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FPGA Implementation of Glaucoma Detection Using Neural Networks

Hitesh Shirke[1], Dr. Nataraj Vijapur[2]

[1] IV Semester M.Tech. Student, Dept. of Electronics and Communication Engineering.
K.L.E. Dr. M.S.Sheshgiri College of Engineering and Technology, Belagum-590008
Karnataka, India-590018
[2]Faculty Dept. of Electronics and Communication Engineering.
K.L.E. Dr. M.S.Sheshgiri College of Engineering and Technology, Belagum-590008
Karnataka, India-590018

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Abstract - *Glaucoma is an eye disease that occurs because of the increased IntraOcular Pressure(IOP) which results in damaged optic nerve. Because of glaucoma the optic cup size gets increased and the optic cup to optic disk ratio(CDR) increases. This paper proposes glaucoma disease detection from retinal images using artificial neural network as the classifier. Optic cup area, optic disk area and neuro-retinal rim area are the features that are used for the classification. FPGA implementation of neural network offers both the adaptability in reconfiguration and parallel architecture of neurons. Hence FPGA is better choice for the neural networks instead of DSP or ASIC implementation. The feed forward back propagation algorithm is used for the neural network. Matlab R2015a software is used to extract the features and the neural network is implemented on Spartan 3a FPGA kit.*

Key Words: Glaucoma, Cup to disk ratio, Neuroretinal rim, Artificial neural network, FPGA implementation

1. INTRODUCTION

The human eye is the most important part of the human body. Therefore detection of human eye diseases is always needed. Diseases like glaucoma, cataract, macular degeneration, diabetic retinopathy affect the patient's eye. Glaucoma is a very silent disease of the eye. The scary part about this disease is that it is so silent that it normally doesn't announce itself. It's a disease which affects the optic nerve of the eye. It causes thinning up and drying up of the optic nerve. This results in visual loss which can be irreversible.

Glaucoma can happen in anyone across the population which means any person and age. The easiest way to prevent glaucoma is to get it diagnosed in the very early stages. There is no prevention of glaucoma if you are the person who is going to have glaucoma in your lifetime. Glaucoma is best treated medically using eye drops or using tablets to reduce the pressure inside the eye. This work aims to detect glaucoma using FPGA hardware. The artificial neural network is used as a classifier to detect glaucoma.

1.1 Glaucoma

Measurably just about 45 million individuals worldwide have glaucoma and around 79 million individuals are expected to suffer from glaucoma by the year 2020. The optic nerve is in charge of conveying the data seen by eye to the brain. If there should be an occurrence of Glaucoma, optic nerve is harmed and the data got by the brain gets debased henceforth the vision loss. The essential reason behind this harm of the optic nerve is increased IntraOcular Pressure(IOP). Keeping in mind the end goal to keep up a steady eye pressure, human eye ceaselessly delivers aqueous humor, a liquid which moreover continually streams out of the eye. In the event of glaucoma, there is an increase in liquid pressure of the eye on the grounds that the aqueous humor does not stream out of the eye as it ought to be which at last results in damage to the optic nerve fiber. This optic nerve harm can be recognized by Optical Coherence Tomography (OCT) and Heidelberg Retina Tomography (HRT). The cost of glaucoma identification utilizing OCT and HRT is high. Colour Fundus Image (CFI) technique has been broadly used to analyze glaucoma and other visual sicknesses.

1.2 Glaucoma Effects

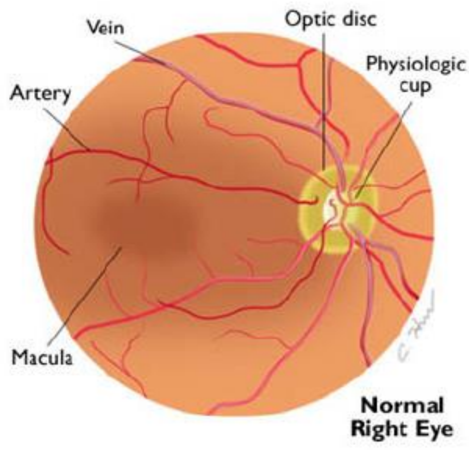

Fig-1: normal fundus image

Fig-1. shows the fundus image of a normal eye taken from a fundus camera. The bigger circular area is the optic disk area and the smaller circular area within the optic disk is the optic cup area. The difference between the optic disk and the optic cup area is called the Neuro-Retinal Rim(NRR).

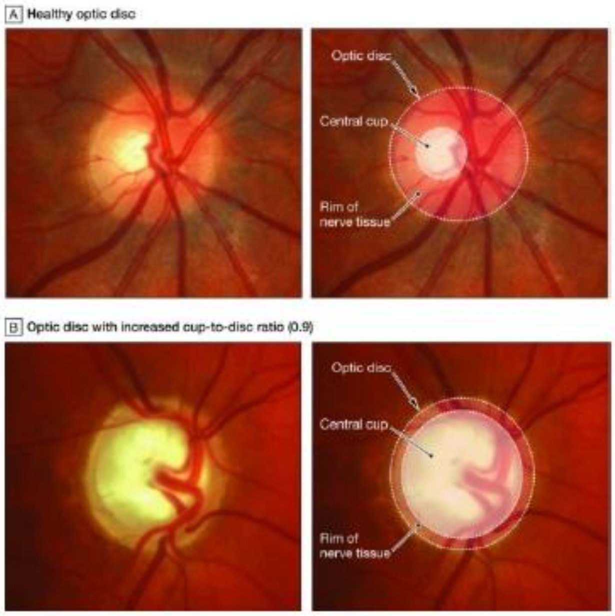

Fig-2: (A) Healthy optic disk (B) Unhealthy optic disk

The glaucoma disease can be determined by observing the changes in the optic disk area. As you can see in fig-2. (A) indicates the healthy eye in which the optic cup size is very small as compared to the optic disk. But because of glaucoma the optic cup size gets increased and the optic cup to optic disk ratio(CDR) increases this is shown in fig-2.(B).

2. METHODOLOGY

Methodology of proposed glaucoma detection system is shown in above fig-3. Input fundus image is initially pre-processed for noise removal. The pre-processed image is subjected to feature extraction. The features such as optic disk area, cup area and neuro retinal rim (NRR) area are extracted. Then the next stage involves classification using neural networks

2.1 Fundus Retinal Images

To determine the performance of the proposed method, we have used 30 fundus images from HRF image database, containing 15 healthy and 15 glaucoma images. The images are in jpeg format with resolution of 3504×2336 pixels. An input fundus image is shown in below fig-4.

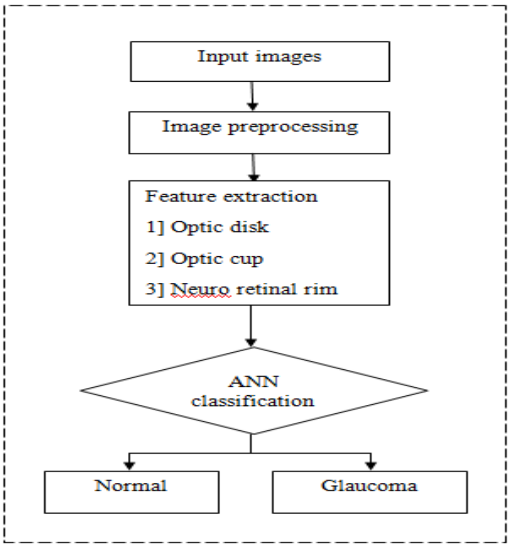

Fig-3: Methodology of the proposed system

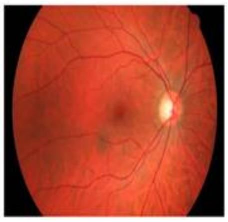

Fig-4: input fundus image

2.2 Image Pre-processing

Goal of the pre-processing is to enhance the picture by improving certain elements and/or by removing unwanted noise. The input images are of high resolution 3504×2336 pixels. Processing such high resolution images can take a lot of processing time hence we have resized the input images to 875×563 pixels. The image is then converted to HSV colour map (Hue, Saturation, Value) by using rgb2hsv(N) command. To highlight the optic disk the red colour is removed from the image and unwanted pixels are removed.

It is important to mark the region of interest (ROI) to reduce the processing time also to initially mark the temporary boundary of the optic disk. ROI is defined by approximately marking the centre of ROI and drawing a rectangle around it. Then the region of interest is cropped from the original image. The pre-processing steps are shown in below fig-5.

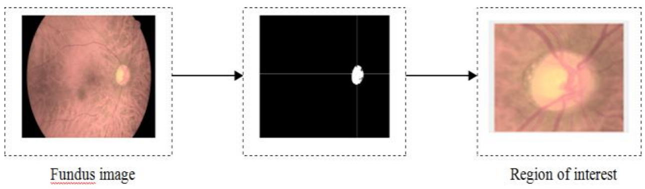

Fig-5: image pre-processing

2.3 Feature extraction

2.3.1 Optic Disk Extraction

Feature extraction from the pre-processed image is done using the segmentation technique called multi-thresholding. This technique is similar to thresholding technique. This technique is based on partitioning an image into regions that are similar according to the thresholding values. The main part of this technique is to determine the threshold value. For example, the threshold value will be between 0 and 255 for an 8 bit resolution image. After determining the threshold values for all regions, every pixel in that region is assigned a fix value. For example, if there are two regions then the pixels belonging to a region can be assigned with a value 1 and the remaining pixels with value 0. When we establish more than one threshold values in the same image, the technique is called multi-thresholding. Here higher and lower limits are set for each region. Thus in order to segment the optic disk we have set the threshold value as shown below;

$$Idisk(x,y) = \{255 \quad \text{if } a(x,y) > T_D$$
$$= \{0 \quad \text{otherwise}$$

Where T_D is the threshold value for optic disk extraction.

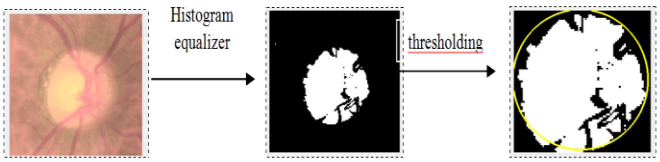

Fig-6: optic disk extraction

First histogram equalization technique is used to enhance the ROI image. Histogram equalization technique is used for adjusting the image intensities so that its contrast can be enhanced. After that thresholding is applied to extract the optic disk as shown in above fig 6.

2.3.2 Optic Cup Extraction

The optic cup extraction is similar to the optic disk extraction, by applying thresholding technique to the ROI image. In order to segment the optic cup we have set the threshold value TC higher than TD since the optic cup area is more brighter than the optic disk area as shown below;

$$Icup(x,y) = \{255 \quad \text{if } a(x,y) > Tc$$
$$= \{0 \quad \text{otherwise}$$

Where TC is the threshold value for optic cup extraction.

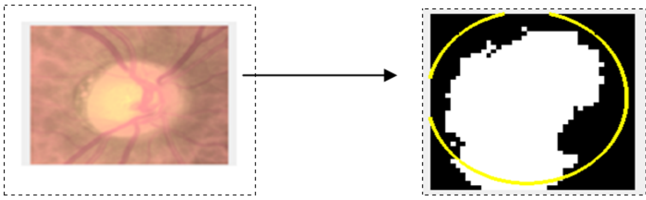

Fig-7: optic cup extraction

2.3.3 Neuro Retinal Rim Extraction

The neuro retinal rim area are is area between the optic cup area and the optic disk area. Hence it can be found by subtracting the cup area from the disk area.

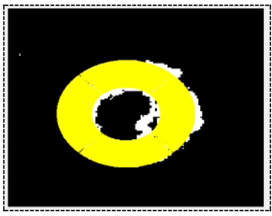

Fig-8: NRR extraction

Finally optic cup to disk ratio(CDR) and neuro retinal rim area is calculated as follows.

Cup to disk ratio = [cup area] / [disk area]

Neuro retinal rim area = [optic disk area – optic cup area]

2.4 Artificial neural networks

Neural networks can be actualized utilizing analog or digital systems. digital implementation is more prevalent as it has the benefit of higher precision, better repeatability, lower noise sensitivity, better testability, higher adaptability, also, compatibility with different sorts of preprocessors. The digital neural network hardware implementation can be classified as (i) FPGA-implementation (ii) DSP-implementation (iii) ASIC-implementation. DSP implementation of neural network doesn't support the parallel architecture which is required for neural networks. The re-configurability is not supported by the ASIC based neural network. FPGA implementation of neural network offers both the adaptability in reconfiguration and parallel architecture of neurons. Hence FPGA is better choice for the neural networks.

Neural network consists of a set of nodes called neurons which are connected to each other. There can be 'n' inputs to a neuron and there is a weight associated with each interconnection between neurons. The neural network can learn by changing the weights of the connections based on the inputs to the neurons. The neural network has three layers namely input layer, hidden layer and output layer.

Based on the complexity of the problem there can be a single hidden layer or multiple hidden layers. But a single hidden layer will be enough to solve most of the problems.

2.4.1 Feed Forward Propagation

There are two algorithms used for neural network feed-forward algorithm and back propagation algorithm. There can't be a neural network based on only feed forward or only on back propagation algorithm. In feed forward the output sum is calculated for the network by taking the summation of the product of weights and the inputs to corresponding neurons. The activation function is applied to the output sum to get the output. For the first feed forward iteration the weights are set randomly.

Fig-4 shows the structure of a neuron. The circle represents the neuron which has x1, x2, x3, ...xn inputs and w1, w2, w3,...wn are the weights on the connections respectively. The output of a neuron is given by the equation

$$y = f(p) \tag{1}$$

and the value of p is given by

$$p = \sum_{i=1}^{n} xiwi \tag{2}$$

Where xi is the ith input of the network and wi is the weight on the ith connection. The function f(p) is called the activation function of the neuron.

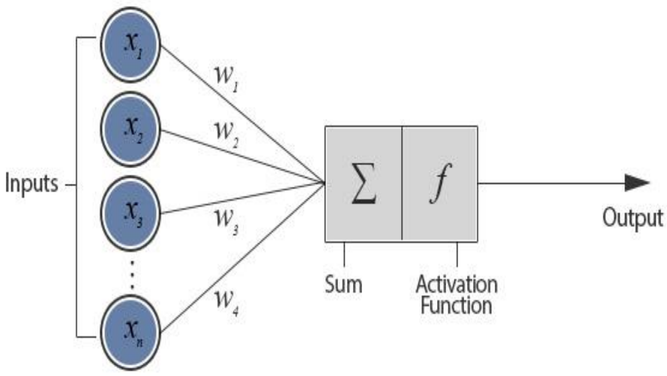

Fig-9: structure of a neuron

There are three types of activation functions namely Linear, Log-sigmoid and Tan-sigmoid functions as shown below.
Linear function,

$$f(x) = x \tag{3}$$

Sigmoid-function,

$$f(x) = \frac{1}{1+e^{-x}} \tag{4}$$

Tan-sigmoid function,

$$f(x) = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}} \tag{5}$$

2.4.2 Back Propagation

In back propagation we calculate the error between the actual output and desired output then we try to adjust the weights to decrease the error. Same as the feed forward the back propagation calculations are applied at each level but the execution is carried out in reverse order i.e. from output layer to the input layer.

Let's first consider the output layer and hidden layer. First the error is calculated at the output by subtracting the actual output from the desired output

error = desired – actual

Change in the output sum is calculated by taking the product of derivation of activation function and the error. We will call this as the delta output sum.

Delta output sum = S`(output sum) * (error)

Where S`(output sum) is the derivation of activation function applied to the output sum.
The change in the nets corresponding to output neurons is calculated by dividing the delta output sum by the hidden layer results.
Delta weights = (delta output sum) / (hidden layer results)
Change in the hidden layer sum is denoted by delta hidden sum and is calculated by following equation.

Delta hidden sum = [delta output sum / hidden-to-output weights] * [S`(hidden sum)]

Now the change in the weights between the input and hidden layer is calculated as follows

Delta weights = delta hidden sum / input data

This completes the back propagation. After this feed forward is applied and the process is repeated thousands of times to get more accurate results.

3 RESULTS

We have tested our methodology on images of high resolution fundus (HRF) database. Sample outputs are as given in the following tables. Results obtained for sample glaucoma images are shown in table-1 and for sample healthy images are shown in table-2.

Table-1: Glaucoma eye results

Filename	Cup area	Disk area	Rim area	Cup/disk ratio	prediction
01_g	804.248	3019.071	2214.823	0.266	Glaucoma
02_g	1256.637	3019.071	1762.433	0.416	Glaucoma

03_g	1385.442	3959.192	2573.75	0.35	Glaucoma
04_g	1194.591	4185.387	2990.796	0.285	Glaucoma
05_g	1520.531	4656.626	3136.095	0.327	Glaucoma
06_g	1194.591	4185.387	2990.796	0.285	Glaucoma
07_g	1134.115	4071.504	2937.389	0.279	Glaucoma

Table-2: Healthy eye results

Filename	Cup area	Disk area	Rim area	Cup/disk ratio	Prediction
01_h	1075.21	5026.548	3951.338	0.214	Healthy
02_h	907.92	3739.281	2831.36	0.243	Healthy
03_h	0	4185.387	4185.387	0	Unknown
04_h	530.929	3848.451	3317.522	0.138	Healthy
05_h	962.113	4901.67	3939.557	.196	Healthy
06_h	855.299	4185.387	3330.088	0.204	Healthy
07_h	346.361	4901.67	4555.309	0.071	Healthy

The extracted disk area, cup area and neuro retinal rim area are fed to the artificial neural network. The performance of ROC is as shown below.

3.1 Receiver Operating Characteristic curve (ROC)

We have used 30 fundus images from HRF image database to determine the performance of our system. For training purpose 16 images (8 healthy and 8 glaucoma images) were used. Remaining 14 images were used during the testing phase, seven images were glaucoma eye images and remaining seven were healthy images. For all glaucoma images the system predicted the result as glaucoma affected and for 6 out of 7 healthy images it predicted the result as healthy eye.

Therefore, accuracy can be given as

$$\text{Accuracy} = \frac{Tp + Tn}{Tp + Tn + Fp + Fn} * 100$$

here,
Tp = true positive = glaucoma image being identified as glaucoma image = 7
Tn = true negarive = healthy image being identified as healthy image = 6
Fp = false positive = glaucoma image being identified as healthy image = 1
Fn = false negative = healthy image being identified as glaucoma image = 0
Therefore,

accuracy= 13 / 14 = 92.85 %

We obtained the accuracy of 92.85 %. The ROC graph is shown in fig-10.

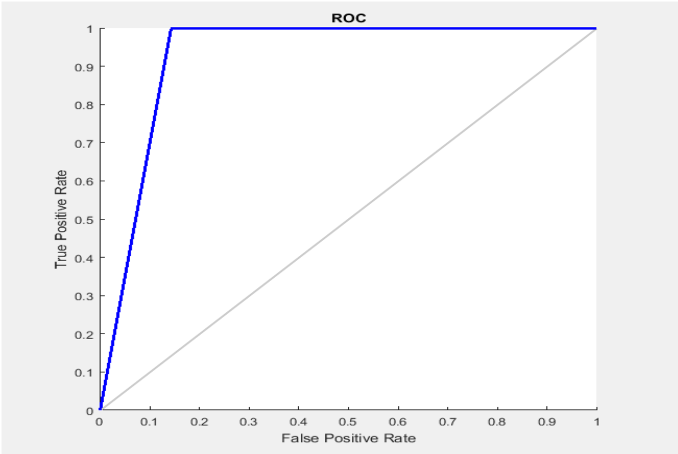

Fig-10: ROC graph

CONCLUSION

The proposed system will be very useful to detect glaucoma efficiently so that the disease can be diagnosed in the early stages. The system does not depend on trained glaucoma specialist and expensive HRT/OCT machines. In this project the glaucoma detection is done by extracting three features i.e. optic disk, optic cup and neuro-retinal rim from a digital fundus image. The artificial neural networks is used as a classifier to identify the disease. The thresholding approach is used for optic disk and optic cup segmentation.

To determine the System performance 30 retinal images (16 images for training and 14 images for testing) were processed and their optic disk area, cup area and NRR area were computed. The system proposed can identify the presence of glaucoma to the accuracy of 92%. The accuracy of the system can further be increased by using the same camera settings for capturing the fundus images. Also it can be improved by using advanced segmentation techniques.

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REFERENCES

[1] Sheeba O., Jithin George, "Glaucoma Detection Using Artificial Neural Network" IACSIT International Journal, Vol. 6, No. 2, April 2014.

[2] Kurnika Choudhary, Shamik Tiwari," ANN Glaucoma Detection using Cup-to-Disk Ratio and Neuro-retinal Rim", International Journal of Computer Applications (0975 – 8887) Volume 111 – No 11, February 2015

[3] Akhade, Snehal B., V. U. Deshmukh, and S. B. Deosarkar. "Automatic optic disc detection in digital fundus images using image processing", 2014 International Conference on Green Computing Communication and Electrical Engineering (ICGCCEE), 2014.

[4] Gopal Datt Joshi, "Optic Disk and Cup Segmentation from Monocular Color Retinal Images for Glaucoma Assessment", IEEE transactions on medical imaging, vol. 30, no. 6, june 2011

[5] Gayathri Devi T. M., Sudha. S. and Suraj. P., ," Artificial Neural Networks in retinal image analysis" 2015 3rd International Conference on Signal Processing, Communication and Networking (ICSCN).

[6] Megha Lotankar, Kevin Noronha, Jayasudha Koti, "Detection of Optic Disc and Cup from Color Retinal Images for Automated Diagnosis of Glaucoma", 2015 IEEE UP Section Conference on Electrical Computer and Electronics (UPCON).

[7] Esraa Zeki Mohammed, Haitham Kareem Ali, ," Hardware Implementation of Artificial Neural Network Using Field Programmable Gate Array", International Journal of Computer Theory and Engineering, Vol. 5, No. 5, October 2013.

[8] Philippe Dondon, Julien Carvalho and Rémi Gardere, ," Implementation of a Feed-forward Artificial Neural Network in VHDL on FPGA", neural network applications in electrical engineering 2014.

[9] Muthuramalingam, A. Himavathi, S. Sriniv. "Neural network implementation using FPGA: issues and application.(field programmable gate array)", International Journal of
Information Tec, April 2007 Issue

[10] www.explainstuff.com/introduction -to-neural-networks.html.

[11] https://www.xilinx.com/support/documentation/boards_and_kits/ug330.pdf

[12] Megha Lotankar, Kevin Noronha, Jayasudha Koti. "Detection of optic disc and cup from color retinal images for automated diagnosis of glaucoma", 2015 IEEE UP Section Conference on Electrical Computer and Electronics (UPCON), 2015.

[13] High Resolution Fundus Image database https://www5.cs.fau.de/research/data/fundus-images/