FPGA Implementation of Image Segmentation Using Gradient Algorithm

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Abstract—**Image processing algorithms has been limited to software implementation which is slower due to the limited processor speed. So a dedicated processor for edge detection is required which was not possible until advancements in VLSI technology. The proposed work presents FPGA based architecture for Edge Detection using Sobel operator. Sobel operator is chosen due to its property of less deterioration in high levels of noise. Sobel edge detector for image segmentation is proposed for VLSI implementation. Processed results of test images are presented to illustrate the performance capabilities of the proposed approach. Sobel edge detector treats edge detection as a signal processing problem to design an optimal edge detector and has been widely used for edge detection. A pipelined implementation on FPGA for modified version of this algorithm is proposed. MATLAB simulation results are given. A newfangled method for segmentation of 2-D imagery that uses best alternative approach for image enhancement as well as edge-detection is proposed.**

Key words: **FPGA, Image segmentation, edge-detection, Sobel-operator, mean, median.**

1. INTRODUCTION

Image segmentation is a key step in digital image processing. It was developed in 1960's for image analysis. Image segmentation is defined as a process of partitioning an image into homogenous groups such that each region is homogenous. The first step in image analysis is to segment the image. Segmentation subdivides an image into its constituent parts or objects.

An object input image is taken and is pre-processed. Pre-processing is done to convert the image in more suitable form and to remove the noise. The impulse noise is the most frequently referred type of noise [1]. This noise, commonly also known as salt & pepper noise is caused by malfunctioning pixels in camera sensors, faulty memory locations in hardware, or errors in the data transmission.

The next step of image segmentation is feature extraction. Feature extraction generally refers to the extraction of discontinuities such as point, line and edge, and pixels forming homogeneous regions. There are two techniques of segmentation, discontinuity detection technique and Similarity detection technique. In the first technique, one approach is to partition an image based on abrupt changes in gray-level image. The second technique is based on the threshold and region growing.

Edge detection is a basic operation in image processing, it refers to the process identifying and locating sharp discontinuities in an image, the discontinuities are abrupt changes in pixel intensity which characterize boundaries of objects in a scene [2]. There are extremely large numbers of edge detection operators available, each designed to be sensitive to edges, typically it reduces the memory size and the computation cost.

Field Programmable Gate Array (FPGA) technology has become an alternative for the implementation of software algorithms. Implementing hardware design in Field Programmable Gate Arrays (FPGAs) is a formidable task. There is more than one way to implement the digital filter. Based on the design specification, careful choice of implementation method and tools can save a lot of time and work. Most of the algorithms are computationally intensive, so it is desirable to implement them in high performance reconfigurable systems. The application of FPGA in image processing has a large impact on image or video processing [3]. This is due to the potential of the FPGA to have parallel and high computational density as compared to a general purpose microprocessor. Firstly, the algorithm is simulated in MATLAB, and then the same is implemented into VHDL with the help of Xilinx

ISE and the Modelsim simulation results are verified with MATLAB results.

2. RELATED WORK

Conventionally, the Gaussian filter is used for the image enhancement purpose followed by first differentiation of it for the edge-detection. From simulation results, it is observed that the Median filter gives better results as compared to it. Therefore we propose to use the median filter instead of the Gaussian [4]. It is well known that the Sobel-edge operator gives expected result for edge detection [5]. Hence we propose to use the Sobel operator instead of first differentiation of the filter.

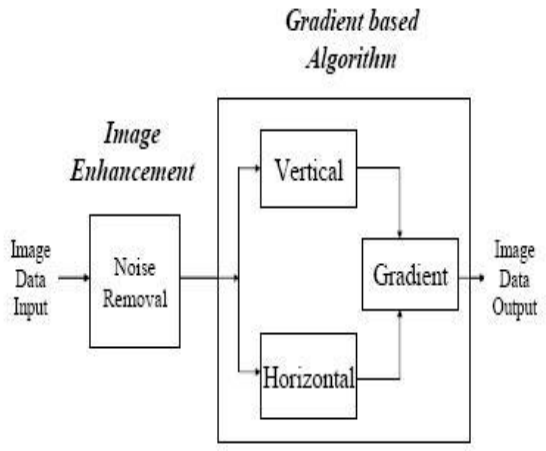

Fig. 1: Approach for FPGA Implementation

The approach for the proposed implementation is shown in the Fig. 1. The input image is first filtered for image enhancement using Median filter. The result of this step is given to the edge-detection filter, which calculates the value of the gradient in both horizontal and vertical direction. Edge detection is done using Sobel mask. The output of this filter gives the segmented image.

2. 1 WHY MEDIAN FILTER?

Image noise is the random variation of brightness or colour information in images produced by the sensor and circuitry of a scanner or digital camera. Image de-noising is a vital image processing task. There are many ways to de-noise an image.The important property of a good image de-noising model is that it should completely remove noise as far as possible as well as preserve edges. Traditionally, there are two types of models i.e. linear model and non-liner model. is an essential part of any signal processing system Median filter, the most prominently used impulse noise removing filter, provides better removal of impulse noise from corrupted images by replacing the individual pixels of the image as the name suggests by the median value of the gray level of the pixels from a chosen neighbourhood [6].

The simulation results for Mean filter and Median filter are presented for comparison. The fig. 2 shows the results with noise of level 0.2 while the fig. 3 shows the results with a level 0.4

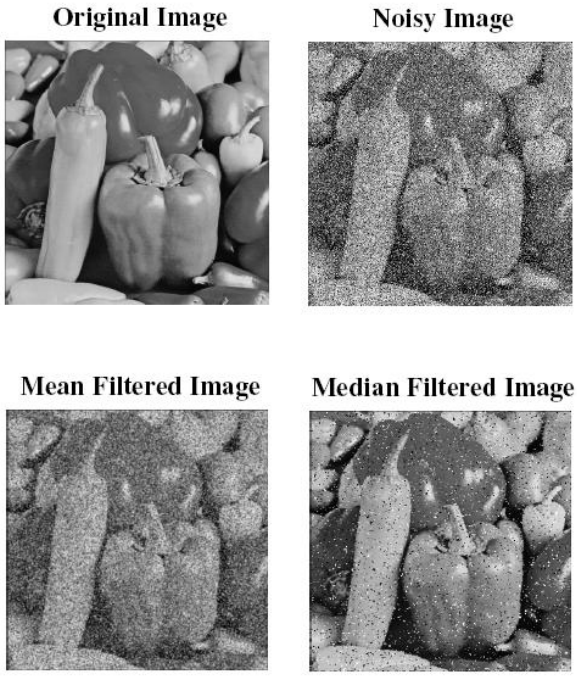

Fig. 2: Results with noise level 0.2

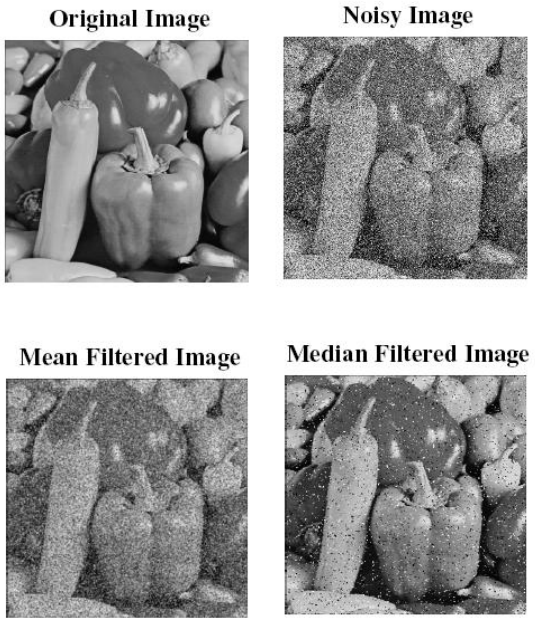

Fig. 3: Results with noise level 0.4

The careful examination shows that the median filter preserves the sharpness in a better way. Also, it removes the noise level more than mean filter.

2.2 FPGA Implementation

The Algorithm is as follows [7]:
1. Sort all the rows.
2. Sort all the columns.
3. Sort both the diagonals.
4. Middle value of step 3 is 'Median'.

The steps are elaborated in the figure 4.

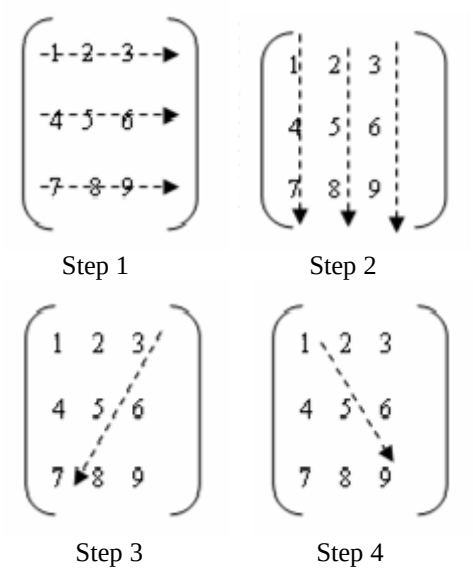

Fig. 4: FPGA Implementation of Median Filter

2.3 Edge-Detection

The edges of image are considered to be most important image attributes that provide valuable information for image perception .The edge detection is a terminology in image processing particularly in the areas of feature extraction to refer to algorithms which aim at identifying points in a digital image at which the image brightness changes sharply.

2.3.1 Gradient-based algorithm

Gradient-based edge detection is the most common approach for detecting meaningful discontinuities in gray level. The most common type of edge detection process uses a gradient operator. Gradient is a vector having both magnitude as well as direction.

The gradient of an image *f(x, y)* at location *(x, y)* is defined as vector. The gradient vector points in the direction of maximum rate of change of f at coordinates *(x, y)*. An important quantity in the edge detection is magnitude of this vector.

$$G[f(x,y)] = \begin{bmatrix} Gx \\ Gy \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

$$magnitude(grad(f)) = \sqrt{\frac{\partial f^2}{\partial x} + \frac{\partial f^2}{\partial y}}$$

2.3.2 Sobel edge detection method

Sobel is a gradient based edge detection algorithm. It core accepts both gray scale image and color image, it looks for edges in both horizontal and vertical directions, then combine the information into a single metric It performs 2D spatial gradient measurement on an image. It uses a pair of 3*3 convolution masks, one estimating gradient in x-direction and other in y-direction [8]

Gx		
-1	0	1
-2	0	2
-1	0	1

Gy		
1	2	1
0	0	0
-1	-2	-1

Sobel Operator 3x3 Masks

Fig. 5: Sobel operator mask

When we use mask of size 2×2, it requires only fewer computations, but it is awkward to implement because they don't have a clear centre. Therefore an approach using mask of size 3×3 is preferred. The corresponding equations required to be implemented are shown below:

$$G_x = (I_7 + 2*I_8 + I_9) - (I_1 + 2*I_2 + I_3)$$

&

$$G_y = (I_3 + 2*I_6 + I_9) - (I_1 + 2*I_4 + I_7)$$

$$f = \sqrt{G_x^2 + G_y^2}$$

For calculation of square-root, cordic core available in Xilinx ISE can be used. It consumes a lot of resources. Alternatively, equation of approximate square-root calculation is used which requires less amount of hardware.

3. SIMULATION WAVEFORMS

The Modelsim simulation waveforms for the modules performing are shown

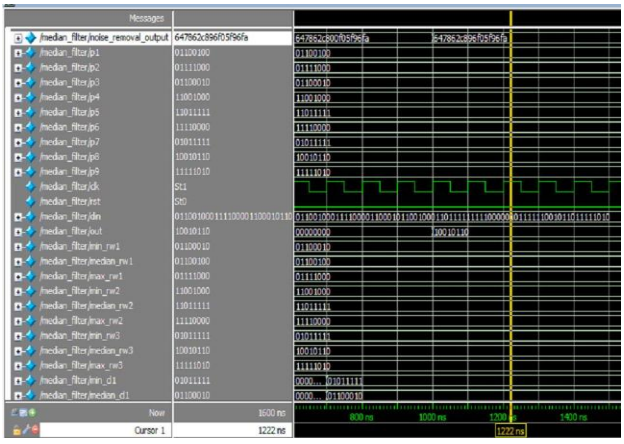

Fig. 6: Noise removal median filter

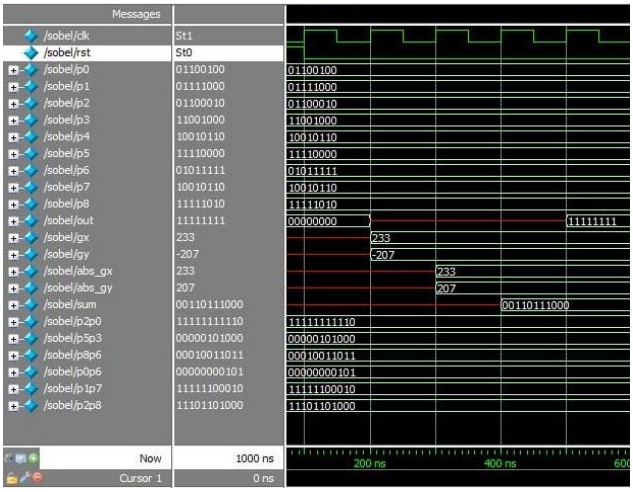

Fig. 7: Sobel operator

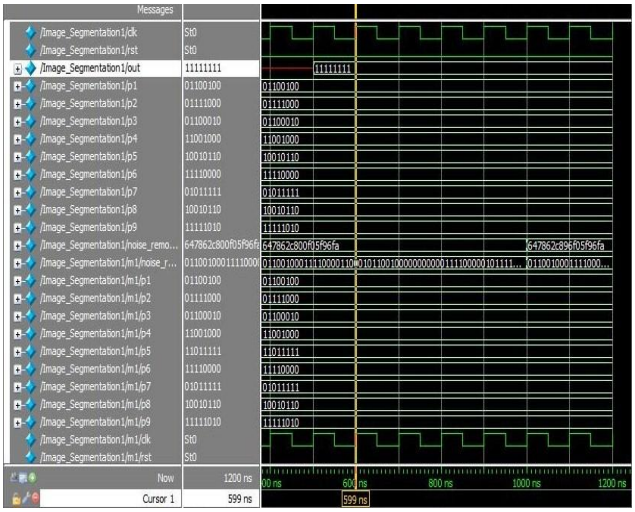

Fig. 8: Image segmentation

The experimental results for image edge detection in MATLAB is shown below

Fig. 9(a): Input image

Fig. 9(b): Output image

4. CONCLUSION

Image filtering is a necessary step in image processing. Median filter intended to reduce impulse noise from the image. Median filter gives better results than mean filter. Therefore, it is considered for image enhancement purpose. Hardware description of a real-time edge detection system based on verilog was considered of high-speed processing in image edge detection. A hardware architecture of Sobel edge detection algorithm for implementing on field programmable gate array (FPGA) chips was proposed. Though computations required are more, Sobel edge-detector is considered on performance basis. The proposed architecture calculates the edges of gray scale images in four directions; vertical, horizontal, right diagonal and left diagonal. Simulation results and synthesizing proposed Sobel edge detection processor on Xilinx Spartan3 XC3S200 FPGA chip demonstrated the efficiency of proposed architecture for edge detecting of gray scale 3×3 images for real-time image processing applications.The processor was coded using Verilog and simulated using Modelsim 6.5e.

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