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A Simple and Fast Algorithm to Detect the Fovea Region in Fundus Retinal Image.

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ABSTRACT

In ophthalmology, the condition of the vascular network of human eye is an important diagnostic factor. Its segmentation in fundus imaging is a nontrivial task due to variable size of vessels, relatively low contrast, and potential presence of pathologies like micro aneurysms and haemorrhages. The Project proposes the Retinal image analysis through efficient detection of vessels and exudates for Retina Eye Disease analysis. It plays important roles in detection of some diseases in early stages, such as diabetes, that can be performed by comparing the states of the retinal blood vessels. Intrinsic characteristics of retinal images make the blood vessel detection process difficult. Here, we proposed a new algorithm to detect the retinal blood vessels and fovea effectively. The green channel will be selected for image analysis to extract vessels and fovea accurately. The directionality feature of the multistructure elements method makes it an effective tool in the edge detection. Hence, the morphology operators using multistructure elements are applied to the enhanced image in order to find the retinal image ridges. Experimental result proves that the blood vessels and the segregated fluids can be effectively detected by applying this method on the retinal images.

Keywords: Introduction, Existing method, Proposed method, Experimental Results, Conclusion, References.

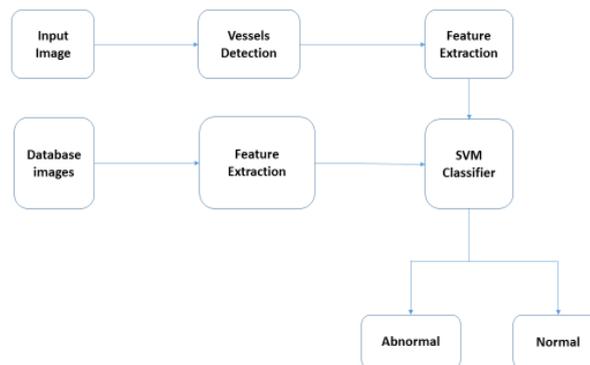
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INTRODUCTION

The image of an eye is to be detected in such a way that it should be declared either as a normal image or as an abnormal image. For that purpose, a colour image is pre-processed and resized. Then, it is enhanced using the clustering techniques. The next process to be proceeded after the clustering is Morphological Image Processing. Morphological Image Processing is a technique used for the Edge Detection of an image. Here, the process is done by image Dilation, Image Erosion. Now, both the Vessels and the Fovea region are detected and the features are extracted using an algorithm or a technique called Gray Level Co-Occurrence Matrix. Finally, the detected image is trained for checking the image feature extraction values. Then, it is classified using NN-Classifier and compared with the Database Images. GRNN is the technique used to classify the detected image. Finally, the result is declared whether the given input image is a normal image or an abnormal image.

EXISTING METHOD

Block Diagram:



In the existing method, the considered input images are the Gray Scale Images only. Then, the considered input image is pre-processed. The term pre-processing refers to the resizing of the image. Then, the Image Segmentation is done. In this method the image can be identified whether it is normal or abnormal only through the Blood Vessels detection.

Image Segmentation:

Segmentation is the process of partitioning a digital image into several segments (sets of pixels). The set of pixels is also known as superpixels. The goal of segmentation is to simplify and change the image representation into something that is more meaningful and easy to analyze. Image segmentation is typically used to locate objects and boundaries like lines, curves, etc. in images. Precisely saying, Image Segmentation is nothing but the process of assigning a label to each and every pixel such that pixels with the same label share certain visual characteristics. The result of image segmentation is a set of segments that cover the entire image and also the set of contours extracted from the image collectively. Each of the pixels in a region are similar with respect to some of the characteristics or computed properties, such as color, intensity, and texture. Adjacent regions are significantly different with respect to the same characteristics.

Algorithm techniques used for the Image Segmentation:

There are 2 algorithm techniques. They are:

1. Simple Thresholding Algorithm
2. Global Thresholding Algorithm

Simple Thresholding Algorithm:

This method first estimates a cut-off, then calculates the pixels distribution in order to determine the final threshold. In Simple Thresholding Algorithm, only a single value is considered as the threshold value in order to estimate the cut-off.

The equation for determining the threshold value is given by

$$th_0 = t_0 + \frac{(\text{max pixel value of the input}) - (\text{min pixel value of the input})}{2}$$

Where, th_0 is the required threshold value

$t_0=60$ (default value)

Global Thresholding Algorithm:

This method is used to segment an object from the background using the threshold. In Global Thresholding Algorithm, different threshold values are calculated.

The equations for determining the threshold values are given by

$$th_0 = t_0 + \frac{(\text{max pixel value of the input}) - (\text{min pixel value of the input})}{2}$$

Where, th_0 is the required threshold value

$t_0=60$ (default value)

Similarly,

$$th_1 = t_1 + \frac{(\text{max pixel value of the input}) - (\text{min pixel value of the input})}{2}$$

$th_1 = t_1 + ((\text{max. pixel value of input} - \text{min. pixel value of input})/2)$

Where, $t_1=th_0$

Likewise, the threshold values are determined and the Image Segmentation is done.

Histogram:

Histogram methods are very efficient when compared to other image segmentation methods because they require only one pass through the pixels typically. In this technique, a histogram is computed from all the pixels in the image, and also, the peaks and valleys in the histogram are used to locate the clusters in the image. Color or intensity can be used as the measure.

Using Histogram method, we can enhance the contrast of the required image. Also, using the Histogram graph, we can show the variation of different intensities.

Edge Detection:

Edge Detection is a well-developed field in Image Processing. It is done on its own within the Image Processing. Region boundaries and edges are closely related because, there is a sharp adjustment in intensity at the region boundaries. Here, the Edge Detection is done using the Sobel Operator and LOG (Laplacean of Gaussian) techniques. In the existing method, Sobel Operator existing technique is used. In this technique, the gap is present between the edges of each and every Blood Vessels of the eye. However, in order to segment an object or an image, closed region boundaries are needed.

Edge detection includes a variety of mathematical methods aiming at identifying points in a digital image at which the brightness of the image changes sharply or, more formally, has some lack of continuity. The points at which image brightness changes sharply are typically organized into a set of curved line segments termed edges.

Feature extraction:

The features used to extract from the image are mean values. Mean values are calculated using the different pixel values of that particular image.

The equation used to calculate the mean values is given by

$$(\text{Mean Value}) = \frac{(\text{Sum of all the pixel values in the image})}{(\text{Total number of pixels})}$$

Now, by finding the mean value we have to extract the features of the required image.

Database Training:

Now, the image which we considered it as the required input image is to be trained from the database. Here, the term Training refers to the comparison of input image with the available database images by extracting their features also. All the images of the database are divided into equal number of sets initially. That is nothing but the first set consists of the normal images. The next set consists of the abnormal images with less affect and the next set of consists of the abnormal images with high affect. Then their features are extracted. Then, the extracted feature value of the input image is compared with all the extracted feature values of the database images.

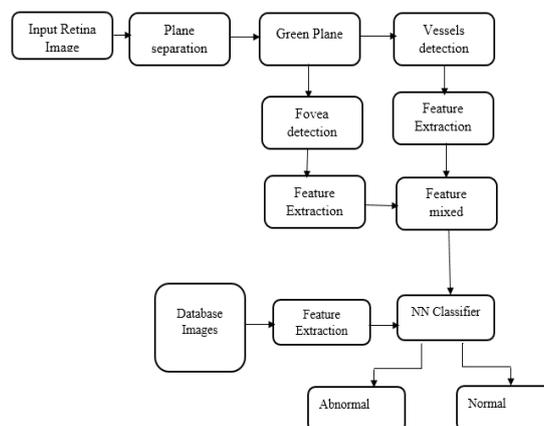
Classification:

Classification is the technique used to declare whether the considered input image is either normal or abnormal. For that purpose SVM Classifier is used.

PROPOSED METHOD

As already mentioned that only the Gray Scale Images are considered as the input images in the existing method, here, in the proposed method, the input images are considered in the form of color images. The color images consist of three planes. The three planes are Red Plane, Green Plane and Blue Plane, which is nothing but RGB. Now, from those three planes of the considered input image, only the Green Plane is taken. Because, the Green Plane has very less noise components. But, the rest of the planes have more noise components. Also, the rest of the planes have more intensities.

Block Diagram:



Hence, the Green Plane is taken from the considered input image. This process is called as the Plane Separation. Now, the image is pre-processed. The Pre-processing of the image consists of two steps. They are Image Resizing and RGB to Gray Conversion. The Image Resizing is the process of removing the noise components present in the selected input image.

RGB to the Gray Scale conversion is done here because, each pixel of the Red plane consists of some value, each pixel of the Green Plane consists of another value and the each pixel of the Blue Plane consists of the other value. Hence, in order to avoid the processing each and every plane separately, the image can be converted into the Gray Scale Image.

The equation for the conversion of a color image into a Gray Scale Image is given by

$$\text{(Gray Image)} = (\text{R} * 0.6) + (\text{G} * 0.3) + (\text{B} * 0.1)$$

As discussed above that the image can be identified whether it is normal or abnormal only through Blood Vessel detection, in the proposed method, this can be done through both the Blood Vessels and the Fovea Region detection.

Here, Morphological Image Processing is done for the detection purpose. This process is done both for the Blood Vessel and the Fovea Region detection.

Image Segmentation:

In the proposed method also, Image Segmentation is done using the process called Clustering. Clustering is defined as the process of dividing the digital image into a number of pixels. There are different techniques in clustering. Here, Fuzzy C means Clustering technique is used. It is nothing but the conversion of Gray Scale image into the Black & White image. Then, it is divided into a number of clusters if there is any unclear information, it can be seen clearly.. It is done by considering the threshold value. For that purpose, we need to calculate the threshold value.. It is done by considering the threshold value. For that purpose, we need to calculate the threshold value.

The equation for the threshold value is given by

$$\text{Th} = \frac{(\text{max pixel value}) - (\text{min pixel value})}{(\text{number of clusters})}$$

Histogram Technique:

As explained in the existing method, the same Histogram technique is used in order to show the variation of intensities and also to enhance the contrast of the required image.

Morphological Image Processing:

It refers to the pre-processing or post-processing of an image in order to remove the undesirable regions or to bridge the gap between the pixels. In this process, we have to perform Image Enhancement process. The Image Enhancement is defined as highlighting the region of interest. Image Enhancement is sub-divided into two types. They are:

- a) Image Smoothing: Image Smoothing is the process of highlighting the low frequency region by removing the fine details which is nothing but, blurring the image.
- b) Image Sharpening: Image Sharpening is the process of highlighting the high frequency region which is nothing but, highlighting the fine details.

Now, there are two techniques in the Image Smoothing. They are Dilation and Erosion.

Dilation and Erosion:

Dilation and erosion process will be used to enhance (smoothing) the swelled part by removing the unwanted pixels from outside region of the tumor part. These morphological operations are performed on images based on shapes. It is formed by structuring element. It is the matrix containing 1's and 0's where 1's are called as the neighborhood pixels. The output pixel is determined by using these processing pixel neighbors. Here, the 'line' structuring elements is used to dilate and erode the image for smoothing.

Dilation Process refers to the highlighting of the region of interest and showing the require information. The entire information can be seen but, it cannot be observed clearly. Hence, Erosion process is done. In Erosion part, the required parts of that image are broadened.

Difference Image:

The difference image is defined as the difference between the Dilated Image and the Eroded Image.

The equation for this is given by

$$\text{(Difference Image)} = \text{(Dilated Image)} - \text{(Eroded Image)}$$

After calculation of the difference image the Blood Vessels are detected using the Median filtering process. By using this Median Filter, only the Blood Vessels will be highlighted and the rest of the image will be complemented which is nothing but the rest of the part becomes black in color.

Edge Detection:

Here, the edges are detected using a process called Morphological Thinning Operation. In the proposed method also, the Edge Detection is done using the Sobel Operator. The Sobel Operator is nothing but the division if an image into the (3*3) matrices both in X-Direction and Y-Direction.

The magnitude of the vector Δf is denoted as

$$(\Delta f) = \text{mag}(\Delta f) = [G_x^2 + G_y^2]^{1/2}$$

Where, G_x is for X-direction and G_y is for Y-direction.

The Sobel masks (3*3) are given by

$$\text{For X-Direction: } \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

$$\text{For Y-Direction: } \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

From the above equations, it is understood that the values in the masks are considered as per our convenience and the magnitude of the vector (Δf) is calculated

Morphological Thinning Operation:

Thinning Operation is nothing but, just the complement of the Blood Vessels present in the Blood Vessels detection image. Also, this operation can be defined as the difference between the eroded image and the complement of the eroded image. Due to the Thinning Operation, only the edges of the Blood Vessels are highlighted. Similarly, the entire process from Morphological Image Processing to the Morphological Thinning Operation is done for the detection of the Fovea region also. Both the blood vessels and the fovea region detection will be done simultaneously.

Wavelet Transformation:

Since, an image consists of the both low frequency components and the high frequency components, Wavelet Transformation is necessary, such that the image will get divided into the different bands. In those bands, both the low band and the high band are present. For, clear-cut information the image is divided into four bands. They are:

1. Low-Low Band
2. Low-High Band
3. High-Low Band
4. High-High Band

The Low-Low Band consists of all the approximate information about the image.

The Low-High Band consists of the horizontal details of the image.

The High-Low Band consists of the vertical details of the image.

The High-High Band consists of the diagonal details of the image.

We should calculate values of both the High Band and the Low Band.

The equation for the High Band is given by

$$\text{(High Band)} = \text{(Even Columns)} - \text{(Odd Columns)}$$

The equation for the Low Band is given by

$$\text{(Low Band)} = \text{(Even Columns)} + \left(\frac{\text{(High Band)}}{2}\right)$$

Feature Extraction:

Now, the features must be extracted from the considered input image. There are different techniques in order to extract the features. The technique is called as the Gray Level Co-Occurrence Matrix (GLCM). Also, there are different techniques apart from this technique. They are (ABCD), Local Binary Pattern (LBP) and Local Ternary Pattern (LTP). All these are done based upon the neighborhood pixels only. The GLCM technique consists of five features. We have to extract all these five features for the further classification. The five features are:

1. Energy
2. Contrast
3. Entropy
4. Correlation
5. Homogeneity

Now, the steps for GLCM are given below.

- a) Read the command line from the users.
- b) Read the content of the image from the .bmp file.
- c) Calculate the Co-Occurrence Matrix.
- d) Calculate Haralick texture features.
- e) Save the acquired information to a database file.

Then, the same features are extracted for all the database images.

Feature	Formula
Energy	$\mu = \left(\frac{1}{MN}\right) * \sum_{i=1} \sum_{j=1} P(i, j)$

Contrast	$f_2 = \sum_{n=0}^{N_g-1} n^2 \left\{ \sum_{i=0}^{N_g-1} \sum_{j=0}^{N_g-1} P_{d, \theta(i, j)} \right\}$ <p style="text-align: center;">where $n = i - j$</p>
Entropy	$f_3 = \left\{ \sum_{i=0}^{N_g-1} \sum_{j=0}^{N_g-1} P_{d, \theta(i, j)} \log(P_{d, \theta(i, j)}) \right\}$
Correlation	$f_5 = \sum_{i=0}^{N_g-1} \sum_{j=0}^{N_g-1} P_{d, \theta(i, j)} \frac{(i - \mu_x)(j - \mu_y)}{\sigma_x \sigma_y}$
Homogeneity	$\sum_{i,j=0}^{N-1} \frac{P_{ij}}{1 + (i - j)^2}$

Database Training:

As explained in the existing method, the same pattern is followed in the proposed method also like dividing the database images into three different kinds of equal sets and input image are compared with the database images theoretically to our knowledge. Then, the classification is done.

Classification:

The classification is done in order to decide whether the image is normal or abnormal. For that purpose Neural Networks Classifier (NN) is used. There are different kinds of NN Classifiers. They are: ANN, KNN, PNN etc....

Artificial Neural Network Classifier (ANN):

There are two types of Artificial Neural Network Classifier (ANN). They are:

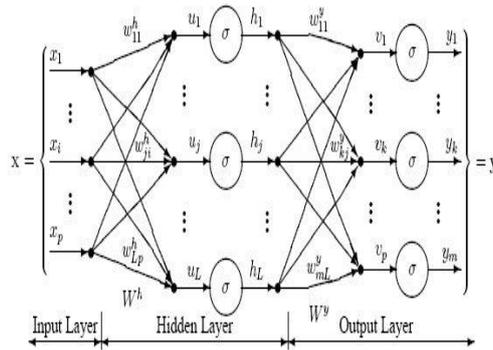
1. Back Propagation Network (BPN)
2. General Regression Neural Network (GRNN)

A general NN-Classifier consists of three layers. They are:

1. Input Layer: This layer is the layer that is visible to the user. It is used to consider the input images for the detection of blood vessels and fovea region and also for the extraction of its features.
2. Hidden Layer: It is the second layer in which it is invisible to the user. Here, the features are extracted for the already considered input images.
3. Output Layer: In this, the detected regions of the considered input image can be observed.

The basic diagram of a Neural Networks Classifier is shown below showing the three layers of the classifier.

The NN-Classifier is based upon the neurons present inside the human eye.



BPN and GRNN:

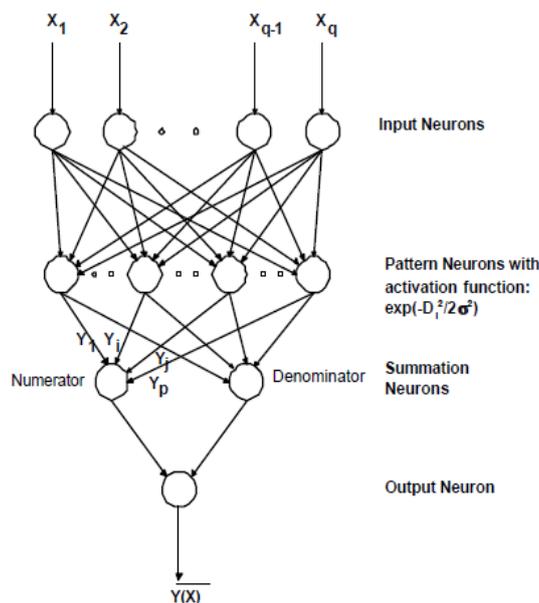
There are four layers to classify the image using both these classifiers. They are:

1. Input Layer
2. Hidden Layer
3. Pattern Layer/ Summation Layer
4. Decision Layer.

But, in this proposed technique, only GRNN classifier is used. The first two steps are same for both the Back Propagation Network and the General Regression Neural Network. But, the third and fourth steps are different for the General Regression Neural Network.

$$Y(X) = \frac{\sum_{i=1}^n Y_i \exp\left(\frac{-D_i^2}{2\sigma^2}\right)}{\sum_{i=1}^n \exp\left(\frac{-D_i^2}{2\sigma^2}\right)}$$

$$D_i^2 = (X - X_i)^T \cdot (X - X_i)$$



The GRNN algorithm is used under the classification with the help of the Normal Distribution. Normal Distribution is the Probability Density Function which is shown above.

PSNR and MSE:

PSNR stands for Peak Signal to Noise Ratio. It is most commonly used to measure the quality of reconstruction.

RMSE stands for Root Mean Square Error. It is also a parameter used for the reconstruction purpose.

The equation for RMSE is given by

$$RMSE = \sqrt{\frac{((\text{input image pixel value}) - (\text{output image pixel value}))^2}{(\text{number of rows}) * (\text{number of columns})}}$$

The equation for PSNR is given by

$$PSNR = 10 * (\log_{10} ((255)^2 / RMSE))$$

EXPERIMENTAL RESULTS

Fig-1: Input Process

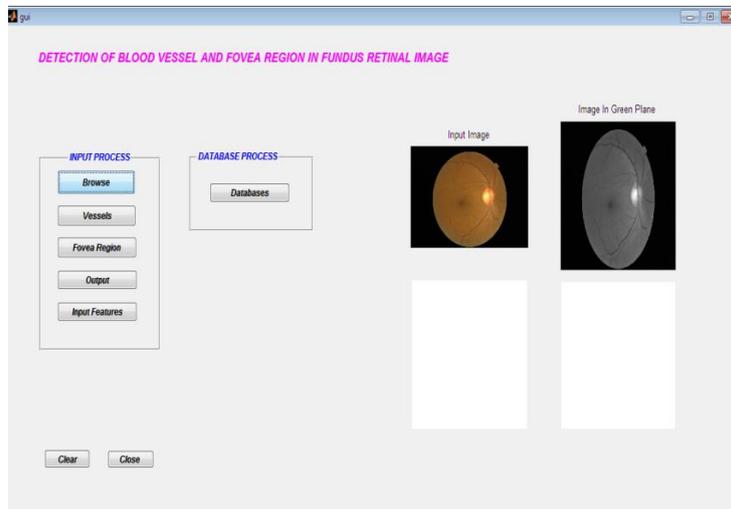


Fig-2: Dilated Image



Fig-3: Eroded Image

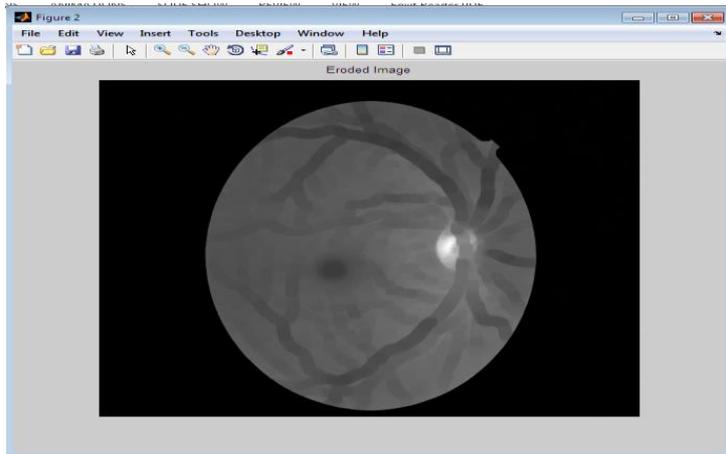


Fig-4: Difference Image

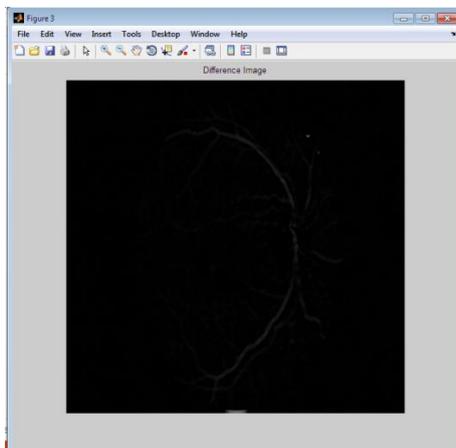


Fig-5: Blood Vessels Detection

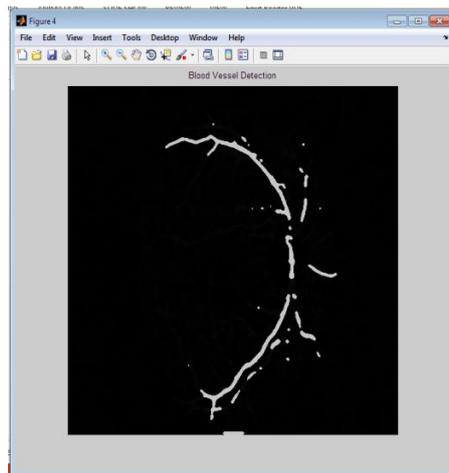


Fig-6: Thinning Operation

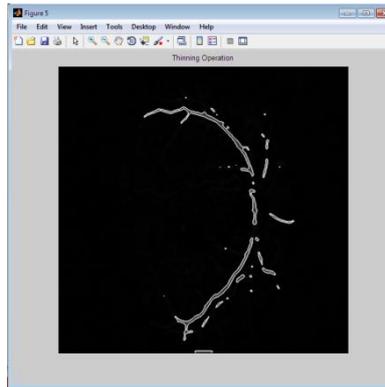


Fig-7: Fovea Region detection

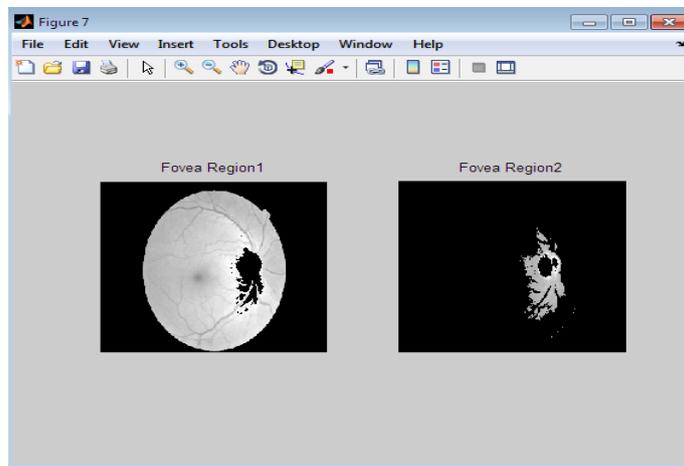


Fig-8: Output

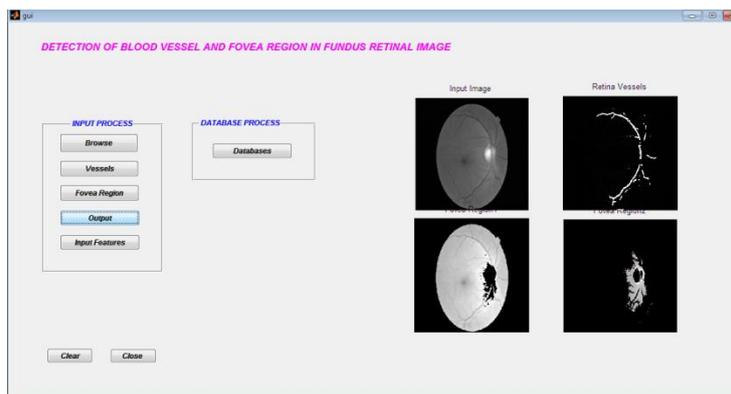
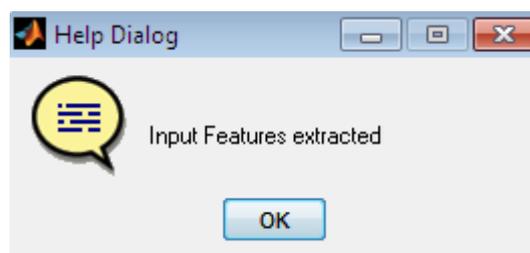


Fig-9: Input features extraction and Database Loading



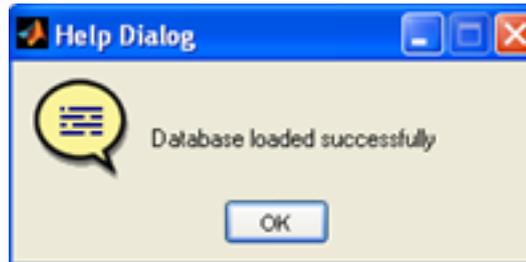


Fig-10: Training Process

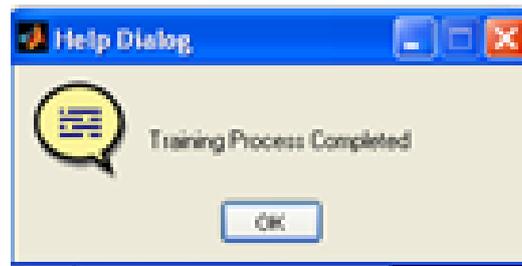
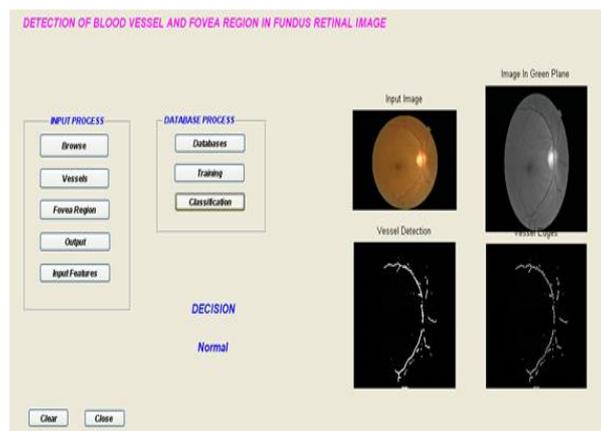


Fig-11: Classification



CONCLUSION

When compared with the existing method, the proposed method has some improved features.

Drawbacks of the existing method:

- a) In this method intrinsic characteristics of retinal images make the blood vessel detection process difficult.
- b) Poor Edge detection.
- c) Not possible to cluster a fundus Exudates.

Advantages of Proposed Method:

- a) Accurate Retina vessel and exudate detection.
- b) Useful in diabetic diagnosis.

Applications:

- a) Bio medical application for retinal image analysis and fundus, exudates detection.
- b) Image Fusion of CT Machine.



Speed of the both methods:

Speed for the existing method is 5.057 seconds and Speed for the proposed method is 3.074844 seconds. Improvement in the speed from the existing method to the proposed method is given by

$$\text{(Improved Speed)} = \text{(Existing Speed)} - \text{(Proposed Speed)}$$

Finally, the improved speed is **1.982156 seconds**.

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