, quantize the image into discrete values. Binary image is obtained

Step6: Convert the labelled matrix to RGB

Step7: The haemorrhages are differentiated by its colour.

Segmenting the Beading Nerves



Step1: Acquire the input image

Step2: Convert the image to double class

Step3: Apply image enhancement technique

Step4: Convert the image to gray scale

Step5: Apply thresholding techniques to segment the beading nerves (only arteries)

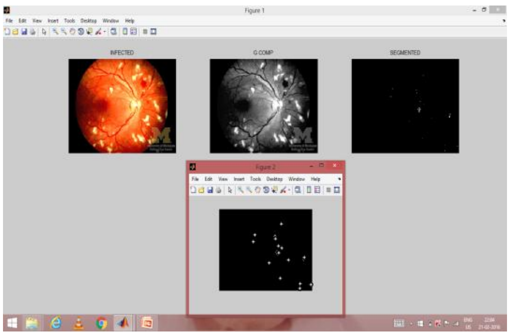
Results and Discussions:

Detection of Exudates and Haemorrhages and nerves are done in this project with image processing. The input image is obtained as shown in Figure 1. The exudates are detected as shown in Figure 1. The input image is obtained as shown in Figure 2. The haemorrhage is segmented as shown in Figure 2. The input image is obtained as shown in Figure 3. The beading nerves are segmented as shown in Figure 3.

Extraction of Exudates

In the initial stage of the disease Diabetic Retinopathy some cotton wools like exudates are found in the retina of the eye. They are detected using segmentation as follows. The count of the exudates are generated by labelling the connected components.

Figure 1

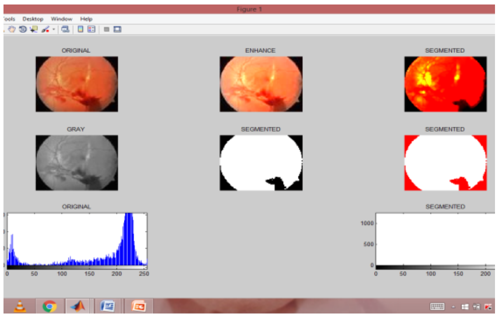


Segmenting the Haemorrhage

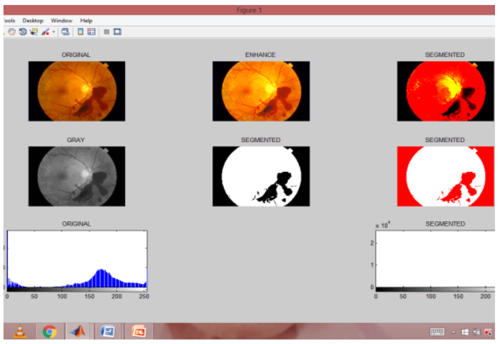
The Diabetic Retinopathy causes haemorrhages and exudates in the retina, those haemorrhages are segmented with otsu's multithresholding method as follows. The histogram of the input image denotes that it has all shades of red whereas the segmented image denotes that it has only red color ,no other shades are found in the image.

Figure 2

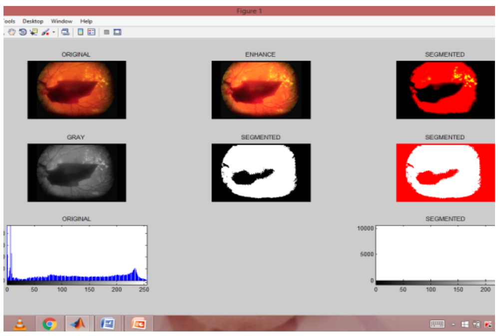
A.Image 1



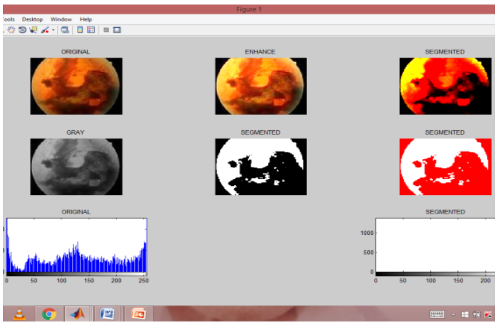
B.Image 2



C.Image 3



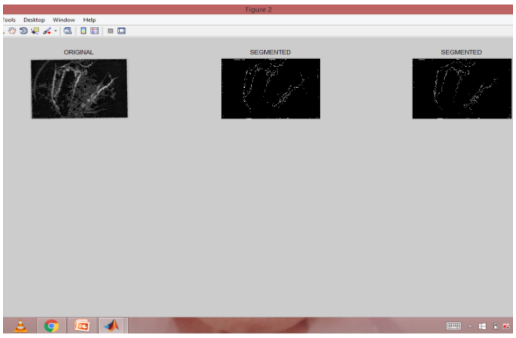
D.Image 4

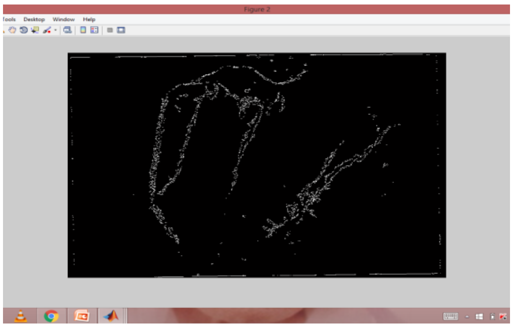


Segmenting the Beading Nerves

The opthamologists also use fluorescein angiography to detect the beading nerves. The beading nerves are segmented from fluorescein angiography images as follows.

Figure 3





Measuring Metrics for Images:

(i)PSNR

Peak signal-to-noise ratio (PSNR) is an expression for the ratio between the maximum possible value (power) of a signal and the power of distorting noise that affects the quality of its representation [16].

$$PSNR = \frac{10 \log_{10}(L-1)^2}{MSE}$$

(ii)MSE

The mean square error (MSE) of an estimator measures the average of the squares of the "errors"[16].

$$MSE= \frac{1}{MN}\sum_{i=1}^{M}\sum_{i=1}^{N}|X((i,j)-Y(i,j))|$$

(iii)RMSE

The root-mean-square deviation (RMSD) or root-mean-square error (RMSE) is a frequently used measure is defined as the square root of the mean square error [16].

$$RMSE=sqrt(MSE)$$

(iv) Michelson contrast:

The Michelson contrast is normally used for model is both bright and dark features are equal and take up related portion of the region.

$$\text{Michelson contrast} = \frac{l_{max}-l_{min}}{l_{max}+l_{min}}$$

Where, Imax & Imin – maximum and minimum intensities in an image. This value should be 1 which proves that total range of image is maintained constant [16]

Table:

Image	ORIGINAL				SEGMENTED			
	MSE	PSNR	RMSE	MC	MSE	PSNR	RMSE	MC
I	0.2359	13.3365	0.4857	0.98	85	10.7799	9.2195	0.99
II	0.1688	13.4818	0.4109	0.99	85	10.7799	9.2195	0.99
III	0.1295	13.5971	0.3598	1	85	10.7799	9.2195	0.99
IV	0.1736	13.4697	0.4167	0.98	85	10.7799	9.2195	0.99

The PSNR values will always be improved from the input image to the enhanced image. But in the above table, the value is decreased since the details in the output image is reduced than the input image. The Michelson contrast value is maintained between the range 0.98 and 1 which shows that the intensities of the image and range of the image is maintained constant.

Conclusion:

Diabetic Retinopathy , is one of the main cause of blindness, can be detected by the presence of microaneurysms and haemorrhages. The detection of haemorrhage is one of the most complex area of detection in image processing. The proposed method is capable of detecting the bright and dark lesions sharply. The strength of the proposed system are accurate feature extractions and accurate grading of non proliferative diabetic retinopathy lesions. This will be helpful to detect NPDR in the retinal images to facilitate the ophthalmologists when they diagnose the retinal images.

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