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Design Strategies For Various Edge Detection Techniques for Disease Detection

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***Abstract*—Edge detection of an image is the primary and significant step in lower level image processing. These edge detection techniques find significant applications in various fields which may include object tracking, image analysis; image segmentation etc. This paper presents implementation of various image processing algorithms applicable for edge detection of an image where one of algorithm is implemented in Xilinx Spartan 3 FPGA using System Generator. Also the work is proposed using modelsim. In System generator, canny edge detection method and Sobel edge detection are done. Both give significant output. The system generator has high level graphical interface under the environment of MATLAB. Since FPGA has large embedded multipliers and internal memory, it offers parallelism. Hence FPGA provides platform for real time processing with higher performance than microprocessor programmable and digital signal processors (DSPs). There is much reduction in FPGA resources which reduces the area of FPGA. The proposed methods precisely detect edges of an image. Different approaches of edge detection are tried for different applications.**

Keywords*—FPGA; System Generator; Modelsim; Canny ; Sobel; MATLAB

I. Introduction

Digital image processing has been a broad and dynamic area with everyday life applications such as in medicine, space exploration, surveillance, authentication, automated industry inspection and in many more areas. These applications consist of different image processing methods like image enhancement, object detection etc. These applications are easy to implement on general computers but their efficiency reduces in terms of speed and reliability. This happens because of constraints of memory and interfacing with other devices. If the hardware design is application specific , then the speed can be increased to better extent. ASIC design and FPGA can be two ways of hardware design. ASIC design offers highest performance, but the design is complicated and very costly. Also the ASIC design cannot be changed if the application is changed; time required to design the hardware is also very high. Because of these issues. If an error exist in the hardware design, the design cannot be changed, rather the hardware then becomes useless. DSPs are specialized microprocessor, typically programmed in C, perhaps with assembly code for performance. Image Segmentation is also one of the areas used in medical image processing. It is a process of partitioning the original natural image into meaningful regions or it can be defined as segregation of interested parts from the original image. The process used to perform image segmentation varies greatly depending upon specific application, imaging modality and other factors. The efficient Gabor filter design is used to remove noise components from input images to be processed.

II. Proposed Methods

A. Block Diagram for Edge Detection Algorithms

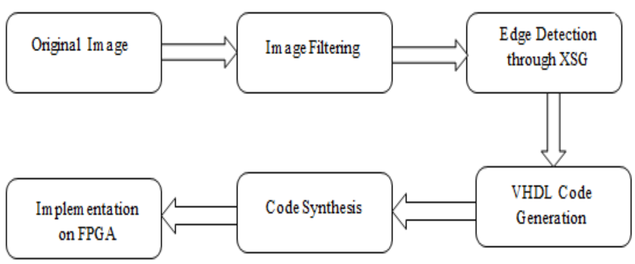
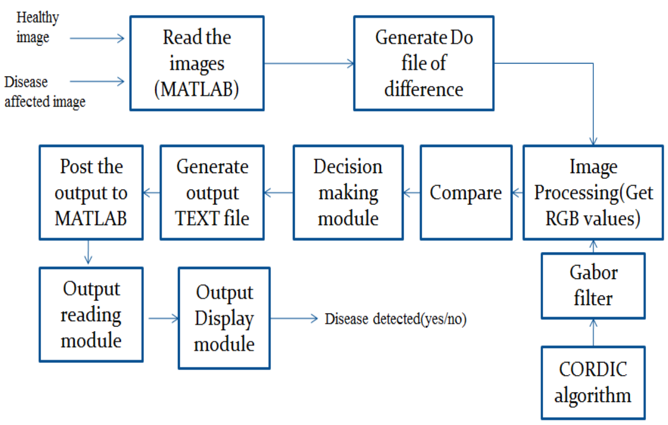


Figure 1. Block Diagram of Edge Detection based on VHDL

The VHDL based Edge Detection Algorithms use Xilinx System Generator as a developing environment. It uses the System Generator block sets to design the architecture. The complete architecture design is done in MATLAB Simulink and it is implemented in ISE Design Suit. Canny and Sobel edge detection using Xilinx System Generator contain various steps. First image is needed to be filtered to remove noise present in an image. For filtering the original image filtering mask is used. Next processing steps are to detect edges of an image. The edge detection of image is implemented by VHDL block sets. Then further steps are generation of VHDL code. Code is generated through Xilinx System Generator.

B. Block Diagram for Gabor Filter Design

Image Segmentation is typically used to find out objects and boundaries (lines, curves etc.) in images. There is a wide variety of techniques available for image segmentation in medical field. A common classification of these methods is thresholding, edge detection, clustering, region growing, active contours and statistical techniques. This design approach provides an idea for efficient Gabor filter design. Early stage of the disease can be detected using textural properties of image.
The block diagram for this method is given as below



III. Methodology

A. Canny Edge Detection Algorithms

The canny edge detector algorithm was developed to give optimal edge detection. The word optimal means it should provide good detection capabilities, good edge point localization and minimal response. While development of canny edge detector some list of criteria was followed to improve edge detection techniques. The first one was to obtain low error rate i.e. it should not miss any single edge occurred in an image. The second criteria were it should localize edge points in perfect manner. The third criteria were that it should give a single response to a single edge. It was necessary because first two criteria were not enough to eliminate possibility of multiple edge response.

- **Noise reduction**

It is all time possible that all images taken from a camera will consist of some amount of noise. This noise percentage must be removed so that it will be seen in the form of edge detection because of which false results will be generated. Therefore the image is first smoothed by applying a Gaussian filtering. The kernel of a Gaussian filter with a standard deviation of σ = 1.4. Let an example of Gaussian filter with 5×5 mask having σ = 1.4.

$$\mathbf{B} = \frac{1}{159}\begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix} * \mathbf{A}.$$

- **Finding gradients**

After the noise is removed, the gradient of the image is to be taken to find the edge strength. The Sobel, Roberts, Prewitt etc. performs 2-D spatial gradient measurement. Then absolute gradient value can be found at each point. The Sobel operator uses two 3×3 convolution masks. One is used to find gradient in x-direction and other in y-direction i.e. rows and columns.

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

Gx

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

Gy

Then gradient approximated using the formula

$$|G| = |GX| + |GY|$$

Finding the edge direction is much easy when the gradients in x and y direction known. Therefore the formula for edge direction is given as

$$\Theta = invtan(GY/GX)$$

Once the edge direction is found, the next step is to compare the edge detection to a direction that can be traced in an image. So the pixel of 5×5 image aligned as follows

x	x	x	x	x
x	x	x	x	x
x	x	a	x	x
x	x	x	x	x
x	x	x	x	x

B. Sobel Edge Detection Algorithm

Edge detection using Sobel operator is based on computing an approximation of the gradient of the image intensity function. Two 3x3 spatial masks convolving with the original image are used to calculate gradient approximation. Two filters Hx and Hy are used here.

$$Hx=\begin{bmatrix}-1 & 0 & 1\\ -2 & 0 & 2\\ -1 & 0 & 1\end{bmatrix} \text{------------} (1)$$

$$Hy=\begin{bmatrix}-1 & -2 & -1\\ 0 & 0 & 0\\ 1 & 2 & 1\end{bmatrix} \text{------------} (2)$$

Where Hx (Convolution kernel in x direction) and Hy (Convolution kernel in y direction)

$$GM(x, y) = |\,Hx\,| + |\,Hy\,| \text{ ------ } (4)$$

This equation preserves any changes in edges of image. The above mentioned process is applied separately for each color channel and final color edge map of color image is computed by fusing the edge maps of each color channel.

C. Gabor Filter Design Algorithm

The system design is divided into six modules.

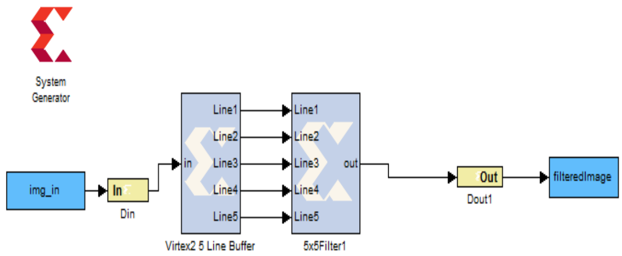
- MATLAB image reading module
- Gabor Algorithm
- Image segmentation module
- Disease Detection/Decision making module
- VHDL output module
- Final result display module in MATLAB

IV. FPGA Implementation

A. Canny Edge Detection

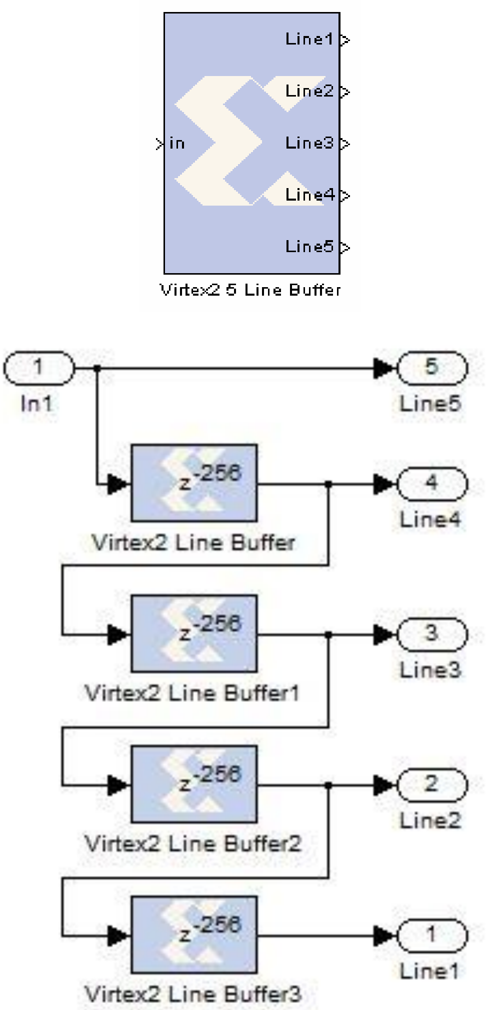
Gaussian filtering using XSG

The model base design uses Xilinx block sets. Gaussian filtering uses 5 line buffer, a sequential stream of pixels to constructs 5 lines of output. Each line is delayed by N samples, where N is the length of line. The designed Gaussian filtering using Xilinx blocks is shown in Figure 6. Further it uses 5×5 filter. It is implemented by using 5n-tap MAC FIR filters. Nine different 2-D filters have been provided to filter gray scale images.



Gaussian Filtering using System Generator Virtex2 5 Line Buffer

The block buffers a sequential stream of pixels to construct 5 lines of output. Each line is delayed by N samples, where N is the length of the line. Line 1 is delayed 4*N samples, each of the following lines are delay by N fewer samples, and line 5 is a copy of the input.

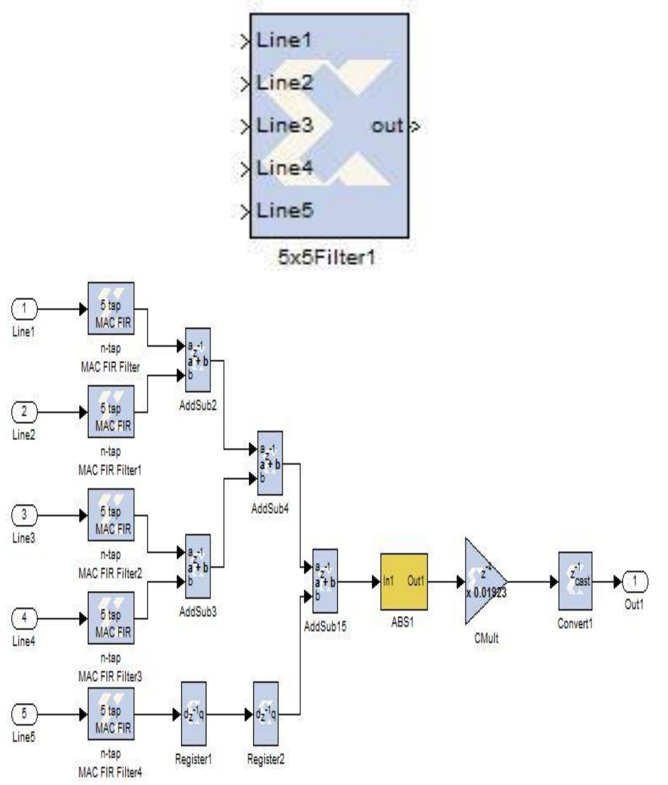


Vertex2 5 Line Buffer & internal structure

By looking into Vertex2 5 line buffer four Vertex2 line buffers are arranged in Series as showen in figure. The Xilinx Virtex2 Line Buffer reference block delays a sequential stream of pixels by the specified buffer depth. It is optimized for the Virtex2 family since it uses the Read before Write option on the underlying Single Port RAM block.

5x5 Filter

The Xilinx 5x5 Filter reference block is implemented using 5 n-taps MAC FIR Filters. Nine different 2-D filters have been provided to filter grayscale images.



5x5 Filter & internal structure

By looking into mask 5 MAC FIR Filters are connected to process input. MAC based FIR filter with n coefficients. It filters coming input which is Line 1-5 and process the output at out port.

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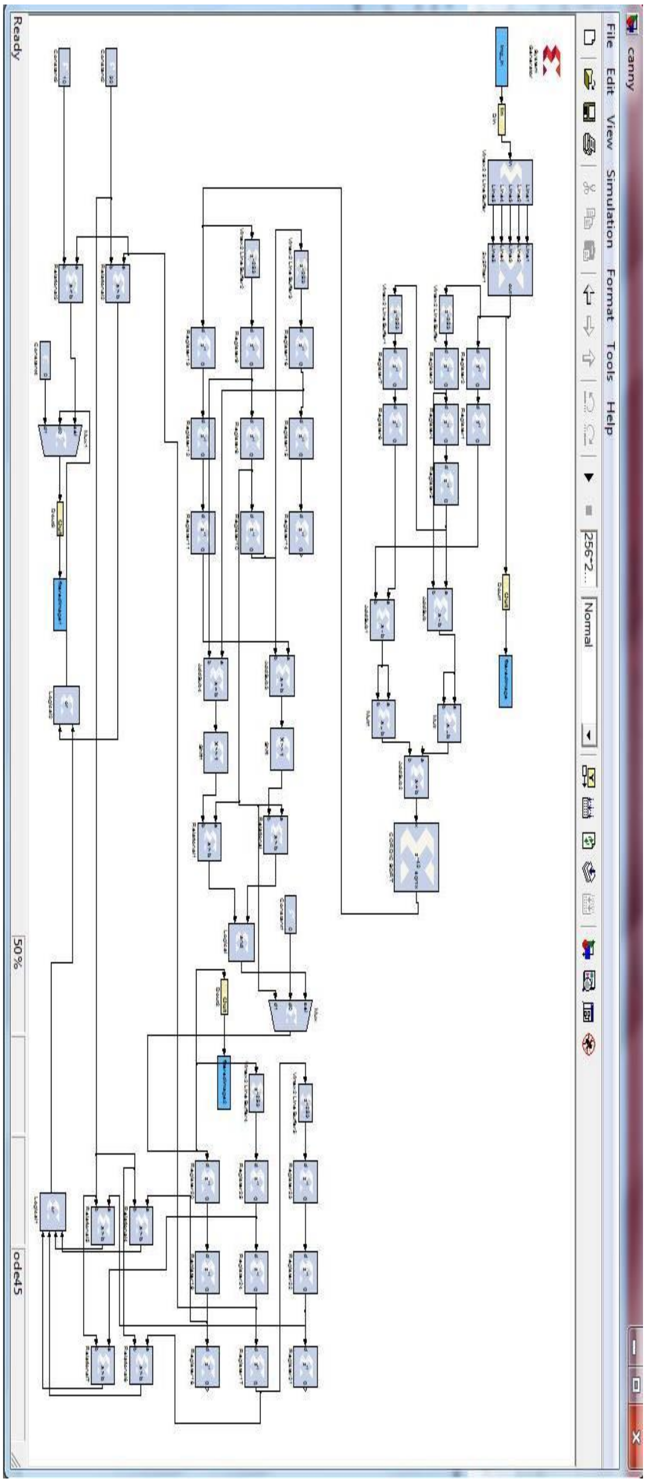


Canny Edge Detection

B. Sobel Edge Detection

Image Pre-processing Block Diagram

The below Figure shows image pre-processing which includes operations such as 2D to 1D conversion, frame conversion and unbuffering to give processed image. Primary significance of image pre-processing operation is serialization of data with suitable data rate for the hardware implementation.

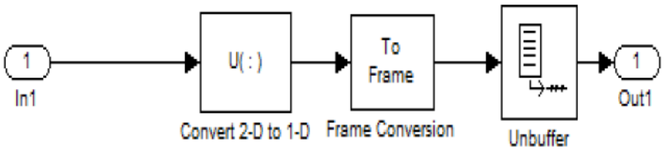


Image Pre-processing Block diagram

Image Post -processing Block Diagram

Here exactly contrary operation performed by image post-processing as shown in Figure 9. Primary significance of image post-processing is to make processed data available and with suitable data rate for displaying in Matlab environment.

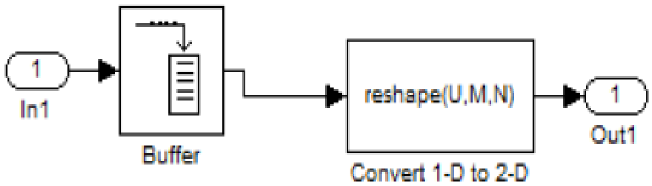
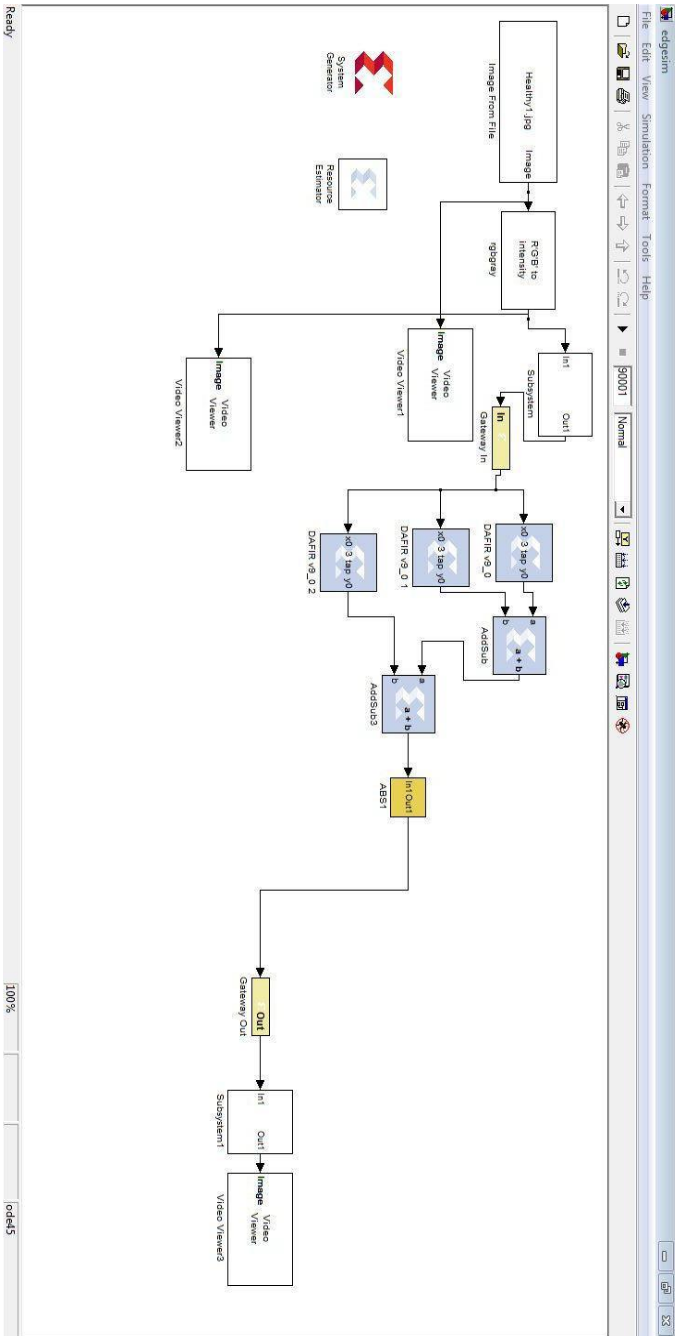
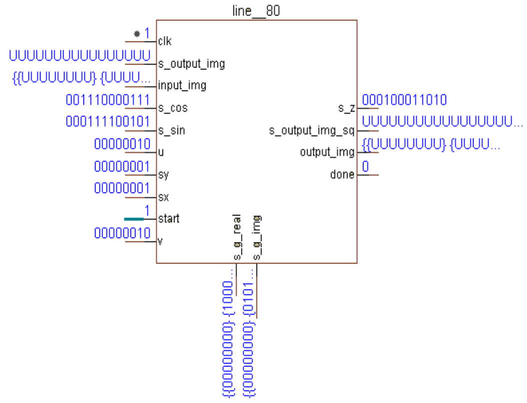


Image Post-processing Block diagram

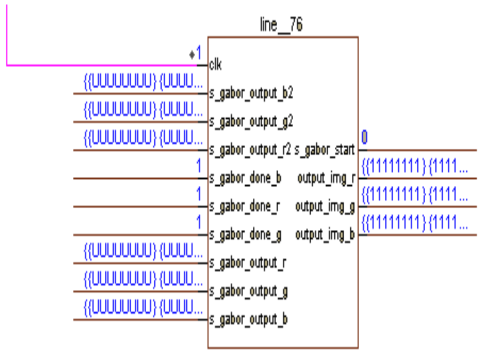


Complete Sobel Edge Detection Algorithm using XSG

C. Gabor Filter Design



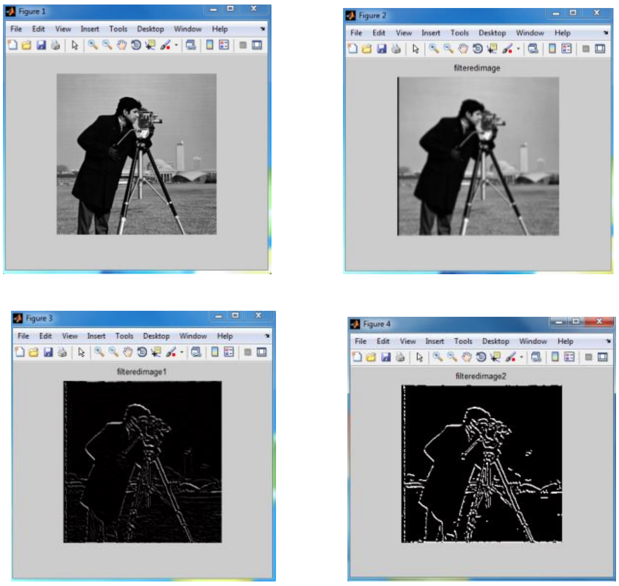
The disease detection module can be given as



V. RESULTS

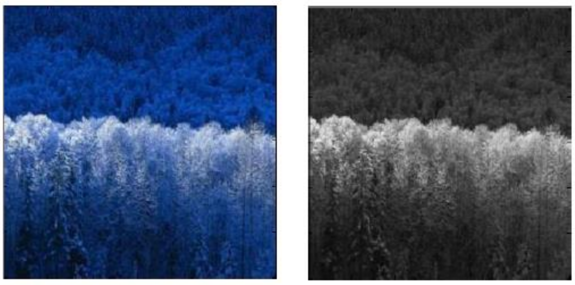
A. Canny Edge Detection:

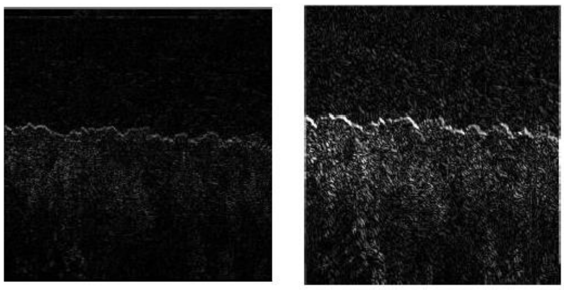
The Canny Edge Detection algorithm which is followed by Gaussian filtering is perfectly implemented on Xilinx System Generator. The implemented design automatically detects the edge of an input image. The method was tested on standard test image like 'cameraman'. The output results show an image filtered from Gaussian filtering, another output is hysteresis thresholding output which removes streaking form an image. Final image is of Canny Edge Detected image. The proposed design is used for the tonsillitis detection. The architecture is efficient to detect edges of bacteria present in tonsils. Therefore two test images are considered one is normal tonsil image and another is affected with tonsillitis disease. By applying canny edge detection to both the images the bacterial and non-bacterial image edges are detected. Therefore the generated output results are compared i.e. normal image and affected image. By visualizing these two images we can easily comment whether the image is affected or not. We have performed different experiments to identify the disease.



B. Sobel Edge Detection

The Sobel Edge Detection algorithm which is followed by FIR filtering is perfectly implemented on Xilinx System Generator. The implemented design automatically detects the edge of an input image. The method was tested on images. The output results show an image filtered from FIR filtering, another output is software based output. Final image is of Hardware based Sobel Edge Detected image.



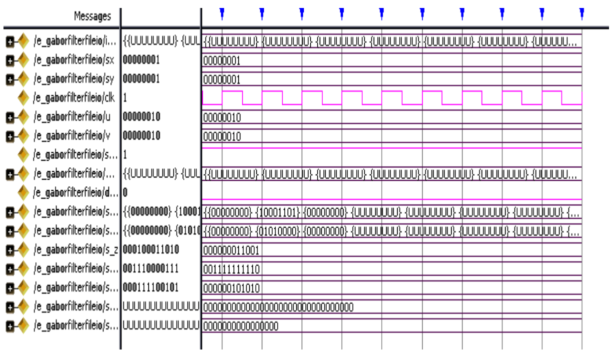


Results of image (I) Original Image (II) Gray scale Image (III) S/W based Edge Detected Image (IV) H/W based Edge Detected Image

The proposed design is used for the tonsillitis detection. The tonsillitis images are taken from website “www.sciencephotolibrary.com” for testing purpose. The architecture is efficient to detect edges of bacteria present in tonsils. Therefore two test images are considered one is normal tonsil image and another is affected with tonsillitis disease. By applying Sobel edge detection to both the images the bacterial and non-bacterial image edges are detected. Therefore the generated output results are compared i.e. normal image and affected image. By visualizing these two images we can easily comment whether the image is affected or not. We have performed different experiments to identify the disease. The comparison of edge detected image is done based on different standard parameters. Also it is implemented on FPGA using Spartan 3 and hardware co-simulation results are observed.

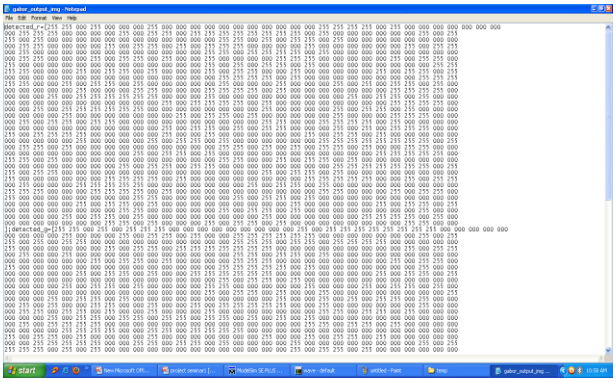
C. Gabor Filter Design

The results of Gabor filter design are given as below

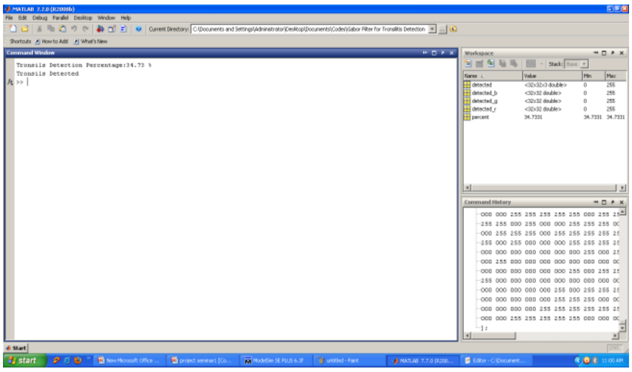


The Output from disease detection module is stored on text file which is ‘output_gabor filter’ stored in predefined location. This file contains the comparison result. i.e. if values of pixel matched then '255' else '0'. This output file is post on MATLAB for observing the result.

The output text file is given as



The post file (code in MATLAB) posts the text file on MATLAB command window to display the result of disease detection module. The result contain percentage of disease present which further decides disease is present or not.



Output of disease detection module

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