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DETECTION OF RETINAL DISEASES AND IMPLEMENTATION USING FPGA

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Abstract: Retinal disorders are conditions that affect any part of the retina. Some can mildly affect a person's vision, while others may lead to blindness.Retinal blood vessel segmentation is useful for experts for accurate and early diagnosis of retinal problems. This paper presents the design and the implementation of real-time hardware enhancement digital image processing techniques for biomedical applications in a spatial domain on FPGA using various technique. We have used PCA(Principal Curvature Algorithm) algorithm for segmentation of input retinal images and CNN(Convolutional Neural Network) algorithm for classification of retinal diseases .Alexnet (a type of deepnet) is used for feature extraction. Then, we will implement our code using FPGA(Field Programmable Gate Array) with which we can able to get output as diseased retinal image or not.We have achieved training accuracy of 100 percent with less than 2s for computation of an image.

Keywords : Segmentation , Classification ,retinal image ,SPARTAN 3AN FPGA

1.INTRODUCTION

Automated Retinal Image Analysis through Image Processing is of great significance in early detection of Retinal diseases especially some sight threatening diseases like Glaucoma, Diabetic Retinopathy, ODC(Optical Disk Catridge), CSR(Central Serous Retinopathy) are irrevocable.Normally, the features of OD(Optic Disc), Optic Cup (OC), neuroretinal rim (NRR), Optic Nerve Head (ONH), Retinal Nerve Fibre Layer (RNFL) around the OD, ISNT rule and cup-to-disc ratio (CDR) is very much expedient for the ophthalmologists in the identification of retinal diseases like glaucoma, diabetic retinopathy (DR) and macular edema during the earlier stages . This manual identification needs more experts in ophthalmology is a limiting factor, hence the automatic system would be a great benefit for the identification and evaluation of pathological behavior.

Many existing techniques used OD features such as shape, size, intensity and blood vessel density for detection of retinal diseases because OD is the brightest circular region in the anatomical structure of an eye which is one of the most important features used to identify diseases including glaucoma, hypertensive retinopathy, brain tumor, cardiovascular diseases, papilledema and retinal lesions.Image segmentation is the process of partitioning a digital image into number of segments. It is used to identify objects or the relevant information in digital images. It divides the image into different regions and extract the interested portion. The task of image segmentation is actually the partition of an image into a number of non overlapping regions, each with distinct properties. Manual segmentation of retinal blood vessels has been used by ophthalmologists to assess the diameter and tortuosity of the retinal blood vessels , which is time consuming and prone to human error when the vessel structures are complicated or a large number of images are acquired.It is long and tedious task and it requires special training and skill. Therefore, there is a need of reliable automated method for retinal blood vessels segmentation in computer-aided diagnosis. It is commonly accepted by the medical experts that the automatic segmentation of retinal vessels is the first step for the development of a computer-assisted diagnostic system in ophthalmology.

This paper presents the design and the implementation of real-time hardware enhancement digital image processing techniques for biomedical applications in a spatial domain on FPGA.To achieve better performance , the algorithm is implemented in hardware using Field Programmable Gate Array (FPGA). The hardware will be used Spartan3an FPGA which is easily available. FPGA is having advantage of reconfigurable logic, parallel data processing. Hence performance, speed will be improved. It also requires minimum developing period and time to market. This approach can be used in various biomedical image processing.The implementation of the system mainly consists of three parts.First one is reading the input image and perform the preprocessing on it to make it suitable for FPGA processing. Second part is to perform the segmentation in MATLAB. Here PCA (Principal Curvature Algorithm) is used for segmentation purpose and is implemented in Xilinx Platform Studio.Third part includes the receiving the segmented output via serial communication on PC and display is segmented image output on Visual Basic GUI.(Graphical User Interface).

The images from the public dataset DRIVE are used. For better segmentation performance Spartan 3 FPGA hardware is used.The preprocessing is done in MATLAB and further processing is carried out using Spartan 3an FPGA. For Segmentation purpose, Principal Curvature Algorithm is used. For classification of diseases like CSR, ODC, DN and some retinal diseases, CNN(Convolutional Neural Network) algorithm is used. Alexnet(deepnet) is used for feature extraction. For the software implementation Xilinx Platform Studio 10.1 is used.The main purpose of the system is to develop a system to assist the opthalmologists in the detection and treatment planning for diabetic patients. Section 2 explains about the systems and algorithms used and the major issues with the existing system. Section 3 describes about the proposed system about the working process of our system and also about the explanation of algorithms used , software and hardware used in our system.Section 4 explains about the results which we got in software and hardware. Section 5 explains gives the conclusion and finally section 6 gives the future scope of our work.

2. EXISTING SYSTEM

There are various algorithms used for retinal blood vessel segmentation but there are many disadvantages like time consuming, accuracy is less , not suitable for more number of images. In paper [1] Deep Residual Learning for Image Recognition (ResNet) algorithm is used where More complex and detailed features of images are extracted but The use of screening tool based on stereoscopic fundus photography is limited , while 2-D fundus photography is widely available .In [2] Circle operator method is used where optic disc is detected accurately with low processing time and moderate OD detection accuracy but it fails for those images which have a brighter or darker lesion or exudate than the OD region . For detection, ISNT Rule is used and for OD and OC segmentation Watershed Transformation is used in paper [3] with the performance in terms of sensitivity, accuracy and specificity is better but his method failed in classifying some of the images due to poor illumination and presence of other pathologies in the OD region.
Cicular Hough Transform and grow cut algorithm is used in paper [4] which has higher accuracy, robustness and is tolerant to a vast variety of images but here Early detection of glaucoma in large population-based screening programs is difficult.In paper [5] Superpixel segmentation using Simple Linear Iterative Clustering (SLIC) technique is used which is resilient against the highly varying nature of optic disc and provides accurate localization and segmentation but here simultaneous optic cup detection is not possible.

Neighboring Differential Clustering (NDC) and Intensity Variation Masking (IVM) is used in paper[6] where it eliminates noise spots but it is a time consuming process.Fuzzy logic controller algorithm is used in paper [7] where promising outcomes are obtained with respect to average runtime speed, OD center distance error and OD overlap ratio but here the average execution time is higher. In [8] Ground truth generation, manually defining independent contour algorithm is used which is a semi-automated system and it requires medical expert.In [10] Generalized Distance Function , the stochastic watershed , geodesic transformations algorithms are used which reduces the consultation time but it has the disadvantage of high number of images makes segmentation difficult.

3. PROPOSED SYSTEM

For segmentation of the blood vessels from the retinal image , first preprocessing is done ,conversion of image into header file , followed by FPGA processing and output section.CNN (Convolutional Neural Network)Algorithm is used to detect retinal diseases in an effective way. In machine learning, a convolutional neural network (CNN, or ConvNet) is a type of feed-forward artificial neural network in which the connectivity pattern between its neurons is inspired by the organization of the animal visual cortex.Individual cortical neurons respond to stimuli in a restricted region of space known as the receptive field. The receptive fields of different neurons partially overlap such that they tile the visual field. The response of an individual neuron to stimuli within its receptive field can be approximated mathematically by a convolution operation.

Convolutional networks were inspired by biological processes and are variations of multilayer perceptron designed to use minimal amounts of preprocessing.They have wide applications in image and video recognition, recommender systems and natural language processing. The convolutional neural network is also known as shift invariant or space invariant artificial neural network(SIANN), which is named based on its shared weights architecture and translation invariance characteristics.

PCA(Principal Curvature Algorithm) is used for segmentation of images.The principal curvatures proved the potential to improve the line/edges contrast to get clearer. The principal curvatures are better than the gradient magnitude to improve the contrast of the lines/edges, because the gradient magnitude focuses on the borders, but the principal curvatures – on the sketch structure. So, the principal curvatures are more helpful for blood vessels segmentation and they are also helpful for segmenting buildings, roads of aerial/satellite images.However, we mainly focus on the adaptive principal curvature, because it enhances blood vessel structures better.This principal curvature is a combination of the maximum and the minimum principal curvatures. This combination is expected to be better than the maximum and the minimum principal curvatures.Our contribution focuses on applying the principal curvatures to improve blood vessel structures and proposing an adaptive principal curvature. Alexnet(deepnet) is used for feature extraction.Average training accuracy achieved for FPGA implemenation for images from DRIVE dataset is 100% with reduction in delay.

3.1 BLOCK DIAGRAM

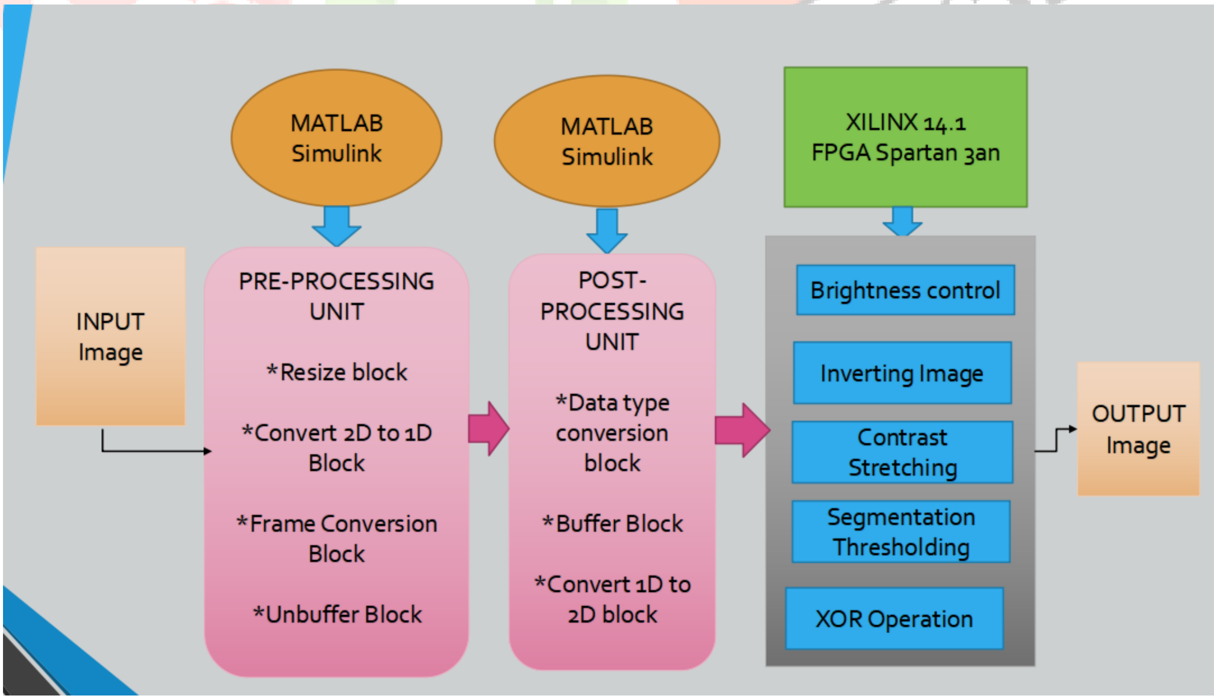

Fig 1.Design flow of hardware implementation of biomedical image enhancement.

In Fig 1. An image is given as input to MATLAB where preprocessing is done which consists of green channel extraction, Adaptive Histogram Equalization (AHE), median filtering and resizing the image. Next postprocessing takes place where conversion of image into header file occurs. Finally FPGA processing is done using SPARTAN 3AN FPGA kit and the output image is displayed in Visual Basic in monitor.

INPUT IMAGE:

Input images are taken from the standard dataset DRIVE . The DRIVE dataset consists of 40 digital images. The images have a size of 568x584 pixels.

PREPROCESSING:

The acquired image may be noisy. We can enhance the image using various image enhancement and filtering techniques.

Green Channel Extraction: As the green channel contains detail information about blood vessels and its background, hence it is extracted first.
Adaptive Histogram Equalization: Histogram equalization is performed to improve the image quality and to improve the contrast. Instead of using normal histogram equalization, adaptive histogram equalization is used which operates on small regions in the image.
Filtering: Filtering is used to remove the unwanted noise in the fundus retinal image. The median filtering is used for the removal of salt and pepper noise present in the image.
Image Resizing: To make the image suitable for FPGA processing ,the image is resized into 128x128.

POSTPROCESSING:

For FPGA processing, the image is converted into headerfile using MATLAB. The header file consists of the pixelvalues of the corresponding image. These pixel values are processed by the FPGA.

XSG(Xilinx System Generator):

After the successful simulation, the results are to be analyzed and XSG token is used for setting the parameter to select proper FPGA kit. The package is to be defined for the kit available with the experimentation lab. If the experimental environment is compatible with the Xilinx ISE edition and Matlab version, then only the VHDL code for the algorithm is created automatically by calling back to ISE.

Different image processing algorithms like Image Negative, Image Enhancement, Contrast Stretching, and Image Segmentation are designed in System Generator with the help of Xilinx and Simulink blocksets.

OUTPUT IMAGE:

The output of segmentation is received by PC via serial communication. A GUI is created in Visual Basic to display the segmented image.

DESIGN AND IMPLEMENTATION FLOW

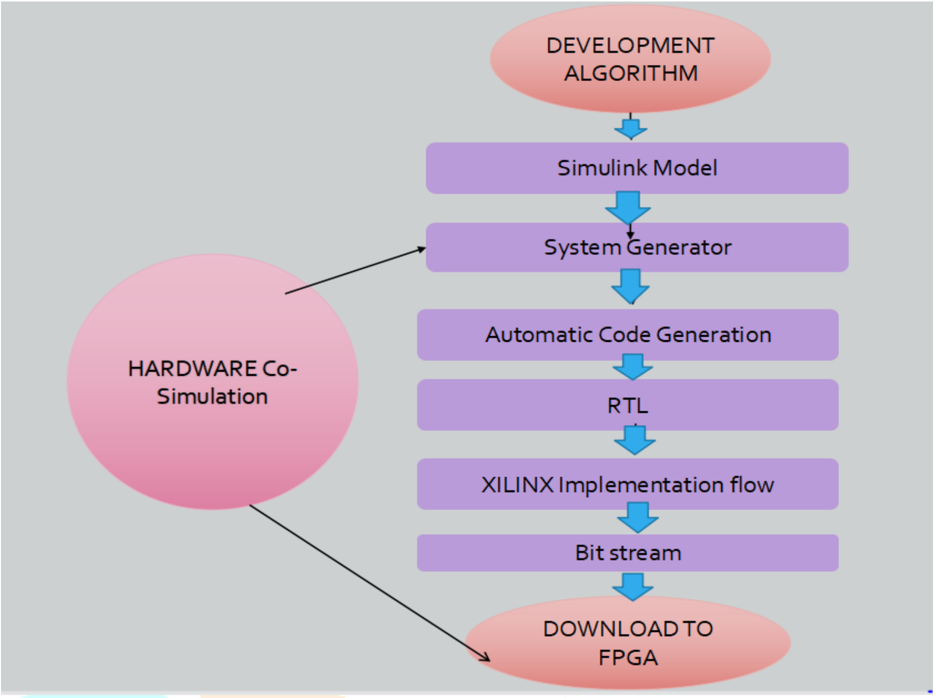

Fig 2. Design and Implementation Flow

Fig 2. represents the block diagram of design and implementation flow which shows the process takes place from MATLAB to FPGA. All steps start by generating the Simulink model for the system using Simulink blocks in MATLAB until it gets downloaded to FPGA. The hardware implementation results are produced using SPARTAN 3AN FPGA. After successful implementation into FPGA the RTL schematic for the biomedical image enhancement algorithms architecture, power analysis and Resource utilization can be observed.

3.2 ALGORITHMS USED:

In this paper Principal Curvature Algorithm (PCA) is used for segmentation of images Convolutional Neural Networks (CNN) is used for identification of diseases like Optical Disk Cartridge (ODC) , Diabetic Nephropathy (DN) , Central Serous Retinopathy(CSR) or normal retinal image without any disease.ALEXNET is used for feature extraction.

Principal Curvature Algorithm:

The blood vessels segmentation for the retinal fundus images plays very important role in the medical image processing. Unlike other medical segmentation tasks of organs, bone, brain,etc., the blood vessels are very small, and their intensity is very similar to intensity of other parts of retinal fundus images. So, the blood vessels segmentation problem is really a big challenge. The principal curvatures proved the potential to improve the line/edges contrast to get clearer image. The principal curvatures are more helpful for blood vessels segmentation and they are also helpful for segmenting buildings, roads of aerial/satellite images.

Adaptive Principal Curvature Algorithm is a combination of the maximum and the minimum principal curvatures. This combination is expected to be better than the maximum and the minimum principal curvatures. We took retinal images from the DRIVE dataset and after segmentation the segmentation quality and contour matching score is analysed. The segmentation quality is compared to the ground truth that is segmented manually. The ground truth is also given in the DRIVE dataset.

Our paper mainly focuses on applying principal curvature algorithm to improve the retinal blood vessel structures. Maximum principal curvature algorithm mainly focuses on several versions of pattern recognition and computer vision.The adaptive principal curvature is expected to improve blood vessels structure better than the maximum principal curvature and the gradient magnitude because the adaptive principal curvature combines both the maximum and minimum principal curvatures. Hence, contrast/brightness of blood vessels will be enhanced better.

Convolutional Neural Networks:

CNN is a deep learning technique which is a type of feed forward artificial neural networks which is applied to visual images.Individual cortical neurons respond to stimuli in a restricted region of space known as the receptive field. The receptive fields of different neurons partially overlap such that they tile the visual field. The response of an individual neuron to stimuli within its receptive field can be approximated mathematically by a convolution operation.

They have wide applications in image and video recognition, recommender systems and natural language processing. The convolutional neural network is also known as shift invariant or space invariant artificial neural network (SIANN), which is named based on its shared weights architecture and translation invariance characteristics.

Process Flow:

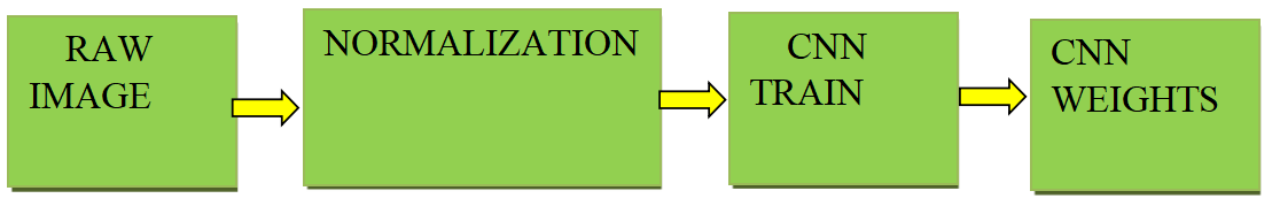

Fig 3.Training Phase

Fig 3. represents training phase where the system received a training data comprising grayscale images of retinal images for various types of diseases with different features and a set of weights for the network. The training step took input image as retinal image. Thereafter, an intensity normalization is applied to the image. The normalized images are used to train the Convolutional Network. To ensure that the training performance is not affected by the order of presentation of the examples, validation dataset is used to choose the final best set of weights out of a set of trainings performed with samples presented in different orders. The output of the training step is a set of weights that achieve the best result with the training data.

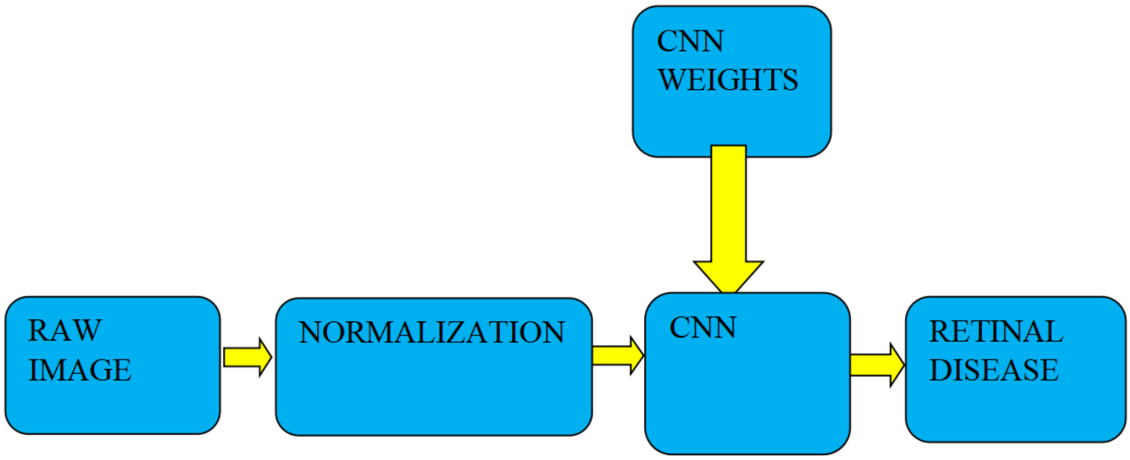

Fig 4. Testing Phase

Fig 4. represents testing phase where the system received a grayscale images of retina and the output which we get is the name of the disease by using the final network weights learned during training. Its output is a single number that represents which type of disease it is , whether it is Optical Disk Cartridge

(ODC) or Diabetic Nephropathy (DN) or Central Serous Retinopathy (CSR) or Normal image without any disease.

ALEXNET:

Alexnet is used for feature extraction.AlexNet was the first convolutional network which used GPU to boost performance.AlexNet is an incredibly powerful model capable of achieving high accuracies on very challenging datasets. However, removing any of the convolutional layers will drastically degrade AlexNet's performance. AlexNet is a leading architecture for any object-detection task and may have huge applications in the computer vision sector of artificial intelligence problems.AlexNet used Dropout in the fully-connected layers. AlexNet 's Dropout nullifies 50% of the neurons for each training epoch. Intuitively there are 2 benefits that Dropout brings. Firstly it causes each neuron to be more independent. Secondly it is like training a sub-network each time and the final result is the ensembling of the sub-networks, which is better than a single big network. It has the features of ReLU Nonlinearity , Multiple GPUs and Overlapping Pooling.

3.3 SOFTWARE USED

In this study ,MATLAB software is used where processing of images is done through which classification of diseases are analysed. We have collected a DRIVE dataset of images and trained those images to identify which type of disease it is . MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar noninteractive language such as C or FORTRAN. Training of images is done and we got the training accuracy as 100% with reduction in loss.

Xilinx is used for transferring the code from MATLAB to SPARTAN 3AN FPGA.Xilinx designs and develops programmable logic products, including integrated circuits (ICs), software design tools, predefined system functions delivered as intellectual property (IP) cores, design services, customer training, field engineering and technical support.[14] Xilinx sells both FPGAs and CPLDs for electronic equipment manufacturers in end markets such as communications, industrial, consumer, automotive and data processing. We got output in MATLAB and for displaying it FPGA we have to use an intermediate that is , Xilinx. The process of translating MATLAB designs to hardware consists of the following steps:

1)Model your algorithm in MATLAB - use MATLAB to simulate, debug, and iteratively test and optimize the design.

2)Generate HDL code - automatically create HDL code for FPGA prototyping.

3)Verify HDL code - reuse your MATLAB test bench to verify the generated HDL code.

4)Create and verify FPGA prototype - implement and verify your design on FPGAs.

3.1 HARDWARE USED

We have used SPARTAN 3AN FPGA is used .The Spartan-3AN FPGA family combines the best attributes of a leading edge, low cost FPGA with nonvolatile technology across abroad range of densities. The family combines all the features of the Spartan-3A FPGA family plus leading technology in-system ,Flash memory for configuration and nonvolatile data storage.The Spartan-3AN FPGAs are part of the Extended Spartan-3Afamily, which also includes the Spartan-3A FPGAs and the higher density Spartan-3A DSP FPGAs. The Spartan-3AN FPGA family is excellent for space-constrained applications such as bladeservers, medical devices, automotive infotainment, telematics, GPS, and other small consumer products. Combining FPGA and Flash technology minimizes chip count, PCB traces and overall size while increasing system reliability.

4. RESULTS

INPUT IMAGE. : Fig 5. shows the set of input images need to be given as input for segmentation followed by classification of images. A collection of images were given as input and an image is selected for which the following outputs are obtained.

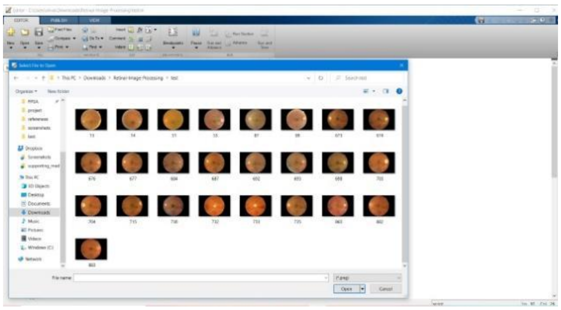

Fig 5. Input Image

OUTPUT IMAGES:

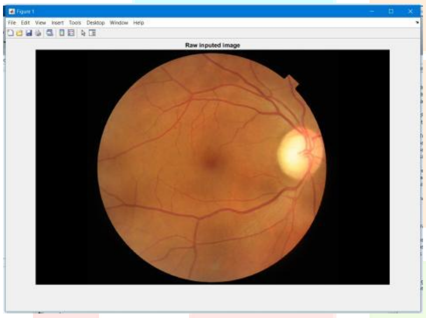

Fig 6. Raw Input Image

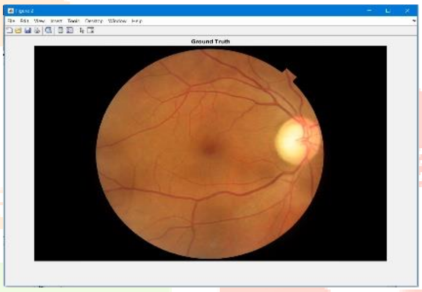

Fig 7. Ground Truth Image

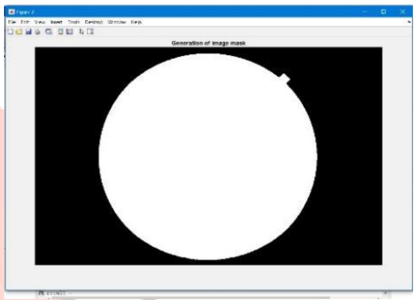

Fig 8 .Generation Of Image Mask

Fig 9. After Gaussian Filter

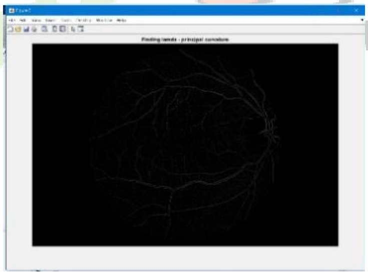

Fig 10. Principle Curvature

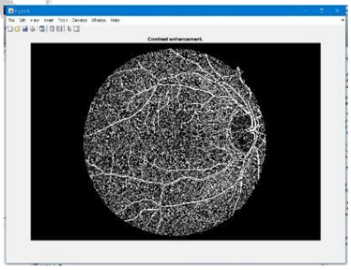

Fig 11. Contrast Enhancement

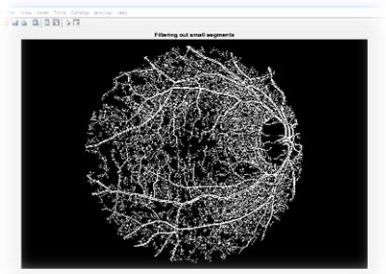

Fig 12. Filtering Of Small Segment

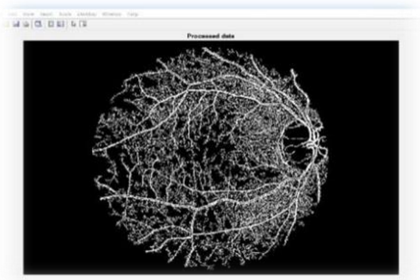

Fig 13. Processed Data

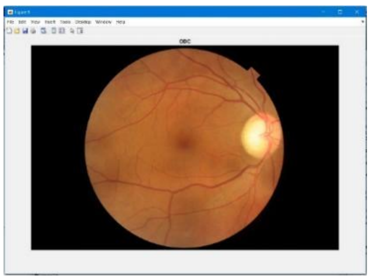

Fig 14 .ODC

Fig 7. represents Ground Truth image.It refers to the information collected on location. Ground truth allows image data to be related to real features and materials on the ground.It means a set of measurements that is known to be much accurate than measurements from the systems you are testing.Ground truth images are not found with MATLAB. These are provided with the dataset . Purpose of these images are just to compare the results with the actual results.

Fig 8. represents the generation of image mask.A mask is a filter. Concept of masking is also known as spatial filtering. Masking is also known as filtering. In this concept it deals with the filtering operation that is performed directly on the image.

Fig 9. represents the image after gaussian filter : Gaussian filtering is used to remove noise and detail It is not Gaussian filtering is used to remove noise and detail. It is not particularly effective at removing salt and pepper noise.

Fig 10. represents principle curvature image. The maximum and minimum of the normal curvature and at a given point on a surface are called the principal curvatures. The principal curvatures measure the maximum and minimum bending of a regular surface at each point.

Fig 11. represents the Contrast Enhancement image. Contrast enhancement processes adjust the relative brightness and darkness of objects in the scene to improve their visibility. The contrast and tone of the image can be changed by mapping the gray levels in the image to new values through a gray-level transform.

Fig 12.represents the filtering of small segment image . Filters are data processing techniques that can smooth out high-frequency fluctuations in data or remove periodic trends of a specific frequency from data.

Fig 13. represents the processed data image. Processed data is defined as the data which is obtained as an output after processing the raw input images successfully.

Fig 14. represents the image of disease identified as ODC **.** ODC is due to genetic and hereditary factors. Chemical, structural and functional abnormalities in the brain are the cause. Distorted beliefs reinforce and maintain symptoms associated with ODC.

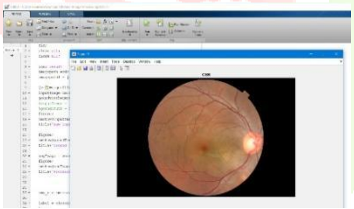

Fig 15.CSR

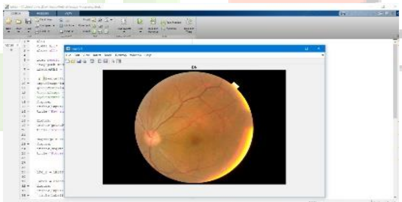

Fig 16.DN

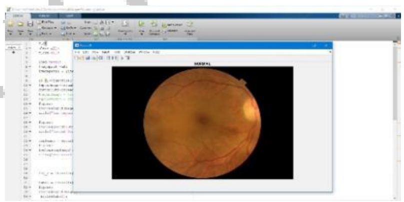

Fig 17. NORMAL

Fig 15. represents the image of disease identified as CSR(Central Serous Retinopathy).Fig 16.represents the image of disease identified as DN(Diabetic Nephropathy).Fig 17. represents the normal retinal image without any disease: is the normal retinal image taken as an output.

4.1 HARDWARE OUTPUT

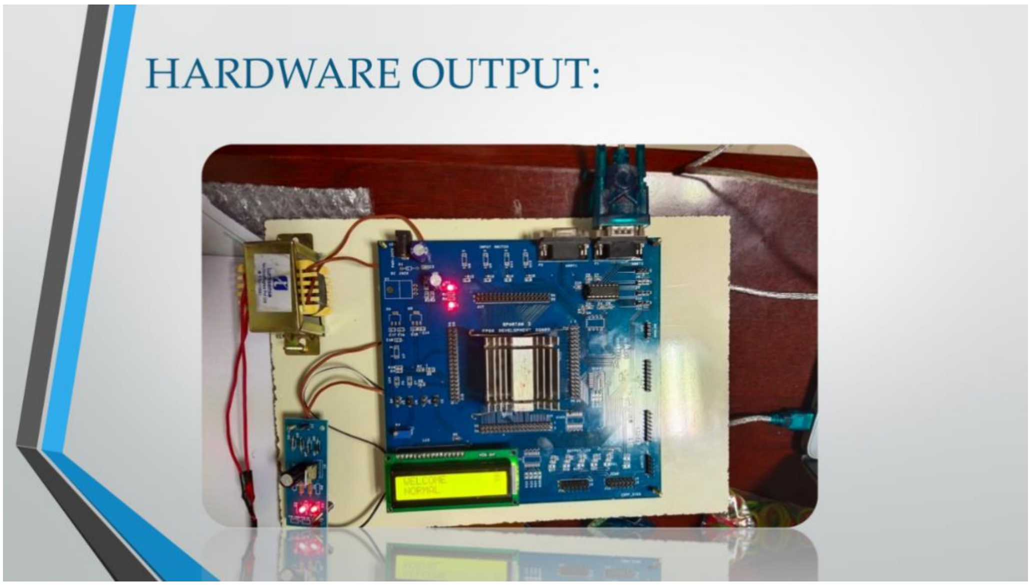

Fig 18. **SPARTAN 3AN FPGA**

Fig 18. is the hardware output of SPARTAN 3AN FPGA.This SPARTAN 3AN FPGA kit which is incorporated with Xilinx. The kit is connected to the personal computer system via communication port to give resultant output.

4.2 COMPARISON OF RESULTS:

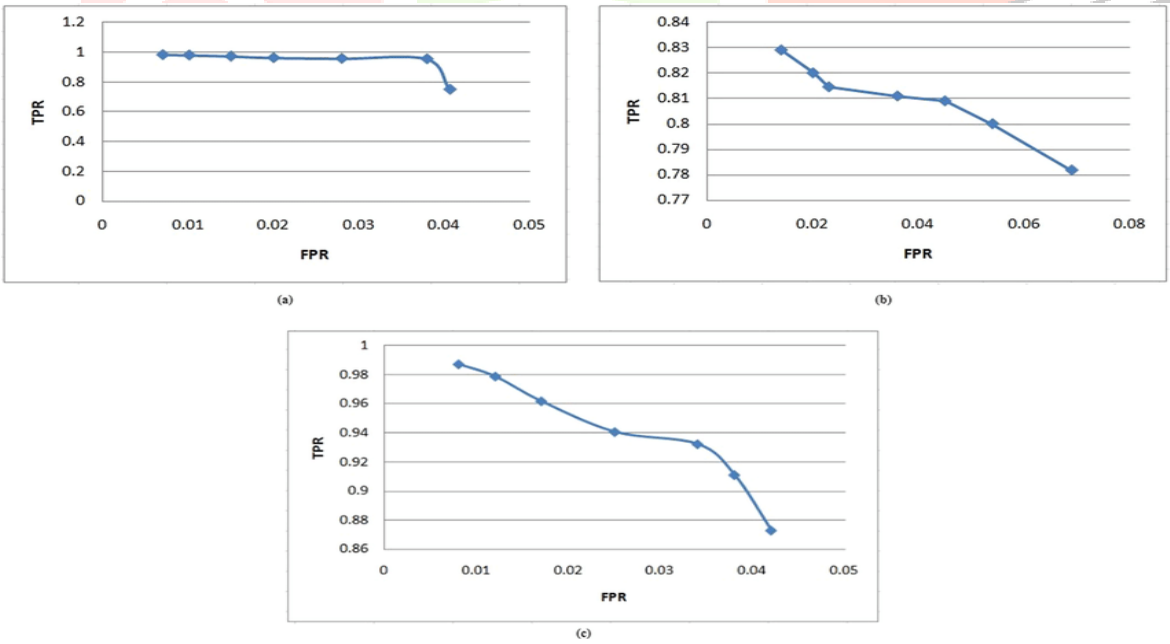

Fig .19 TPR and FPR for 50–50 training to testing ratio.

Fig.20 TPR and FPR for 30–70 training to testing ratio.

Fig.21 TPR and FPR for 70–30 training to testing ratio.

$$TPR = \frac{TP}{Actual\ Positive} = \frac{TP}{TP+FN}$$

$$FNR = \frac{FN}{Actual\ Positive} = \frac{FN}{TP+FN}$$

$$TNR = \frac{TN}{Actual\ Negative} = \frac{TN}{TN+FP}$$

$$FPR = \frac{FP}{Actual\ Negative} = \frac{FP}{TN+FP}$$

Fig .19 represents the TPR and FPR for 50–50 training to testing ratio. Fig.20 represents the TPR and FPR for 30–70 training to testing ratio.Fig.21 represents the TPR and FPR for 70–30 training to testing ratio.

For attaining better performance and to achieve with good accuracy, this paper deals with four different cases to measure four different parameters as follows:

CASE 1: True Positive(TP): Values that are actually positive and predicted positive.

CASE 2:False Positive(FP): Values that are actually negative but predicted to positive.

CASE 3:False Negative(FN): Values that are actually positive but predicted to negative.

CASE 4:True Negative (TN): Values that are actually negative and predicted to negative.

TABLE.1 Comparison of TPR,FPR,TNR,FNR

No. of Tree	FPR	FNR	TPR	TNR
10	0.055	0.005	0.995	0.945
20	0.048	0.005	0.995	0.952
30	0.048	0.002	0.998	0.952
40	0.048	0.002	0.998	0.952
50	0.045	0.002	0.998	0.955
60	0.045	0.002	0.998	0.955
70	0.045	0.002	0.998	0.955
80	0.045	0.002	0.998	0.955
90	0.045	0.002	0.998	0.955
100	0.043	0.002	0.998	0.957

The above table.1 shows the comparison between TPR, FPR, TNR and FNR. Based on the number of retinal vascular tree present in a extracted feature of an input retinal image, it is tabulated.

5. CONCLUSION :

The detection of retinal diseases is done by using CNN (Convolutional Neural Network) algorithm whereas the segmentation of images can be done by using PCA (Principal Curvature Algorithm). For feature extraction, Alexnet is involved in our work. Finally, the implementation is done by using Spartan 3an FPGA (Field Programmable Gate Array). This work overcomes the problems mentioned in the existing system like accuracy is more and loss is also less.

The aim of this paper is to prove the role of System Generator in designing a hardware system for the recognition of Retinal exudates and thus identify the abnormalities present in retina. The results obtained via hardware software co-simulation use limited FPGA resources at higher maximum frequency and low power consumption. FPGA implementation will provide the advantage of speed, reconfigurability. One of the real-life practical applications of automatic blood vessel segmentation in health care includes diabetic screening programs.

6. FUTURE SCOPE:

- ✓ This system processes one image at a time .
- ✓ The system can be modified for multiple images.
- ✓ From the segmented blood vessels, diabetic retinopathy can be detected.

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