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Design and Implementation of Sobel Edge Detection technique using VHDL

Sheetal D. Bhoyar(ME, BE) , Tarnnum Pathan (Mtech , BE), Amit D. Landge(Mtech , BE)

Assistant Professor, Department of Electronics Engineering, Priyadarshini Bhagwati College of Engg., Nagpur, India,
Assistant Professor, Department of Electronics & Communication Engineering, P.B.C.E, Nagpur, India,
Assistant Professor, Department of Electronics & Communication Engineering, P.B.C.E,Nagpur, India ,

ABSTRACT*:* This paper based on edge detection using sobel operator for real time applications using FPGA. Due to the better noise sensitivity as compared to sobel operator. This has been overcome with the advancements using VHDL. The proposed work presents implementation of edge detection algorithm in FPGA chip named Spartan-3-XC3S200 that can process 1024x1024x8 grey scale image with the help of Sobel Operator**.**

KEYWORDS: FPGA, Gradient operator, Image processing, Matlab, Sobel edge detection, VHDL,Xilinx system generator

I.INTRODUCTION

Digital image processing is an ever expanding and dynamic area with applications reaching out into our everyday life such as medicine, space exploration, surveillance, authentication automated industry inspection and many more areas also in intelligent transport system, autonomous vehicles and self-guided armaments. Applications such as these involve different processes like image enhancement and object detection. With advances in the VLSI technology hardware implementation has become an attractive alternative. Implementing complex computation tasks on hardware and by exploiting parallel is made pipelining in algorithms yield significant reduction in execution times.

Implementing image processing algorithms on reconfigurable hardware minimizes the time-to-market cost, enables rapid prototyping of complex algorithms and simplifies debugging and verification. Therefore, FPGAs are an ideal choice for implementation of real time image processing algorithms. In this project our objective is to design and implement a co-processor for image processing in FPGA. The co-processor will be designed for edge detection of images. Edge detection will be performed using Sobel. Edge Detection algorithm. FPGA has become an alternative for the implementation of algorithms that unique structure permitted the technology used in many applications, video surveillance and medical imaging. Edge detection becomes a more complicated task when using much improved edge detection masks. Moreover the process becomes lengthier when it operates on an image of very high resolution. Most hardware implementations are faster than its corresponding software implementations. So implementing edge detection in hardware will be more efficient. Since FPGA have got the added feature of parallelism, the edge detection can be effectively implemented.

During the recent years, field programmable gate arrays (FPGA) have become the dominant form of programmable logic. In comparison to previous programmable devices like programmable array logic (PAL) and complex programmable logic devices (CPLD), FPGA can implement far larger logic functions. FPGA supports sufficient logic to implement complete systems and sub-systems. FPGA provides designers with reconfigurable logic that can be reprogrammed on application-specific basis. This drastically increases flexibility in the design process.

II. SYSTEM OVERVIEW

The project essentially consists of manipulating images in order to perform the Sobel Edge detection algorithm. The image of selected formats like .JPEG, .PNG and .BMP are converted to the raw image data using a C program. The image was represented as pixels of 8bits (values ranging from 0 to 255).

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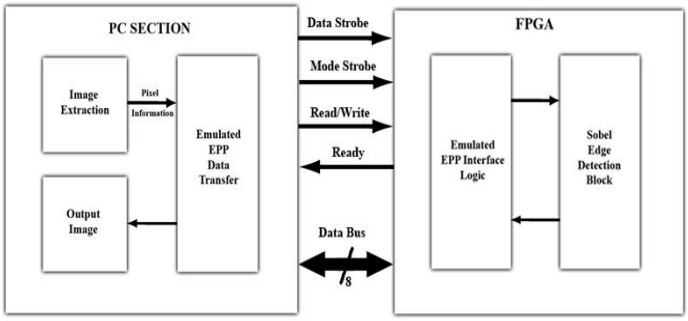

Fig. System overview

Once the computer performs the image extraction, the information thus obtained is to be sent to the FPGA in order to perform the mathematical computations. The communication between the computer and the FPGA is done via the parallel port which is operating in bidirectional mode. The Sobel operator is applied on the block of pixels received in the memory. The processed data is transferred to the computer using the parallel port. The data thus received is further manipulated to reconstruct and display the edge detected image.

III. SOFTWARE USED

A. MATLAB7.5 : MATLAB is used to model the whole system for an easy understanding of hardware implementation of the algorithm. Once the algorithm was realized successfully Edge Detection of a real time video streamed from web was done in Simulink.

B. XILINX ISE 14.7 :Xilinx ISE 14.7 is used for design, simulation and synthesis of hardware system model in verilog HDL. In Xilinx the target device used to implement the design isxc3s1500-4fg676

C. MODELSIM : ModelSim is a multi-language HDL simulation environment by Mentor Graphics, for simulation of hardware description languages such as VHDL, Verilog and SystemC, and includes a built-in C debugger. Model Sim can be used independently, or in conjunction with Altera Quart's or Xilinx ISE. Simulation is performed using the graphical user interface (GUI), or automatically using scripts.

IV. METHODOLOGY

A. EDGE DETECTION

In digital image processing, each image is quantized into pixels. With gray-scale images, each pixel indicates the level of brightness of the image in a particular spot: 0 represents black, and with 8-bit pixels, 255 represents white. An edge is an abrupt change in the brightness (gray scale level) of the pixels. Detecting edges is an important task in boundary detection, motion detection/estimation, texture analysis, segmentation, and object identification.

- **Types of Edge Detection**

Edge detection makes use of differential operators to detect changes in the gradients of the grey levels. It is divided into two main categories:

- First order derivative based edge detection (gradient method)

Second order derivative based edge detection (laplacian based edge detection)

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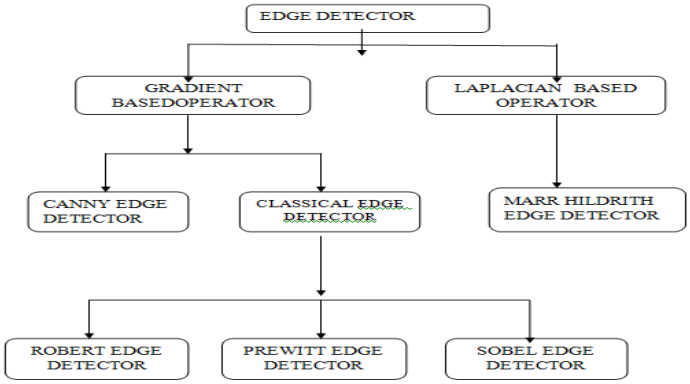

Fig: Types of Edge detection

A. First order derivative based edge detection (gradient method):

It is based on the use of a first order derivative or can say gradient based. The magnitude of gradient computed gives edge strength and the gradient direction that is always perpendicular to the direction of image edge. If f (x , y) be the input image, then image gradient is calculated by following formula;

$$\nabla \mathrm{f} = \begin{bmatrix} Gx \\ Gy \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

Where, Gx is the gradient in x direction. And Gy is the gradient in y direction. The gradient magnitude can be calculated by the formula.

B. Second order derivative based edge detection (laplacian based edge detection):

This method search for zero crossings in the second derivative of the image to find out edges. An image edge has the one-dimensional shape of a ramp and find out the derivative of the image can highlight its location. This method is characteristic of the "gradient filter" family of edge detection filters. A pixel location is only declared an edge location, if the value of its gradient exceeds some threshold. As mentioned earlier, edges have higher pixel intensity values than those are surrounding it. So once a threshold is set, the gradient value with the threshold value can be compared and an edges can be detected whenever the threshold is exceeded.

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

C. Robert Edge Detector

It is a gradient based operator. It computes the sum of the squares of the difference between diagonally adjacent image pixels through discrete differentiation and then calculate approximate gradient of an image. The input image is convolved with default kernels of operator and gradient magnitude and directions are computed. It uses following 2 x2 two kernels,

$$\mathrm{Gx} = \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix} \quad \text{and} \quad \mathrm{Gy} = \begin{bmatrix} 0 & -1 \\ -1 & 0 \end{bmatrix}$$

Fig : Original image

Fig : Robert edge detected image

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D. Sobel Edge Detector

Sobel operator is a discrete differentiation operator used to calculate an approximation of the gradient of an image intensity function for edge detection. At each pixel of an image, it gives either the corresponding gradient vector or normal to the vector. this convolves the input image with kernel and computes the gradient magnitude and direction. It uses following 3x3 two kernels,

$$Gx = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \text{and} \quad Gy = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

Fig : Original image

Fig : Sobel edge detected image

E . Prewitt Edge Detector

The function of Prewitt edge detector is almost same as of sobel detector but have different kernels:

$$Gx = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \text{and} \quad Gy = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

Fig : Original image

Fig : Prewitt edge detected image

F. Horizontal Gradient Filter For Sobel Operator

Horizontal filter required for sobel edge detection. By moving horizontal kernel of 5×5 over an image horizontalgradient of an image is computed for sobel edge detection.

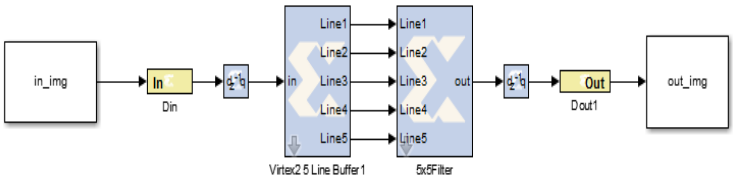

Fig. Horizontal Gradient Filter

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G. Vertical Gradient Filter For Sobel Operator

The vertical filter for sobel edge detection is shown in figure 6. By moving vertical kernel of 5×5 over an image vertical gradient of anis computed for sobel edge detection. Here the same blocks ets of Xilinx are used as that of horizontal gradient but we have toselect vertical gradient by double clicking on 5×5 filter.

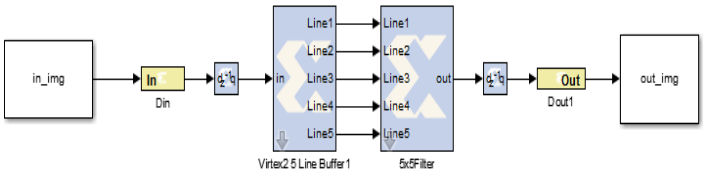

Fig. Vertical Gradient Filter

The four steps of edge detection are:

1**. Smoothing**: suppress as much noise as possible, without destroying the true edges.

2**. Enhancement**: apply a filter to enhance the quality of the edges in the image (sharpening).

3**.Detection**: determine which edge pixels should be discarded as noise and which should be retained (usually, thresholding provides the criterion used for detection).

4. **Localization**: determine the exact location of an edge (sub-pixel resolution might be required for someapplications, that is, estimate the location of an edge to better than the spacing between pixels).

V. RESULT ANALYSIS

- **Script Based**

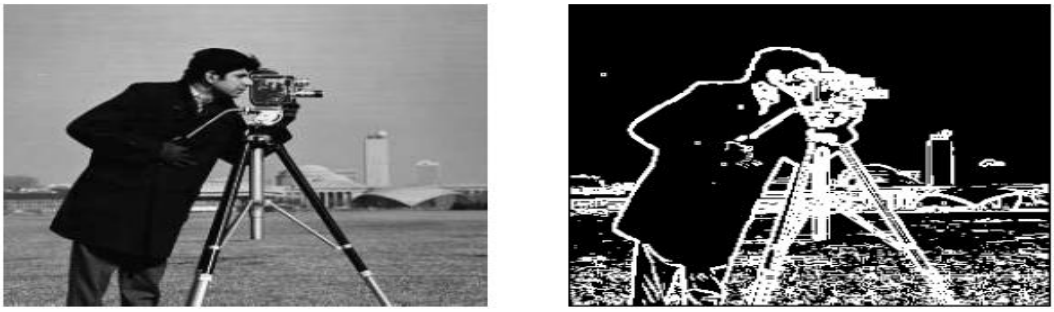

Fig : Result of testbench code

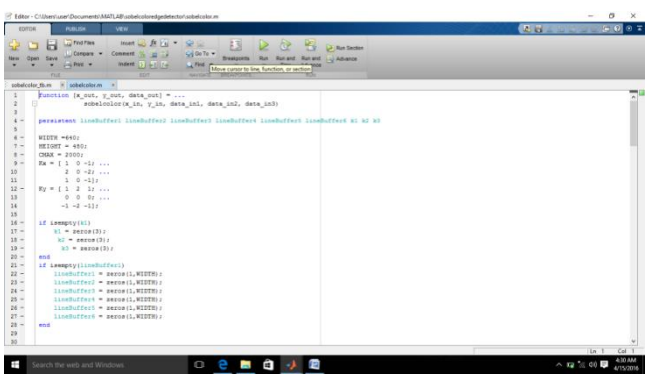

Fig: Code for colour image processing

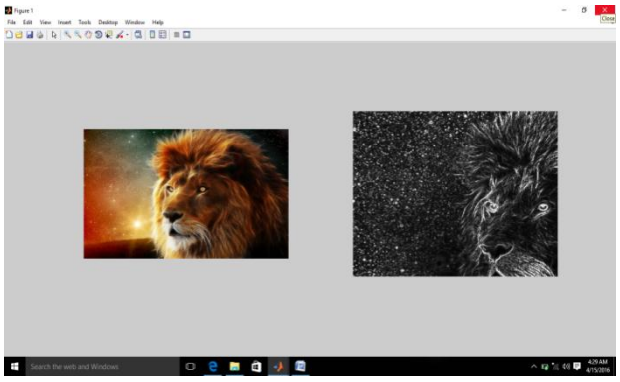

Fig :Result of colour image processing

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- **ISE Simulator**

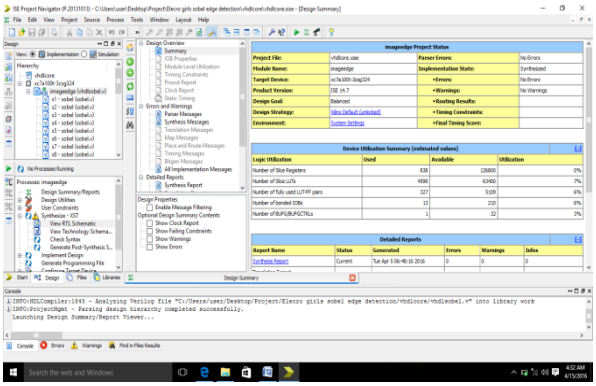

Fig : ISE window

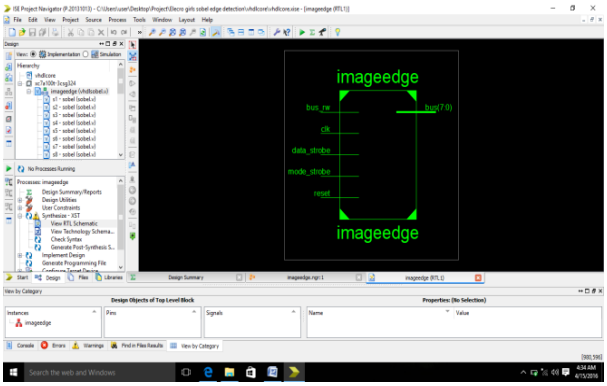

Fig.: RTL schematic

- **MODELSIM**

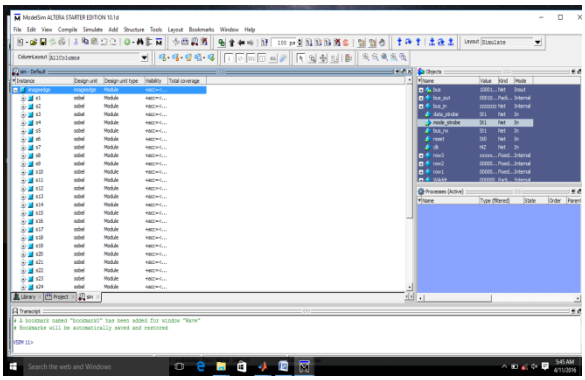

Fig.Modelsim Software window

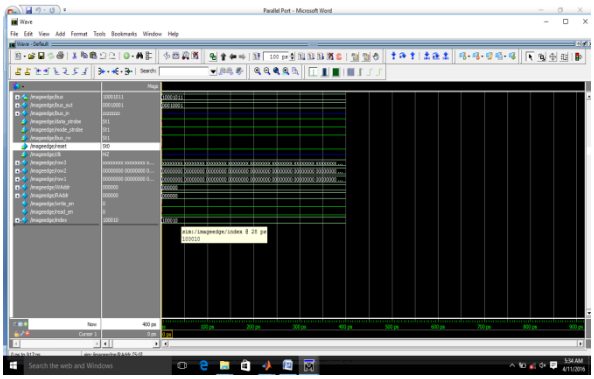

Fig. Waveform of edge detection using Modelsim Software

- **Model based**

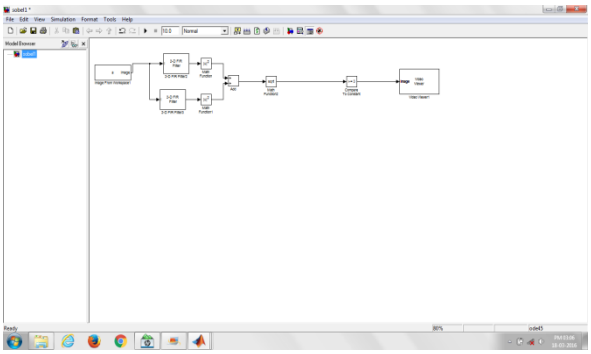

Fig. Model of Sobel Edge Detection

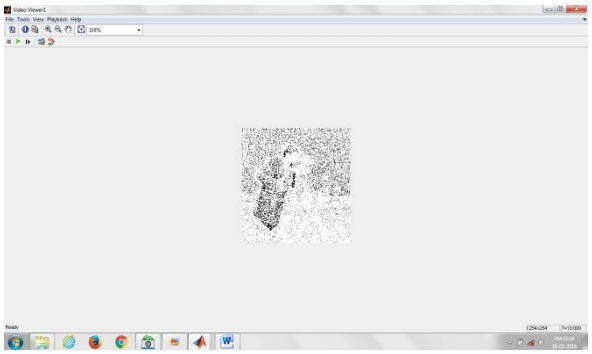

Fig. Result for model of Sobel Edge detection

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VI. ADVANTAGES

- The first advantage of sobel operator is intuitiveness and easiness.
- Sobel edge detector method is somewhat tough than prewitt edge detector, but prewitt produces slightly noisy results.
- Robert edge detector is one of the simplest edge detectors in digital image processing but it is preferably less in use than other edge detectors as it gives minor details.
- The sobel, prewitt operators are used for the edge detection and finding directions of gradient magnitude as the approximation of gradient magnitude is easy.
- Sharp and thin edges leads to greater efficiency in object recognition.

VII. APPLICATIONS

- Different pixels intensities for sudden change in intensity value is manipulated using convolution operation and edges are worked out.
- Edge detection can acts as a tool machine region region feature detection , feature expaction in machine region feature detection , feature expaction used in biomedical application. Ex :- Tumour detection , tonsilitist detection.
- Edge detection can used for object detection for security purpose at airports, but stands and other government and non government organizational entrance.

VIII. CONCLUSION

In this project edge detection using Sobel Operator is reviewed and focus has been made on detecting the edges of the digital images. The hardware was realized in Spartan XC3S200 Kit. The processor was coded using VHDL. It cannot handle the standard image formats so the images were converted to ASCII text files using MATLAB. The ASCII text file was applied as vector to the hardware interface. The output files were equally converted and viewed in MATLAB. Since Sobel edge detection operator is insensitive to noise, this methodology reduces the complexity of the look and conjointly the processing time. The execution time for the complete program of edge detection for a picture of size 256×256 is few seconds. Our design can locate the edges of the given gray image quickly and efficiently. To improve the speed and efficiency pipelining will be done.

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