AUTOMATIC DETECTION OF BLOOD VESSELS AND CLASSIFICATION OF RETINAL IMAGE INTO DIFFERENT STAGES OF DIABETIC RETINOPATHY

Mr. Shobhit Khandare[1], Gaurav Belsare[2], Shaikh Abdul Gaffar[3], Ashutosh Upadhyay[4]

[1]Assistant Professor, Dept. of Electronics and Telecommunication Engineering, Vivekanand Education Society's Institute of Technology (VESIT), Maharashtra, India

[2,34,]Student, Dept. of Electronics and Telecommunication Engineering, Vivekanand Education Society's Institute of Technology (VESIT), Maharashtra, India

---***---

Abstract - *Diabetes is a rapidly increasing worldwide problem which is characterized by defective metabolism of glucose that causes long-term dysfunction and failure of various organs. The most common complication of diabetes is diabetic retinopathy (DR), which is one of the primary causes of blindness and visual impairment in adults. The rapid increase of diabetes pushes the limits of the current DR screening capabilities for which the digital imaging of the eye fundus (retinal imaging), and automatic or semi-automatic image analysis algorithms provide a potential solution. This project aims to automatically detect diabetic retinopathy (DR), which poses a high risk of severe visual impairment. The symptoms of DR are neovascularization, cotton wool spots, hemorrhages, hard exudates, dilated retinal veins and the growth of abnormal new vessels. Their tortuous, convoluted and obscure appearance can make them difficult to detect. In this project a supervised algorithm is used for the retinal image classification. Artificial Neural Network (ANN) is used to classify the retinal image into one of three stages of the Diabetic Retinopathy. During this work, the publicly available retinal image (fundus Image) database DRIVE is used for the analysis of the algorithm.*

*Key Words***: Diabetic Retinopathy (DR), Automatic detection, Supervised Classification, DRIVE database, Artificial Neural Network (ANN), etc.**

1. INTRODUCTION

Retina is the tissue lining the interior surface of the eye which contains the light sensitive cells (photoreceptors). Photoreceptors convert light into neural signals that are carried to the brain through the optic nerves. In order to record the condition of the retina, an image of the retina (fundus image) can be obtained. A fundus camera system (retinal microscope) is usually used for capturing retinal images. Retinal image contains essential diagnostic information which assists in determining whether the retina is healthy or unhealthy.

Retinal images have been widely used for diagnosing vascular and non-vascular pathology in medical society. Retinal images provide information on the changes in retinal vascular structure, which are common in diseases such as diabetes, occlusion, glaucoma, hypertension, cardiovascular disease and stroke. These diseases usually change reflectivity, tortuosity, and patterns of blood vessels. If left untreated, these medical conditions can cause sight degradation or even blindness. The early exposure of these changes is important for taking preventive measure and hence, the major vision loss can be prevented.

1.1 MOTIVATION

Retina is the tissue lining the interior surface of the eye which contains the light sensitive cells (photoreceptors). Photoreceptors convert light into neural signals that are carried to the brain through the optic nerves. In order to record the condition of the retina, an image of the retina (fundus image) can be obtained. A fundus camera system (retinal microscope) is usually used for capturing retinal images. Retinal image contains essential diagnostic information which assists in determining whether the retina is healthy or unhealthy.

Retinal images have been widely used for diagnosing vascular and non-vascular pathology in medical society. Retinal images provide information on the changes in retinal vascular structure, which are common in diseases such as diabetes, occlusion, glaucoma, hypertension, cardiovascular disease and stroke. These diseases usually change reflectivity, tortuosity, and patterns of blood vessels. If left untreated, these medical conditions can cause sight degradation or even blindness. The early exposure of these changes is important for taking preventive measure and hence, the major vision loss can be prevented.

2. SIGNS OF DIABETIC RETINOPATHY

2.1 SIGNS OF DR

Diabetic retinopathy is a microangiopathy affecting the retinal vasculature caused by hyperglycemia. The damage to the retinal blood vessels will cause blood and fluid to leak on the retina and forms features such as micro-aneurysms, hemorrhages, exudates, cotton wool spots and venous loops. Below the significance and appearance of a few of the main features of DR will be described in more detail and corresponding images will be provided. features of DR will be described in more detail and corresponding images will be provided.

1. **Micro-aneurysms:** These are balloon-like structures on the sides of capillaries which arise due to the weakening of capillary walls. Micro-aneurysms appear like isolated red dots unattached to any blood vessel. They are often the first signs of DR that can be detected. See Fig-1(A).

---

2. Hemorrhages: Breakdown of the capillary walls results in the leakage of blood, which can take on various forms of size and shape depending on the retinal layer in which the vessels are located. These different forms are referred to as dot, blot or flame hemorrhages. See Fig-1(B).

3. **Exudates:** Capillary breakdown can often result in the leakage of oedema. The buildup of oedema causes retinal thickening. Exudates are the lipid residue from the oedema. They appear as waxy yellow lesions and take on various patterns including individual patches, tracking lines, rings (circinates) and macular stars. See Fig-1 (C,D).
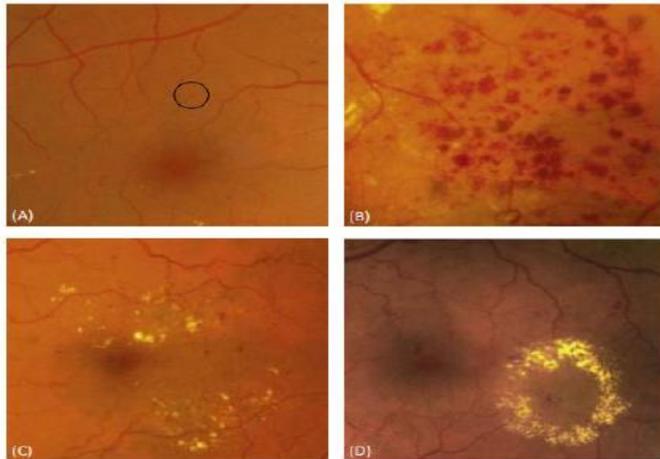
Fig-1 : Signs of Diabetic Retinopathy

2.2 STAGES OF DR

There are many more features of DR and table 1 provides an exhaustive list as well as the stage of the disease they present. Background DR is the earliest stage of DR and is not a threat to vision. Pre-proliferative DR represents progressive retinal ischemia. Proliferative DR is characterized by neovascularization it is the most advanced stage of the disease and can pose a high risk of severe loss of vision.

Table-1 : Stages of Diabetic Retinopathy

Stage of retinopathy	Features
Background	Microaneurysms.
	Dot and blot haemorrhages.
	Exudates.
Pre-proliferative	Multiple dot and blot haemorrhages.
	Cotton wool spots (CWS).
	Venous beading and loops.
	Intra-retinal microvascular abnormalities (IRMA).
Proliferative	New vessels elsewhere (NVE).
	New vessels at the disc (NVD).
	Pre-retinal/vitreous haemorrhage.
	Retinal detachment.
Maculopathy	Microaneurysms, haemorrhages, exudates at the macula.
	Macular oedema.

3. DATABASE

The vessel segmentation methodologies were evaluated by using the publicly available database containing the retinal images, DRIVE [1] .

DRIVE Database : The DRIVE (Digital Retinal Images for Vessel Extraction) database contains 40 retinal color images among which seven contain signs of diabetic retinopathy. The images have been captured using Canon CR5 non-mydriatic 3-CCD camera with a 45° field of view (FOV). Each image has 768×584 pixels with 8 bits per color channel in JPEG format. The database is divided into two groups: *training set* and *test set*, each containing 20 images. The training set contains color fundus images, the FOV masks for the images, and a set of manually segmented monochrome (black and white) ground truth images. The test set contains color fundus images, the FOV masks for the images, and two set of manually segmented monochrome ground truth images by two different specialists.

4. METHODOLOGY

4.1 FLOWCHART
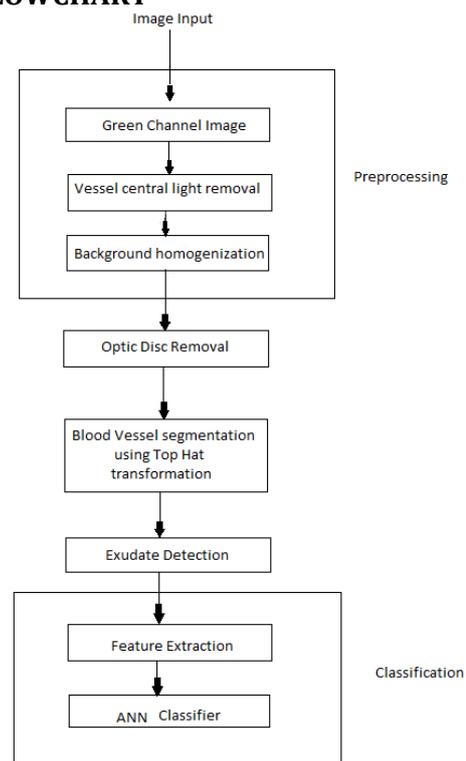
Fig-2 : Flowchart of proposed methodology

4.2 PRE-PROCESSING [2]

The image is selected from the DRIVE database. The green channel of an RGB (red/green/blue) image is extracted because it provides better vessel-background contrast than red or blue channels, and can thus be used for identifying blood vessels from retinal images. The Shade corrected image is generated to mitigate the non-uniform illumination effects occurred during the image acquisition phase. Initially,

the occasional salt and pepper noise is removed by using *3 x 3* mean filter, and the resultant image is convoluted with a Gaussian kernel of dimension *m x m = 9 x 9, mean = 0*, and *standard deviation = 1.8*, which further reduces the noise and is denoted by *Ig*. Secondly, *Ig* is passed through *69 x 69* mean filter, which blurs the retinal image and yields the background image, *Ib*. The difference between *Ig* and *Ib* is calculated for every pixel, and the result is used for generating shade-corrected image :

$$D(x,y)=Ig(x,y)-Ib(x,y)$$

Lastly, the shade-corrected image (*Isc*) is generated by transforming linear intensity values into the possible gray levels (8-bit image: 0-255) values. See Fig -3(b).

(a)   (b)
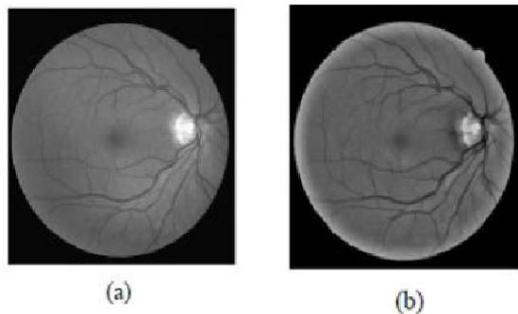
Fig-3 : Shade Corrected Image (a) Green Channel Image (b) Shade Corrected Image

Moreover, during image acquisition process, different illumination conditions are possible which results in significant variations in intensities of images. This is minimized by forming homogenized image *Ih*, using gray-level transformation

$$g_{Output} = \begin{cases} 0, & if\ g < 0 \\ 255, & if\ g > 255 \\ g, & otherwise \end{cases}$$

Where,

$$g = g_{Input} + 128 - g_{Input\_max}$$

Here, *g*Input and *g*Output are the gray level variables of input (Isc) and output (Ih) respectively and *g*Input_max is the gray level value of input (Isc), which has highest number of pixels. The homogenized image is shown in Fig-4(b).

(a)   (b)
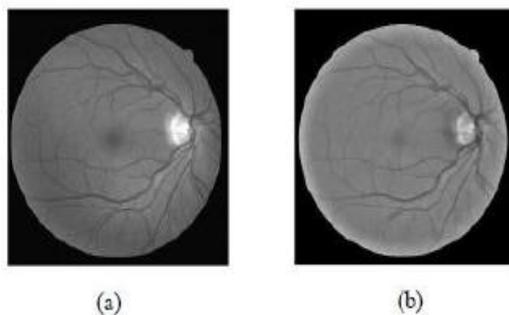
Fig-4 : Homogenized Image (a) Green Channel Image (b) Background Homogenized Image

4.3 OPTIC DISC REMOVAL [3]

The retinal blood vessels originate from the center of OD and spread over the region of the retina. The existence of blood vessels within the optic disc region may cause misdetection of pixels belonging to blood vessels as OD. In order to detect and segment the retinal blood vessels accurately, the optic disc should be detected and eliminated from the retinal image. The flowchart for OD removal is shown in the Fig-5.
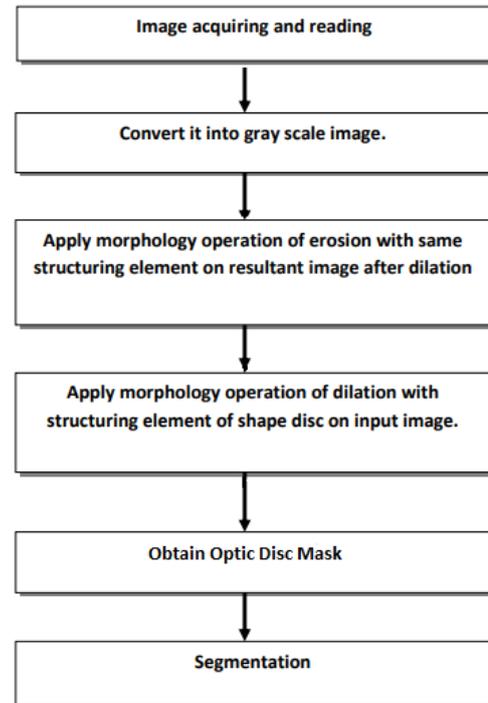
Fig-5 : Flowchart for OD removal

1. The image is acquired and converted to gray scale equivalent, and erosion operation is performed to reduce the enhanced regions to increase the sharpness of the image by restoring the boundary size of the optic disc.

$$(I\ominus G)(x,y) = \min_{(z_x,z_y)\in G,(x-z_x,y-z_y)\in I}\{I(x+z_x,y+z_y)+\overline{I}(x+z_x,y+z_y).G(z_x,z_y)\}$$

2. The dilation operation is performed to increase the luminance level of regions with sizes equal to that of the structuring element.

$$(I\oplus G)(x,y) = \max_{(z_x,z_y)\in G,(x-z_x,y-z_y)\in I}\{I(x-z_x,y-z_y)+\overline{I}(x-z_x,y-z_y).G(z_x,z_y)\}$$

3. Morphological reconstruction is performed to include the maximum information from the original and eroded forms.

$$I_{rec} = \max\{I(x,y),((I\oplus G)\ominus G)\}$$

4. Level Set method for segmentation is applied to the image thus generated to obtain the fine boundary of the optic disc in the retinal image by final contour.

Fig-6 : OD removal Image

4.4   BLOOD VESSEL SEGMENTATION [4]

The blood vessels in the retinal image are detected using the combination of 2-D Gabor Filter and Top Hat transformation. A Gabor filter is a linear filter whose impulse response is defined by a harmonic function multiplied by a Gaussian function. The general equation for 2-D Gabor filter is as follows :

$$g(x, y; \lambda, \theta, \sigma, \gamma) = \exp\left(-\frac{x'^2 + \gamma^2 y'^2}{2\sigma^2}\right).\cos\left(2\pi.\frac{x'}{\lambda}\right)$$

$$x' = x.\cos\theta + y.\sin\theta \quad y' = -x.\sin\theta + y.\cos\theta$$

Where,

θ =   Angle of the pattern

λ =   Wavelength

γ =   Ratio of gauge core to aspect ratio

σ =   Scale

The Gabor filter kernel is rotated in 12 different directions with 15 degree spacing. The green channel image is convolved with all the Gabor filter cores, 12 different values for each pixel of the image are obtained. From each of these values, a maximum value is selected and assigned to the pixel in the convolved image.

In mathematical morphology and digital image processing, top-hat transform is an operation that extracts small elements and details from given images. The top hat transform is given by the following equation.

$$Iwth = I - (I \, b)$$

Where,

Iwth = White Top Hat transformed image

I   = Original Image

b   = Structuring element

$\circ$ = Opening Operation

Here, the structuring element used is a disc shaped of radius of 8 pixels. The blood vessel segmented image using Gabor filter and top hat transformation is shown in the Fig-7.
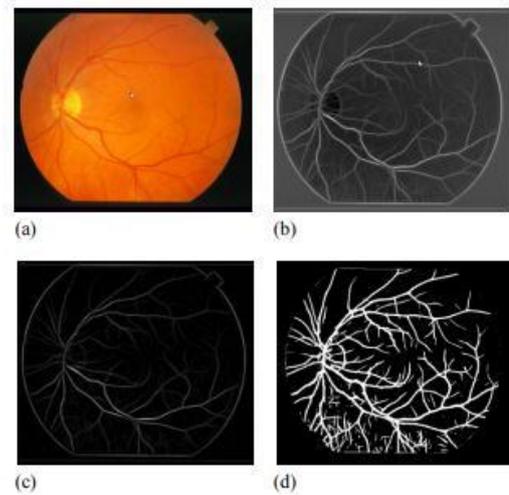
Fig-7 : Blood vessel segmentation using Gabor filter and Top Hat transformation (a) Original Image (b) Gabor filtered image (c) Top Hat transformation output (d) Segmented Image

4.5   EXUDATE DETECTION

Attributes that characterize exudates are their color (yellow), high intensity values, high contrast with background, and sharp edges. Hard exudates are identified using DWT [5] . Single level 2D-DWT is used to extract hard exudates. The 2D DWT computes the approximation coefficients matrix cA and details coefficients matrices cH, cV, and cD (horizontal, vertical, and diagonal, respectively), obtained by wavelet decomposition of the input matrix X.

4.6   FEATURE EXTRACTION

Transforming the input data into a set of features is called feature extraction and feature selection is the technique of selecting a subset of relevant features for building robust learning models. The seven different features are selected per image. These extracted features are given to ANN classifier for the classification. The extracted features are :

1. Average

2. Energy

3. Entropy

4. Standard Deviation

5. Correlation

6. Area

7. Homogeneity

4.7   CLASSIFICATION

Neural network is defined as a computing system consisting of a number of simple, interconnected processing elements, which respond to and process information from external inputs. Neural networks are typically organized in layers consisting of a number of interconnected 'nodes', which contain an 'activation function'. Input data are presented to

the network via the 'input layer', which transfers input data to one or more 'hidden layers' where the actual processing is done via a system of weighted 'connections'. The 'output layer' gets result from hidden layer and transfer that output for corresponding agent.

5. SOFTWARE IMPLEMENTATION

The **Graphical User Interface** (**GUI**) [5] , is a type of user interface that allows users to interact with electronic devices through graphical icons and visual indicators such as secondary notation, instead of text-based user interfaces, typed command labels or text navigation. GUIs were introduced in reaction to the perceived steep learning curve of command-line interfaces (CLIs), which require commands to be typed on a computer keyboard. The GUIDE Toolbox provided by MATLAB allows advanced MATLAB programmers to provide Graphical User Interfaces to their programs. GUIs are useful because they remove end users from the command line interface of MATLAB and provide an easy way to share code across nonprogrammers.
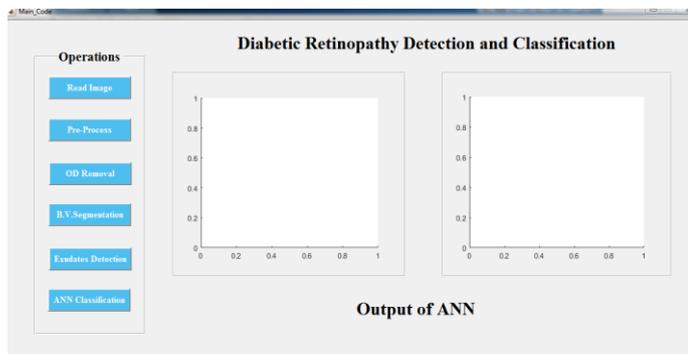
Fig-8 : Graphic User Interface (GUI)

6. RESULTS

1. Image acquisition : The input image is selected from the DRIVE database. The retinal image is converted into a green channel image which provides better vessel-background contrast than red/blue channel image.
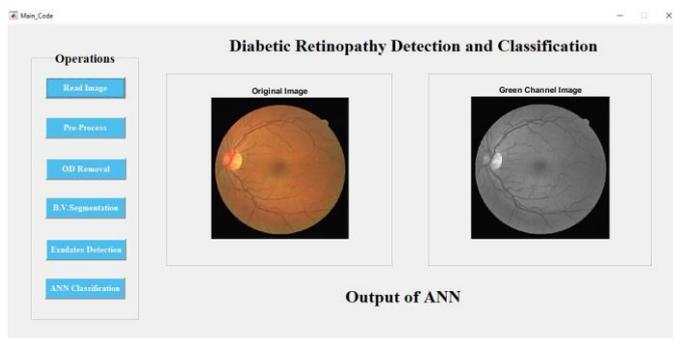
Fig-9 : GUI with Image Acquisition

2. Pre-processing : The illumination corrected image and noise removed images are obtained during the preprocessing stage.
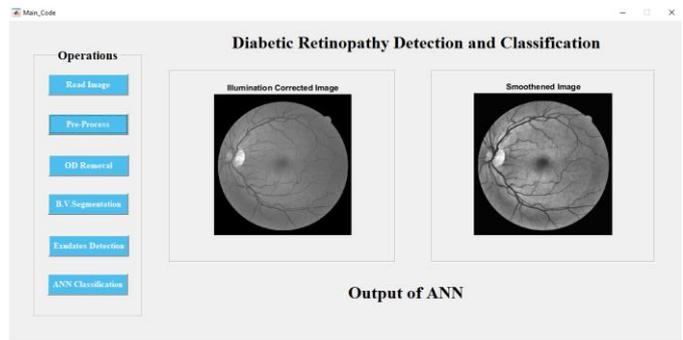
Fig-10 : GUI with Preprocessing

3. Optic Disc Removal : Here, we have achieved up to 60% accuracy for detection and removal of Optic Disc (OD). Firstly, the OD mask is obtained by using the morphological operations (erosion and dilation) and the original image is segmented to remove the optic disc.
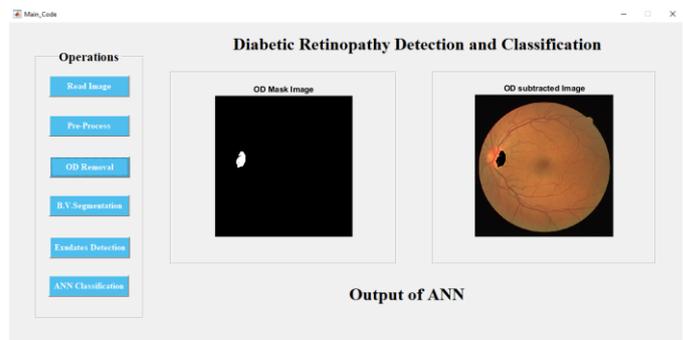
Fig-11 : GUI with OD removal

4. Blood Vessel segmentation : The blood vessels in the retinal image obtained after subtracting the optic disc are obtained using the combination Gabor filter and Top Hat transformation.
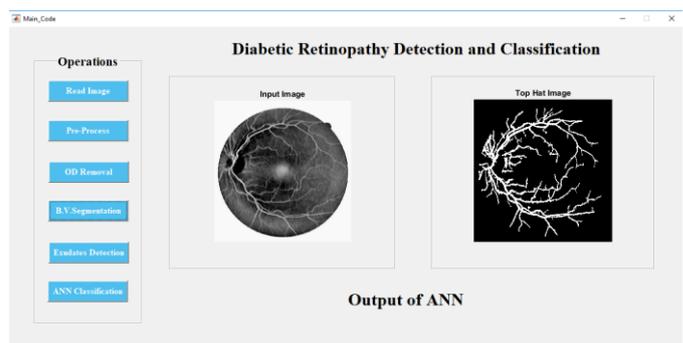
Fig-12 : GUI with Blood Vessel Segmentation

5. Exudate Detection : The exudates in the image are detected using the combination of morphological operations and 2 dimensional Discrete Wavelet Transform (2D DWT). The exudates are detected and are mapped onto the original image.
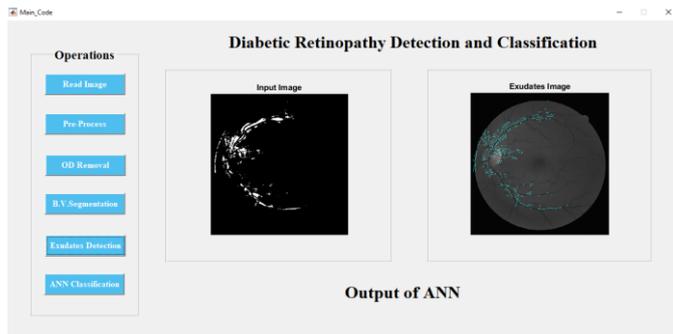
Fig-13 : GUI with Exudate Detection

6. Feature Extraction : The values of the features extracted for the above image are as follows :

Standard Deviation	0.2502
Mean	0.0671
Entropy	0.3550
Area	22141
Correlation	0.7942
Energy	0.8494
Homogeneity	0.9871

7. ANN Classifier : The Artificial Neural Network (ANN) inputs the features extracted during the feature extraction phase and classifies the input image into one of three classes namely

i) Normal Retinal Image

ii) Non-Proliferative Retinal Image

iii) Proliferative Retina Image.
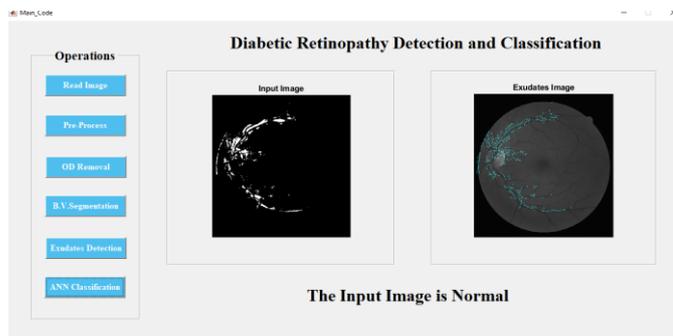
Fig-13 : GUI with ANN Classifier Output

7. CONCLUSION

Diabetic retinopathy (DR) is a sight threatening disease. The DR screening process allows for the early detection of the disease and therefore allows for timely intervention in order to prevent vision loss. The integration of automated detection systems has numerous benefits including significantly reducing the manual grading workload and helping towards ensuring time targets are met for referrals. This project focuses on blood vessel segmentation, exudate detection and retinal image classification. The blood vessel segmentation is achieved using the top-hat transformation. The top hat transformation is preferred over any other

transformation since it enhances the bright objects of interest in a dark background. Therefore top hat transformation enhances the vessels over the background which helps in blood vessel segmentation.

The exudates are detected using the combination of morphological operation and 2D DWT. The seven different features are extracted which are given to the Artificial Neural Network (ANN) which classifies the input image into one of three classes namely Normal, NPDR and PDR retinal image.

REFERENCES

[1] https://www.isi.uu.nl/Research/Databases/DRIVE/

[2] Anil Maharjan, "Blood Vessel Segmentation from Retinal Images" dept. of computer science, June 2016

[3] https://pdfs.semanticscholar.org/da35/5107e98367 dd01b53ee7137010b1a11d000.pdf

[4] http://ieeexplore.ieee.org/document/5929708/

[5] https://www.mathworks.com/products/matlab.html