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Implementation of Sobel Edge Detection using MATLAB-XILINX co-simulation

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Abstract: Digital image processing is widely used for image processing like feature extraction, segmentation, pattern recognition, etc. Edge detection, within image processing is a basic tool used to obtain information from the frame for feature extraction and object segmentation. The purpose of edge detection is to reduce the amount of data in an image significantly and to preserve the structural properties for further processing of image. It plays a vital role in image processing for finding out the boundaries in an image. Sobel operator is a gradient based operator which is used in edge detection of an image which creates accenting edges of an image. The image pixels are read by MATLAB and processed in Xilinx to find the gradient. This project presents implementation of sobel edge detection using MATLAB-XILINX co-simulation, thus solving the problem of image processing using HDL.

Keywords: Sobel operator, kernel, image gradients, edge detection, MATLAB, XILINX.

I. INTRODUCTION

Digital image processing is an ever-growing area with extensive variety of applications in day to day life such as medical imaging, surveillance, automobile safety, consumer electronics and intelligent systems. In the field of image processing, edge detection is an essential tool. Edge detection involves collection of mathematical formulas and methods. The main goal of edge detection is identifying the pixels in a digital image in which the brightness level of the image changes acutely and furthermore to decrease the amount of information in an image significantly and to protect the structural properties for further image processing. The image is defined in spatial domain. Edge detection technique divides this domain into significant parts or regions. In terms of digital image processing, edge is a collection of pixels. An edge is characterized as sharp transitions in the area of a visual observations as we move from one pixel to neighbour pixel in an image. Typically, the edges are classified as horizontal edges, vertical edges and diagonal edges.

There are two types of edge detection methods: First order/Gradient based edge detection and Second order/Lapacian based edge detection. In first order edge detection method, the edge of the image is determined by finding the maxima and minima in the first order derivative of the image. It depends on the utilization of a first order derivative or can state gradient based. The magnitude of gradient processed gives edge quality and the direction of the gradient which is always perpendicular to the direction of image edge. In second order edge detection method, the edge of the image is determined by finding out the zero crossings in the second order derivative of the image. An image edge has the one-dimensional state of a incline and find outs the derivative of the image that can highlight its area. This strategy is normal for the “gradient filter” group of edge detection filters. A pixel location declares the edge location, if the value of its gradient estimation surpasses some threshold. As said before, edges have higher pixel intensity values than those values which are surrounding it. So once a threshold is set, the gradient value with the threshold value can be looked at and an edges can be detected at whatever point the threshold is exceeded.

II. SOBEL EDGE DETECTION

Sobel operator is utilized as a part of image processing and computer vision, especially within edge detection algorithms where it creates an image emphasizing edges. It is named after Irwin Sobel and Gary Feldman. Sobel and Feldman presented the idea of an "Isotropic 3x3 Image Gradient Operator". In fact, it is a discrete differentiation operator, figuring the estimations of the gradient of the image intensity function. At every point in the image, the resultant of the Sobel operator is corresponding gradient vector. The Sobel operator relies on convolving the image with a small, separable, and integer-valued filter in the horizontal and vertical directions and is therefore consequently generally cheap as far as calculations. The gradient approximation that it produces is reasonably rough, specifically for high-frequency variations in the image.

Sobel is first order or gradient based edge operator. It performs a 2-D spatial gradient measurement on an image. The operator uses two 3×3 kernels (or masks) which are convolved with the original image to calculate approximations of the derivatives – one is for the horizontal changes, and the other is for vertical changes. Each point contain the horizontal and vertical derivative approximations respectively, the kernels are as follows:

Gx

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

Gy

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

Figure 1: Sobel masks

When one kernel is rotated by 90 degree, another kernel is obtained as shown in Figure 1. Gx is used to determine horizontal edges and Gy is used to determine vertical edges. The direction and the strength of the edge at a specific area in the image can be calculated by using the gradients Gx and Gy. These resulting gradient approximations can then be put together to give absolute gradient magnitude at every point in the image. The magnitude of the gradient is calculated as:

|G|= (Gx2 +Gy2)1/2

In this case, orientation is interpreted as meaning that the direction of most extreme differentiation from dark to white keeps running from left to appropriate on the picture, and different points are measured against clockwise from this. Figure 2 demonstrates the marking of neighborhood pixels.

A0	A1	A2
A7	[i,j]	A3
A6	A5	A4

Figure 2: Labeling of neighborhood pixels

For pixel [i,j], partial derivatives Gx and Gy can be computed using the following equations:

Gx= (A0 + CA1 + A2)-(A6 + CA5 + A4)

Gy= (A2 + CA3 + A4)-(A0 + CA7 + A6)

Where, constant C=2.

A(1,1)	A(1.2)	A(1,3)	.. .. ..	A(1,n)
A(2,1)	A(2,2)	A(2,3)		
A(3,1)	A(3,2)	A(3,3)		
: : :		: : :		: : :
A(m,1)			.. .. ..	A(m,n)

Figure 3: Arrangement of pixels for an image

Figure 3 shows the arrangement of pixels for an image. 3x3 kernels are are placed on the image as shown in the figure and kernel convolution is carried out.

III.ALGORITHM FOR IMPLEMENTATION OF SOBEL EDGE DETECTION

This project proposes implementation of edge detection using sobel operator, with the help of verilog hardware description language. Process flow of edge detection is as shown in the Figure 4. An image is acquired as an input using MATLAB. If this input image is colored, then firstly, this RGB image is converted to grayscale image with the help of MATLAB. If the image is very large, it is resized. Then this image is written into a text file and value of every pixel in an image is obtained. Input textfile contains data matrix of size m x n obtained from m x n size gray scale image using MATLAB software. Data written in text file is of type integer. Verilog program written in test bench and read pixel data from input text file in Xilinx. Code is written to detect vertical and horizontal edges and combine both. Synthesization and simulation is done in Xilinx. Output of simulation iscollected in output text file in form of edge detected data matrix. The content from output text file is loaded to MATLAB software to obtained image from edge detected data matrix. Finally edge detected image is obtained in MATLAB.

With the help of Xilinx ISE, text file generated by MATLAB is read. Gradients gx and gy are calculated. By adding both the gradients that is gx+gy resultant gradient G is found by making use of ripple adders. Mask is applied to 3x3 pixels and gradient values are found at each pixel. After synthesizing the code in verilog, it is simulated and its timing analysis is done. After simulation the output text file is read again in MATLAB where a threshold value is set.

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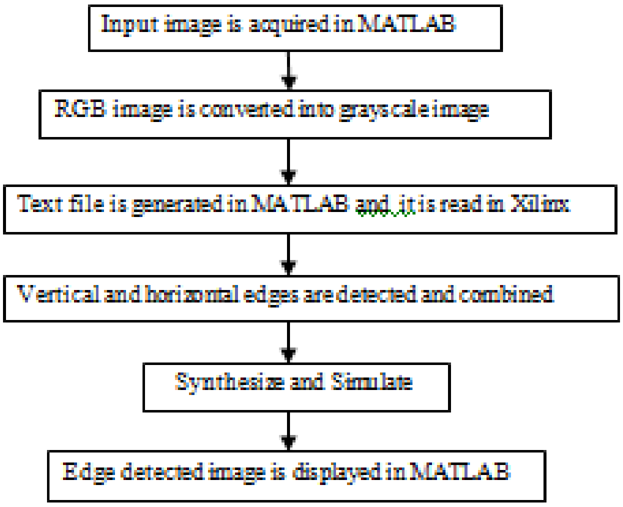

Figure 4: Flow chart of edge recognition method

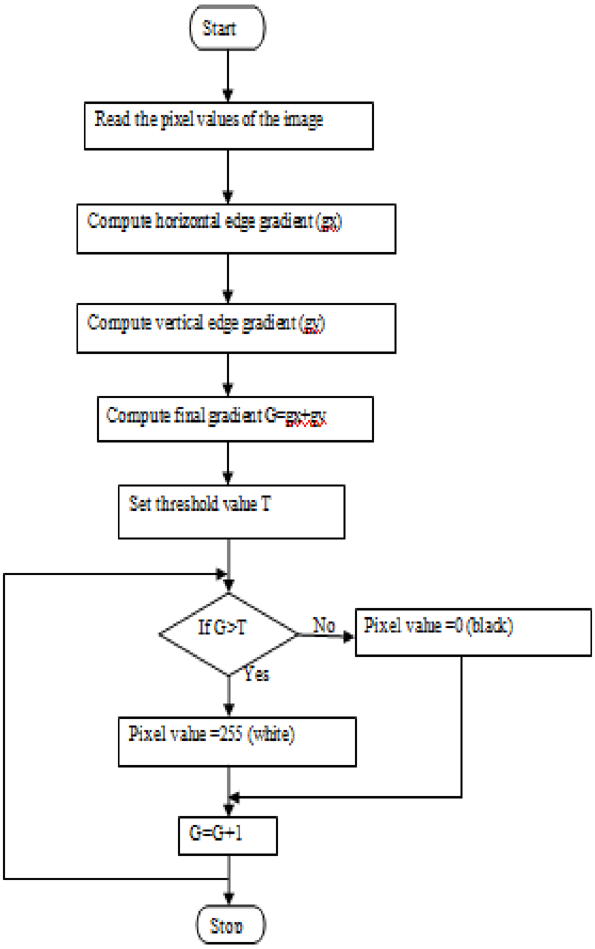

Figure 5: Flow chart of sobel edge detection

If the gradient value is greater than the assumed threshold value, then set the pixel value to 255 (white). If the gradient value is lesser than the assumed threshold value, then set the pixel value to 0 (black). For each value of gradient, the respective pixel values are set. Process flow of sobel edge detection is shown in the Figure 5.

IV. RESULTS AND DISCUSSIONS

The original image of which the edge has to be detected is as shown in the Figure 6.

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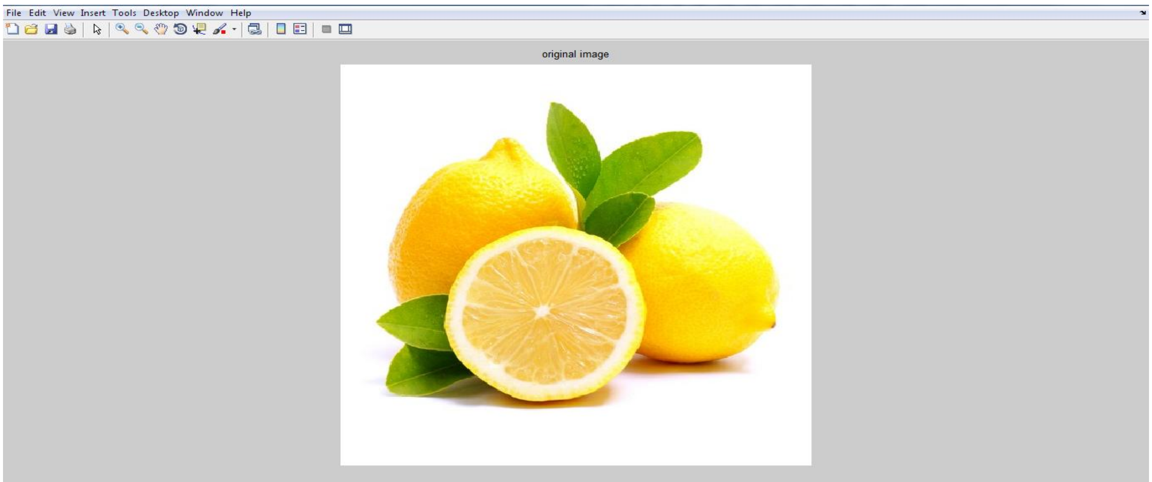

Figure 6: Original image

Figure 7: Grayscale image

This original image which is color image is initially converted into grayscale and resized in MATLAB and the gray image is as shown in the Figure 7.

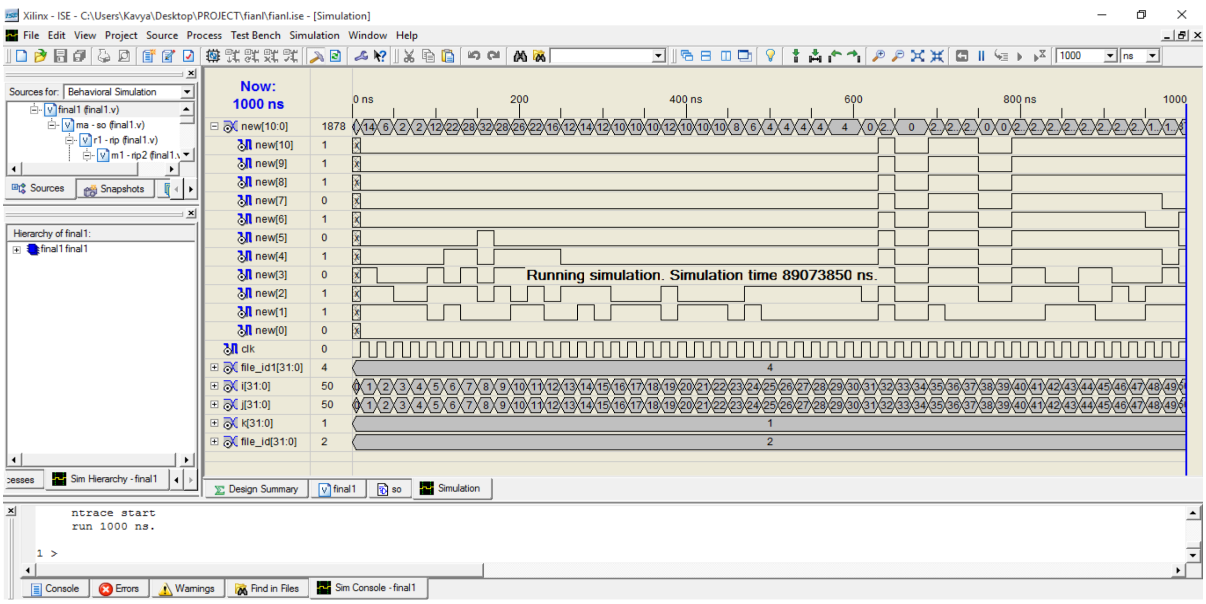

Figure 8: Output waveform

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Pixel values are read and further processing is done to detect the edge in Xilinx and simulated. Simulation waveform is shown in the Figure 8.

Figure 9: Edge detected image

Edge detected image is as shown in the Figure 9.

V. CONCLUSION

This project presented is based on sobel edge detection. Sobel edge detection algorithm is picked up because it has less deterioration at high levels of noise. Algorithm for sobel edge detection is coded using verilog HDL. The output file is equally converted and viewed in MATLAB. This algorithm can be used in various image processing applications such as in medical imaging, video surveillance. It can also be used in lane departure warning system to detect edges of lanes. This project can be further implemented using pipelined sobel edge detection algorithm which can be used in future to enhance speed. In real time image processing applications, it is required to process large data of pixels in a given timing constraints. Hence, speed of image processing is a big problem. Reconfigurable device FPGA's deploy parallelism techniques in image processing algorithm thereby reducing execution times and increasing speed of operation. This project can be further implemented using FPGA for hardware realization.

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