Vitreous Hemmorages Detection Due To Diabetic Retinopathy: Severe Proliferative Disease

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Abstract*:*
Proliferative Diabetic Retinopathy (PDR) is the advanced stage of Diabetic Retinopathy(DR) which includes Vitreous Hemorrhages (VH) disease, the severe stage of diabetic retinopathy occur in the vitreous region of the eye. VH is caused due to the bleeding in the vitreous region of the eye, which appears as new floaters like the number of dots and swirls and sometimes dots which may cause loss of vision. In our proposed work, Vector quantization method is used which involves the grouping of the test image into clusters by finding the difference of the intensity values from the cluster. The pre-processing of the image includes the noise removal by using the median filter followed by the normalization of the image using histogram equalization. The segmentation of the blood vessels is done by using line tracking method which detects the leakage of the blood vessels. The approximation of Optic Disc(OD) and the thinning of the blood vessels are done and removed from image and VH is extracted from the image. Linde-Buzo-Gray (LBG) method, based on vector quantization concept, is used for the extraction of the VH then feature extraction and the classification of the VH is done using SVM classifier. Results reveal that LBG reduces the over-segmentation and under-segmentation by using the Mean Square Error (MSE) values. An approach is also proposed to detect the VH by using Xilinx System Generator (XSG). Sobel detector is used for the segmentation of the test image and the VH is detected in the Xilinx System generator, MATLAB, and SIMULINK.

Keywords: *Calculate the difference between high intensity regions,OD approximation, LBG (Linde Buzo Gray), SVM (support vector machine), MSE (mean square error),*

1. Introduction

Nowadays Medical imaging is the most depurative branch in many branches of medicines as it facilitates medical image to capture, transmission and analysis the image by provoking assistance towards medical diagnosis. Medical imaging is filed of interest for the researchers and hence still on the rise with new imaging modalities and continuous improvements of devices capabilities. Diabetes is non-fatal disease which can affect the sensitive vital organs of the human being, if not treated in the early stages; the sensitive organs can malfunction or completely stop functioning. Diabetes severely affects the eye of the human being by causing the change in the retinal blood vascularization known as Diabetic Retinopathy (DR). Automated analysis of the fundus images of eye aims at the objective to assist the ophthalmologists in the diagnosis of DR which may cause the blindness in several patients. DR is of two types i.e. NPDR (Non Proliferative Diabetic Retinopathy) and PDR (Proliferative Diabetic Retinopathy).The high sugar level damages the blood vascularization structure of the retina causing to leak lipids or bleed, which causes the retina to swell and form deposits in early stages of diabetic retinopathy. In the advance stage, leakage of
blood may occur in the jelly like vitreous, constitutes the vitreous hemorrhages, causing serious vision loss.

Vitreous Hemorrhages causes the change in the structural integrity of the retinal blood vessels by rapturing the normal vessels, causing lots of new floaters like number of dots and swirls and sometimes dots may look like hundreds of pepper spots or cigar smoke or coffee ground in the vision which may cause darkening or loss of vision. Therefore, the analysis and the detection of this VH play a vital role and the automated system helps in the diagnosis of VH in the early stage.

In [1], the author provided line detection algorithm to detect the skeleton of the blood vessels tree. OD is detected by calculating the average intensities by placing the window at different points inside the OD in which it intersects the blood vessel. The approximation of OD is done by identifying the points of intensities greater than a threshold. Mathematical morphology and subtraction technique is used for exudates detection. In [1], the drawback is that the small and faint exudates are too elusive to be detected and also the false negative results were obtained as noise in image acquisition can be detected as exudates.

In [2], the blood vessels are extracted by using Deformable models or *snakes* method which is capable of detecting accurately the fine and small blood vessels and the contours of large vessels from the blood vascularisation. A vertical and a horizontal one-dimensional matched filters are used to detect the cores of large vessels followed the Hough transform enabling us to identify the OD by considering it as the brightest area in the retinal images. The result reveals high accuracy but with high calculation complexity.

In HIS color space, author in [3] used a fuzzy k-mean means clustering algorithm following contrast enhancement and color normalization. The exudate or non-exudates were classified using a neural network which needed long time for the execution and hence increased the calculation complexity. In [4], using *k*-means clustering after median filtering to compute intensity difference map was used to detect the exudates in the test images which gave the specificity of 74%.A three-dimensional feature space consisting of features like color ,shape and the size of the exudates for discriminating them from other identities in the fundus image[5]. To classify “lesions” or “others”, a discriminating function derived from Bays rule was used. Drawback of the work was that the approach worked well in the same illumination and hence to overcome this drawback, statistical classification followed by the local-window-based verification strategy was done. Although the technique still has low accuracy.

In the detection of the exudates and haemorrhages, contrast enhancement plays a vital role, hence in [6] Sopharak et al, enhanced the contrast in HIS color image by applying median filtering followed by contrast-limited adaptive histogram equalization (CLAHE). Morphological closing reconstruction method enabled in detecting the exudates and the OD along with the distance information of exudates from the macula. Drawback of the work was that it failed to detect small and faint exudates resulted in the false positive exudates detection in normal eyes

The edge detection algorithm is the most promising algorithm enabling the system to detect the non-selectively edges of the object, thereby, the extraction of the edges of exudates attracted the researcher as a challenging task.In our proposed work ,we aimed at the detection of the VH by overcoming the traditional methods of treating vitreous hemorrhages include retinal photography and Fluorescein angiography ,using a robust method ,the blood vessels line tracking algorithm based on edge detection and morphological image processing to improve the detection of the VH. Our detection method uses Linde-buzo-gray (LBG) algorithm which uses the vector quantization concept for the extraction of the area as feature extraction and the classification of the VH is done. The validation of the LBG method is done with the k-means clustering and watershed algorithm. Results reveal that LBG reduces the over segmentation and under segmentation by using the Mean Square Error (MSE) values are calculated for comparison. Thus LBG algorithm is easy and efficient and the result reveals that detection of VH is more accurate as compared to the other method. The classification of VH into moderate or severe is also proposed in comparison with ground truth images with the help of SVM (support vector machine) classification using Mathwork environment.

Xilinx System Generator [7] is a DSP design tool which enables a system level environment for Simulink modeling, by using Xilinx specific blocksets. An FPGA programming file is generated by using System Resource automatically including synthesis and place and route, Hardware Co-Simulation [8] and accelerated simulation hardware in the loop co-simulation, thus increasing the simulation performance. Xilinx System Generator (XSG) is thus a compatible tool which makes it very easy to handle software environment with respect to hardware by using a high- level graphical interface under the Matlab and Simulink based blocks [10]. Hence, an approach is also proposed to detect the VH by using Xilinx System Generator (XSG). Sobel detector is used for the segmentation of the test image and the VH is detected in the Xilinx System generator, MATLAB and SIMULINK.

According to the ophthalmological survey the area and height of various hemorrhages are discussed below:-

Table 1:- Area and Height of different hemorrhages

Hemorrhages	Area	Height
Micro-aneurysms	2071	508
Dot and blot hemorrhages	1814	93639
Float hemorrhages	335	199
Flame shaped hemorrhages	2880	547
Boat hemorrhages	400	714
Cotton wool spots	919	1288
Hard – exudates	1008	8096
Intra-retinal micro-abnormalities	3409	5056
Macular edema	2451	5342
Vitreous hemorrhages	1011	3202

2.Methodology

Data base required for the proposed work is the color fundus image collected from the ophthalmology clinic and others are downloaded from the DRIVE and STARE database. The database contains about 1000 retinal images having the different retinal disorders which intended to be used for building a diagnostic system that can be used for screening and teaching purposes. The different disorders in the dataset include hemmorhages, exudates, neovascularisation, abnormalities in optic disc and blood vessels. Out of such a large database, only seven images are found to have vitreous haemorrhages (VH) as it is the advance stage of DR. The pre-processing of the images for the diagnosis of VH plays a vital role as the removal of the noise along with the small objects other than VH is an essential step.

2.1 Pre-processing

In the image processing, the pre-processing is an essential stage in designing the automated system which corrects the non-uniform illumination by enhancing the low contrast of the retinal images and suppressing the presence of the noise. The fundus images are the color images in RGB format. Out of the three color channels, we extract the green channel of the fundus images as it resembles the maximum contrast and gives reasonable information about the different anatomic structures and lesions of the retina. Median filtering is used on the green components of the image to remove the noise Ig of the image is given by the equation

$$[p, q] = \{ \mathrm{Ig}[i, j], (i, j) \in w \} \qquad (1)$$

where *w*- represents a neighbourhood, centred at [p, q] in the image. The median filter degrades the edges minimally and hence it helps in the shade correction by equalizing histograms.

The test image under test is brightened by Grayscale dilation using a disk shaped structuring element. Grayscale diation results in

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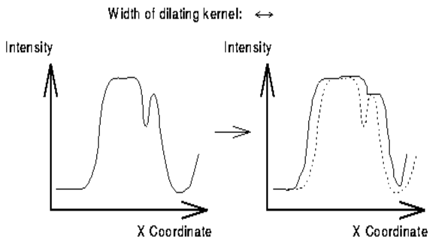
Due to the grayscale dilation, the bright region surrounded by the dark region in the fundus image grow in size, whereas, the dark region surrounded by bright regions shirk in size as small dark spots are 'filled in' to the surrounding intensity value and hence disappears. On the contrary, small bright spots in the image will become larger spots. Intensity changes rapidly and regions of fairly uniform intensity is marked by grayscale dilation except at their edges[11]



(a)

(b)

Figure1.(a)Graylevel dilation using a disk shaped structuring element. The graphs show a vertical cross-section through a gray level image (b) Dilated Fundus image after illumination correction [11]

To find the high intensity pixels from the image and its component connectivity,the filtered image is converted into binary and Otsu thresholding method is used for binarizing the image[13].

Consider the image is represented by gray levels *(0, 1, ..., L-1) with the pixel count at level i is fi; hence* all pixel count N is given as N= $f_0 + f_1 + \ldots\ldots + f_{L-1}$.The filtered image is segmented into *K* clusters $(C_0 + C_1 \ldots . C_{K-1})$,*and K-1 thresholds are required to be selected.*

Let $(t_0^*, t_1^*, \ldots, t_{K-2}^*)$ *be the optimal thresholds that find the maximise class variance given as*

$\{t_0^*, t_1^*, \ldots, t_{K-2}^*\} = arg_{\ 0 \leq t0,\ t1\ ,\ldots\ ,tK-2\ < L-1} \max \{\sigma_{2B}\ (t_0, t_1,,,, t_{K-2})\}$ (2)

where σ_{2B} is is obtained by subtracting the class variance from the total variance which the class-variance :

$\sigma_{2B}\ (T) = \sigma_{2B} - \sigma_{2\ W}\ (T)$, (3)

where σ_2 is combined variance $\sigma_{2\ W}\ (T)$ is within class variance defined as the weighted sum of the variances of each cluster.

$\sigma_2\ W(T) = n_B(t)\sigma_{2B}(T) + n_0(T)\sigma_{2o}(T)$ (4)

Here $\sigma_2(T)$ is variance of pixels below threshold,σ_{2o} is variance of pixels above threshold,

$(t) = \sum_{i=0}^{T-1} p(i);\ n_0(t) = \sum_{i=0}^{N-1} p(i)$ (5)

where [0, N-1] is the range of intensity levels. Thus, the high intensity region is approximated

2.2. Approximation of Optic Disc (OD)

As per the previous work, the detection of exudates is based on the edge detection which unfortunately detects all points having some contrast to their background. In addition, the edges of the blood vessels of the retina too have more impact in the detection of the edges of the vitreous haemorrhage (VH). Consequently, for the design of the automated system for the detection of VH, the implementation of the algorithms for the detection of blood vessels and optic disc plays an vital role. For the detection of VH, the detection algorithm is applied after the removal of the blood vessels and OD from the image under test.

After the preprocessing of the image , the approximation of the OD is done.OD appears as the most bright region as compared to the other retina components.As in above section we have discriminated the high intensity regions present in the test Image,so the approximation of OD is done by considering the pixels having the weighted sum of the clusters as maximum.The OD is removed from the filtered green channel image by subtracting it from the filtered green image.

2.3. Extraction of blood vessel from the image

In our proposed work, for the extraction of blood vessels from the test image we used the green channel image as blood vessels appear as dark regions in brighter background. The thinning of the blood vessels is done by morphological dilating of the image followed by the eroded image using the same structuring element which results in the elimination of the very small dark region from the test image. The morphological closing operation uses the dilation followed erosion so in our proposed work the blood vessels detection are done by closing the image with two linear structuring elements of different sizes. The blood vessels from the test image are removed by using the morphological closing with the bigger structuring element while the cores of the vessels are removed by closing with the smaller structuring elements [14]. The brighter areas of blood vessels in a darker background with a contrast higher than that of the original image is extracted by subtracting the two closed images.

The structuring elements are rotated in different orientation to extract the vessels at different orientations at angle θ ($0 \leq \theta \leq \pi$), the closing of the image in 6 different angles is applied at an angular resolution of 30^o.The region of interest (ROI) is obtained by extracting pixels of values greater than a threshold and accumulating them into the binary output image. In our proposed work we set threshold value greater than 0.7 of the maximum intensity of the image depending on trial and error basis. Any small regions, if any, due to the noise are removed by using morphological opening the output image. Thus the Region of Interest (ROI),i.e.,VH is extracted.

2.4. Detection of Vitreous haemorrhage

For the detection of VH, Linde-Buzo-gray(LBG) algorithm is used which follows the Vector Quantisation (VQ) which resembles to the power technique for data compression. The LBG algorithm is an iterative algorithm which is like the K-mean clustering which solves the two criteria nearest neighbour condition and centroid condition which takes a set of input vectors $S=\{x_i \in R^d \mid i= 1,2, \ldots, n\}$as input and generates a representative subset of vectors $C = \{c_j \in R^d \mid j = 1,2, \ldots, K\}$with a user specified K << n as output according to the similarity measure. Thus it requires initial codebook, which is generated using a training set of images, which can be obtained by different methods like random codes and splitting. A set as the average of the entire training sequence is taken as an initial code vector which is then split into two and the iterative algorithm is run with these two code vectors as an initial codebook. If the code vector does not satisfy the below condition, the two code vectors are again splitted into four and the iteration is repeated until the desired code vector is not obtained.by using the algorithm [15]

1. Input training vectors $S=\{x_i \in R^d \mid i= 1,2, \ldots, n\}$
2. Initiate a codebook $C= \{cj \in R^d \mid j = 1,2, \ldots, K\}$
3. Set $D_0= 0$ and let $k = 0$.
4. Classify the n training vectors into K clusters according to $x_i \in S_q$ if $\| x_i - c_q \|_p \leq \|x_i - c_j \|_p$ for $j \neq q$
5. Update cluster centers c_j, j= 1,2,…, K by
   $c_j= \frac{1}{|Sj|} \sum_{xi \in Sj} x_i$
6. Set $k \leftarrow k+1$ and compute the distortion as
   $D_k= \sum_{j=1}^{k} \sum_{xi \in Sj} \|x_i - c_j \|_p$
7. If $(D_{k-1}-D_k)/D_k > \in$ (a small number), repeat steps 4~6.
8. LBG Output the codebook
   $C=\{c_j \in R^d \mid j= 1,2,\ldots,K\}$

The total count of the codebook resembles to the area of the VH which we are interested to detect. As elaborate in the table 1, the area of the VH is 1011 for the affected person; depending on this the threshold for VH to detect the disease is set to 1011 pixels. If the detected area is more than the mentioned threshold then the person has severe VH and need to be operated immediately by the eye specialist otherwise less area confined to be medium VH and can be inspected by the eye specialist by providing precautions treatment.

As LBG measures the distortion and hence guarantees less distortion from one iteration to the next which is validated with the k-mean clustering and the Watershed algorithm It is validated that the LBG performance of Mean Square Error (MSE) is less as compared to the other segmentation method as illustrated by table 2 [16].

Table 2:-Comparison between watershed, k-means clustering and Linde-Buzo Gray

Sr . No	Algorithm	Initial MSE(mean square error)	Final MSE(mean square error)	Time Consumed
1.	Watershed	225.04	89.35	50.004 sec
2.	K-means clustering	273.82	94.08	64.990 sec
3.	LBG(Linde – Buzo- Gray)	143.74	64.25	13.004 sec

2.5 SVM (Support vector machine) Classification

To classify the disease using the input data ,a supervised learning methodology known as a Support Vector Machine(SVM) is used which incorporates the classification of high dimensional images by primary object of finding the the effectiveness of the objects based on the images and secondary objective is to find the accuracy of the system based on the nearest neighboring object in the images.Thus SVM uses non-probabilistic binary linear classifier concept using by labeled two-class training set $\{x_i,y_i\}$,i=1…….1,$x_i \in R^d$,$y_i \in \{1,-1\}$ is the associated truth value obtained from truth images[15].

To separate the hyperplane ,it must satisfy the following constraints:

$y_i [(w.x_i) +b] \geq 1-\xi_i , \xi_i \geq 1$ (6)

where b is the bias, ξ is the slack variable and w is the weight vector. To find the optimal separating hyperplane, the following function should be minimized subjected to the above constraint:

$\varphi(w)=\|w\|^2/2 +C (\sum_{i=1}^{1} \xi_i)$ (7)

where C is a constant chosen by the user which controls the trade-off between maximizing the margin and minimizing the training error. Higher penalty to constraint violation is assigned if C is chosen large. The classifier can be constructed as:

$f(x) = sgn(w0 .x + b0) =sgn(\Sigma_{support\ vectors}\ yi\ \alpha^0{}_i (xi.x)+ b0)$ (8)

where w0,b0, α^0 denotes the optimum values of weight vectors ,bias and Lagrange multiplier respectively.

3. Proposed Hardware Implementation

Sobel edge detection using Xilinx system generator utilizes various methods .The first method is to load the original image and the second method is to detect the edges are detected and then the VHDL synthesis and VHDL co-simulation is done.

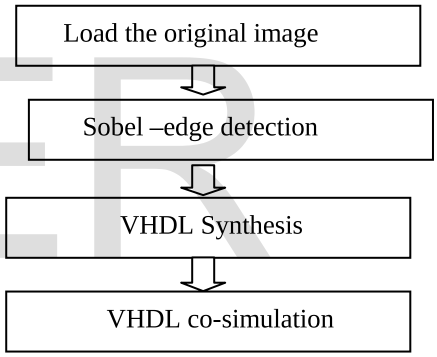


Figure 3:- Block diagram of sobel edge detection using VHDL synthesis.

3.1 Sobel –edge detector

The sobel operator performs 2D spatial gradient magnitude on image and so emaphsizes regions of high spatial performance that corresponds to edges. Normally it is used to find the approximate absolute gradient magnitude at every point in a gray scale image.

The sobel operator consists of 3×3 convolution kernels as shown in figure 4. Each kernels are rotated by 90 degrees.

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

Figure 4: Convolution of Sobel edge detector

These kernels are applied separately to the input image, to create separate measurements of the gradient element in each orientation (call these Gx and Gy). These kernels are designed to rejoin maximally to edges running vertically and horizontally to each of the pixel grid, one kernel for

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each of the two perpendicular directions.. The gradient magnitude is given by:

$$|G| = \sqrt{Gx^2 + Gy^2} \quad (9)$$

A predictable magnitude is computed using:

$$G=||Gx||+||Gy|| \quad (10)$$

which is much faster to compute.
Finally breaking up of the edges is performed with the help of sobel edge detector.

3.2 VHDL Synthesis.

The implemented design is needed to be synthesized in ISE Design Suit 13.1. It creates device deployment summary for hardware implementation.

3.3 Hardware co-simulation

A code generation option allows the authenticating the working hardware and accelerates simulation in Simulink and Matlab. Xilinx System generator supports JTAG communication between a hardware platform and Simulink .

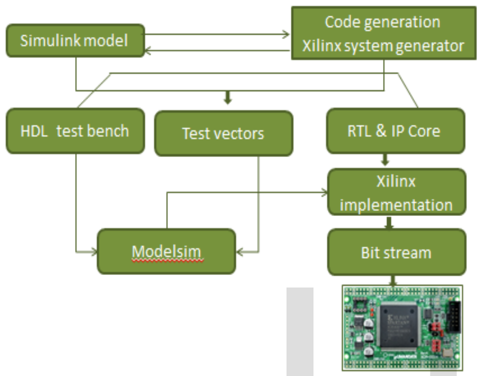


Figure 5:-Hardware co-simulation using XSG

4. Pre-Processing steps

This method utilizes the Xilinx System generator which utilizes the Xilinx block-sets for image filtering.
Xilinx system generator is one of the industry important high level tool for manipulating high performance DSP systems using Xilinx. These develop high systems with the industry's most innovative FPGA. It provides system modeling and spontaneous code creation from Simulink and MATLAB. It also provides integration with RTL , embedded, MATLAB and hardware components of a DSP system.JTAG co-simulation support for virtex -5 family is enhanced to utilize and improve performance.

4.1 Sobel edge detection using XSG

The model base design uses Xilinx block-sets. Sobel edge detector uses 5 line buffer, a sequential stream of pixels to constructs 5 lines of output.. Nine unlike 2-D filters have been on condition that to filter gray-scale images.
The primary advantages of the Sobel operator lie in its easiness. The Sobel method provides an approximation to the gradient magnitude. It can detect edges and their orientations.
The main disadvantage of Canny edge detector is that it is time consuming, due to its difficult computation.

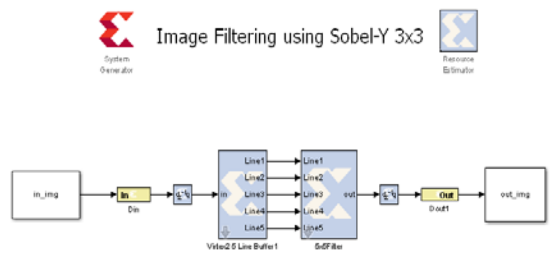


Fig5:- Sobel edge detector using XSG

4.2 Setting code generation for XSG

By utilizing HDL coder, multiple XSG subsystεms can be dεsigned , but XSG should have same port sεttings.
HDL coder supports XSG code generation with the following settings

1. Hardware description language should have the same as target language set as in HDL coder.
2. Compilation should be HDL net-list.
3. Create test bench should be unchecked.
4. Synthesis strategy should be XST default.

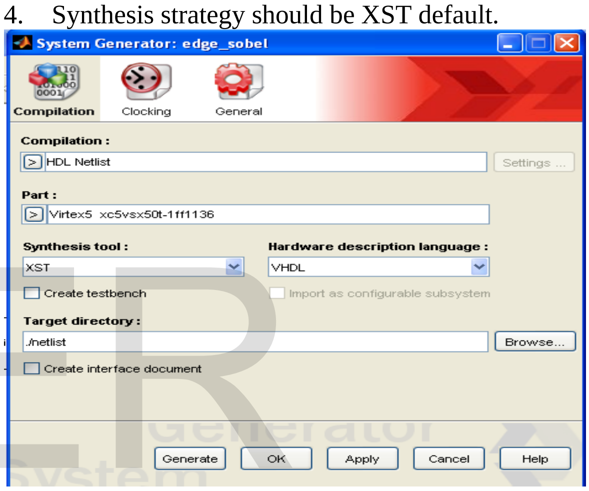
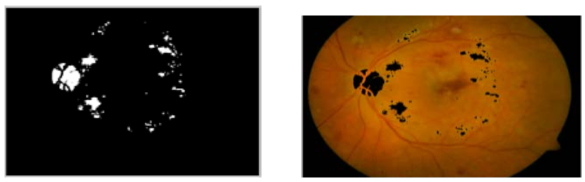


Figure 6:-system generator block.

5.Result and Conculsion

In this paper we found the area of the VH as a feature vector and according to the ophthalmological survey, the area of vitreous is found to be in between 1010 to 3230 pixels,the VH is classified into normal,moderate & severe according to the specified area .The LBG algorithm is used for the segmentation of the VH and it is concluded that it avoid the over segmentation and under segmentation which occurs due to the watershed and k-means clustering algorithm .Additionally, it provides less MSE and thus provides less distortion as compared to is also found to be high which the watershed and k-means clustering algorithm, herby confining more accuracy as illustrated in table 2.



(a) (b)

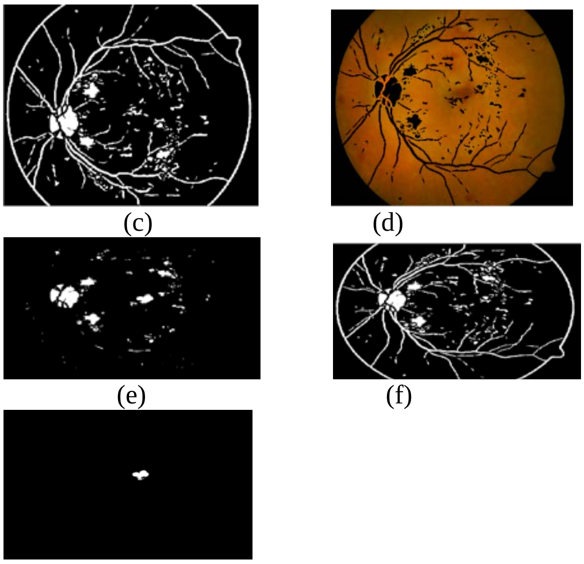


Figure 7:- image (a) obtained from median filtering and dilation of image in which the approximate disc area is calculated. (b) high intensity removed image.(c) tracking of blood vessels. (d) pre-processed region.(e) reference region (f) unwanted region (g) detected hemorrhages region with LBG algorithm

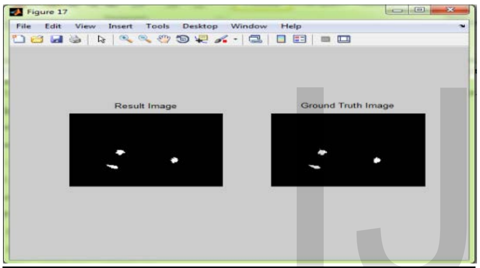


Figure 8:- comparison with Ground truth images

Table 2: Calculation of Sensitivity, Specificity, Accuracy, Area and time consumption

Total time required= 20.702, 'Severe Condition', Detected area=3202
Predicted Classes
1 | 428775.0 | 23.0
2 | 0.0 | 3202.0
Actual Classes
TP | 428775.00 | 3202.00
FP | 23.00 | 0.00
FN | 0.00 | 23.00
TN | 3202.00 | 428775.00
Detection Accuracy=99.2535

Output images after each step of analysis using the Xilinx System Generator .The results obtained with the help of Xilinx system generator in which are obtained by sobel edge detector.

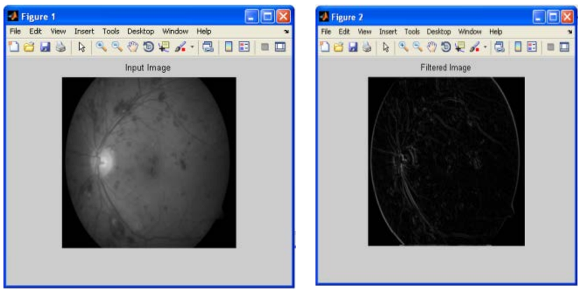


Figure 9:- (a) input gray scale image . (b) filtered image obtained with the help of Xilinx System Generator)

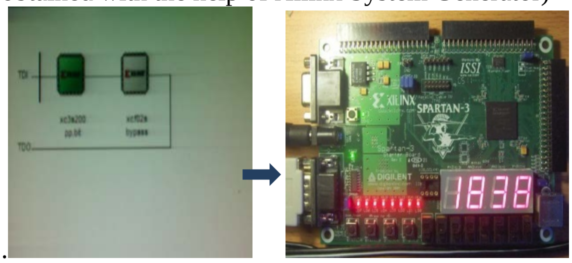


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Figure 10:- The implementation of bit file with the help of spartan 3 FPGA kit Edges are detected with the Xilinx system Generator

This hybrid approach for the detection of vitreous hemorrhages with the help of Xilinx System Generator with Xilinx design suite 13.1 and MATLAB 2009a detects the severity of the disease.ith the help Xilinx System Generator ,the hardware based implementation of detector results is carried out with the help of Xilinx family using Spartan 3 FPGA kit. The software is designed using the Xilinx ISE design suit 13.1, with the support of Xilinx system generator a bit file is generated which is dumped on Spartan 3 FPGA kit in addition to MATLAB. The proposed work gives better results as compare to canny, Prewitt, Robert and Laplacian because these methods utilizes more computational time . The results obtained with the sobel edge detector are comparatively better. These technique is updated with the help of Xilinx ISE design suit 13.1. The implemented design is targeted on Vertex5 xc5vsx50t-1ff1136 starter kit. This method is very useful in medical images to detect the disease.

Table 4. shows the results and the accuracy values obtained after the Classification of the test images.

Sr no.	Images	condition	sensitivity	specificity	Accuracy	Area	Time consumed
1	Image 1	Severe	0.99	0.5	99.25%	3202	17.74
2	Image 2	Normal	0	0	0	0	15.04
3	Image 3	Moderate	0.1	0	99.66%	1010	12.954
4	Image 4	Moderate	0.1	0	99.01%	1010	13.294

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