



Real Time Image Enhancement Algorithms Using Verilog HDL on FPGA

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Abstract—Digital image enhancement techniques are to improving the visual quality of images. Main objective of image enhancement is to process an image so that result is more suitable than original image for specific application. This paper presents real time hardware image enhancement techniques using field programmable gate array (FPGA). This paper focus on implementation of image enhancement algorithms like brightness control, contrast stretching, negative transformation and thresholding on fpga that have become a competitive alternative for high performance digital signal processing applications. These algorithms successfully implemented in Verilog HDL using Xilinx ISE, MATLAB and MODELSIM. The aim of this paper is to simulate and implement these algorithms using verilog HDL. The device selected here for implementation is (Spartan-3E) from Xilinx.

Index Terms— FPGA, image enhancement, Verilog.

I. INTRODUCTION

Digital image processing plays a vital role in the analysis and interpretation of remotely sensed data. Especially data obtained from Satellite Remote Sensing, which is in the digital form, can best be utilized with the help of digital image processing. Image enhancement and information extraction are two important components of digital image processing. Image enhancement techniques help in improving the visibility of any portion or feature of the image.

Image enhancement processes have different techniques to improve the visual appearance of an image. Meanwhile, the term image enhancement is mean as the improvement of an image appearance by increasing dominance of some features or by decreasing ambiguity between different regions of the image. Enhancement methods can broadly be divided into following two categories: Spatial domain methods

1. Frequency domain methods

Spatial domain techniques, directly deal with the image pixels. The pixel values are manipulated to achieve desired enhancement. In frequency domain methods, the image is first transferred in to frequency domain. It means that, the Fourier transform of the image is computed first. All the enhancement operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image. 8-bit digital gray image can have pixel values in the range of 0 to 255.

The digital image processing is impacted today in some way with a very large area of technical endeavor. Digital image processing is used in very large and expanding areas covering applications in multimedia services, arts, medicine, space exploration, surveillance, authentication, automated industry inspection and many more areas [1]. S. Sowmya, et.al, addresses the implementation of image enhancement algorithms like brightness control, contrast stretching and histogram equalization on FPGA. The minimum period to the implemented algorithms is 5 ns for an image size 100x100 [2]. Nitin Sachdeva et.al, give a design of real time histogram equalization circuit for enhancement of images using FPGA [3]. Varsha S. et.al, explain about hardware implementation of negative transformation, thresholding and contrast stretching using Spartan-3E board. And the resultant images showed on monitor using vga [4]. Terek m. bittibssi et.al, propose algorithm for different image enhancement algorithms using FPGA. Like median filter, contrast

stretching, histogram equalization, negative image transformation and power law transformation. All these design algorithms was implemented on cyclone-III fpga based hardware on a 100x100 size grayscale 'Lena' image[5]. Enhancement algorithms using Xilinx system generator (XSG) tool. In these all paper they explain different image enhancement algorithms using fpga[7] & [8].

Firstly, here image converted to coefficient (.coe) file using MATLAB. This data processed through digital

design and the output processed data is converted to image. Different digital image enhancement algorithms are implemented using Verilog HDL.

Figure1 shows the block diagram for proposed algorithm.

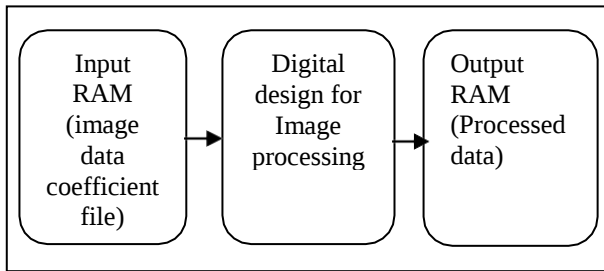


Figure 1: Block diagram of system

This paper introduces Implementation of image enhancement algorithms include: brightness control, contrast stretching, negative transformation and thresholding. The organization of this paper as follows: Section-II, discusses the theory of the implemented image enhancement algorithms. Section-III, introduces hardware realizations for these techniques. Section-VI, reports experimental results. Finally, the conclusion of this paper presented in section V.

II. METHODOLOGY

This section discusses the theory of most commonly used image enhancement algorithms like 1) brightness Control 2) Contrast Stretching, 3) Negative Transformation, 4) Thresholding.

A. Brightness control

Brightness control is the process of increasing gray level of each pixel by adding a constant value to the image pixels with poor brightness. If the digital image is of poor brightness, the objects in the image will not be visible clearly. This is due to image is captured under low light conditions. To rectify this problem, we can further increase the brightness of the captured digital image and make the image more attractive. In the histogram of a low-brightness image, most of the pixels lie in the left half of the gray value range. The brightness of a dark image can easily be increased by adding a constant to gray value of each pixel. This addition operation will shift the histogram towards brighter side with a constant factor. While applying this method to increase brightness of an image, we must choose the constant wisely so that the complete range of gray values lies within 0 to 255. If the final gray value of any pixel is greater than 255 then we will lose the information.

This algorithm works as follows:

$$J(r) = \begin{cases} I(r) + g, & \text{if } I(r) + g \leq 255 \\ 255, & \text{if } I(r) + g > 255 \end{cases}$$

g -is a constant value ($g > 0$). $I(r)$ -is gray level of input pixel (r) and $J(r)$ is the gray level of output pixel (r) after the brightness increasing process.

B. Contrast Stretching

Contrast stretching attempts to improve an image by stretching the range of intensity values it contains to make full use of possible values. This is stretching is restricted to a linear mapping to a linear mapping of input to output values. If low contrast image is resulted due to low light conditions, lack of dynamic range of the camera sensor, contrast stretching operation results in the good quality image. During the contrast stretching operation, we basically increase the dynamic range of the gray values in the image being processed. A piecewise transformation function is used to achieve contrast stretching. Contrast stretching algorithm works as follows:

$$255, \text{ if } I(r) > T_2$$

$$J(r) = \begin{cases} I(r), & \text{if } T1 \leq I(r) \leq T2 \\ 0, & \text{if } I(r) < T1 \end{cases}$$

$I(r)$ is the color level for the input pixel (r) and $J(r)$ is the color level for the output pixel(r) after the contrast stretching process. $T1$ is minimum threshold value, $T2$ is maximum threshold value.

C. Negative transformation

There are a number of applications in which negative of the digital images are quite useful. For example, displaying of medical images and photographing a screen with monochrome positive film with the idea of using the resulting negatives as normal slides. The negative of the digital image is obtained by using the transformation function:

$$J(r) = (L-1)-I(r)$$

Where L is the number of gray levels, $I(r)$ is input pixel gray level and $J(r)$ is output transformed gray level. The idea is to reverse the order from black to white so that the intensity of the output image decreases as the intensity of the input increases.

D. Thresholding:

Thresholding an image means transforming all pixels in two values only. This is the special type of quantization comparing the pixel values with a given threshold value. Thresholding makes output image with only two values that is 0 and 255 for 8bit gray level image.

$$J(r) = \begin{cases} 0, & \text{if } I(r) \leq T \\ 255, & \text{if } I(r) > T \end{cases}$$

Resulting of Thresholding image is a black and white image, this has only two gray level values.

III. IMPLEMENTED ALGORITHMS

Fig 2, Fig 3, Fig 4 and Fig 5 shows the RTL schematic of the image enhancement algorithms implemented for brightness control, contrast stretching, and negative transform and threshold algorithms respectively.

Brightness control RTL schematic has D-flip-flops, adder unit, comparator and 2X1 multiplexers. Thus 8bit adder unit is for adding input pixel and constant brightness factor. Depending on comparator output the output pixel value is either sum of input pixel value and brightness factor or 255 (maximum gray level for 8-bit gray scale image).

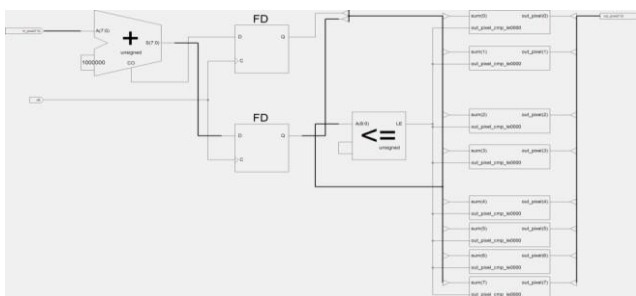


Fig. 2. RTL schematic of brightness control algorithm

Contrast stretching RTL schematic has D-flip-flops and comparators. Here the input pixels between two threshold values are kept same as input pixel. Below that minimum threshold value stretched towards minimum gray level value (i.e. 0). Above that maximum threshold value stretched towards maximum gray level value (i.e. 255).

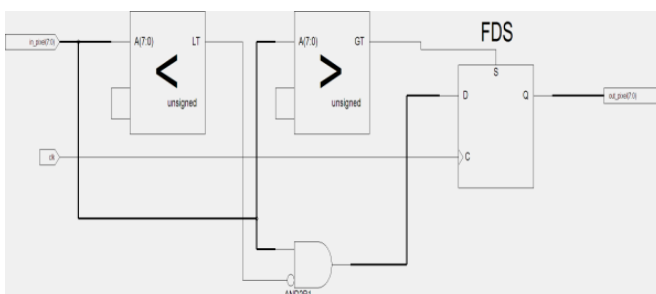


Fig. 3. RTL schematic of contrast stretching algorithm Negative transformation RTL schematic has D flip-flops and subtraction (adder unit one input has inverted unit). Here all input pixels are subtracted from maximum gray value

255. Output image as negative for input image. Here this results in reversing of the gray level intensities of input image.

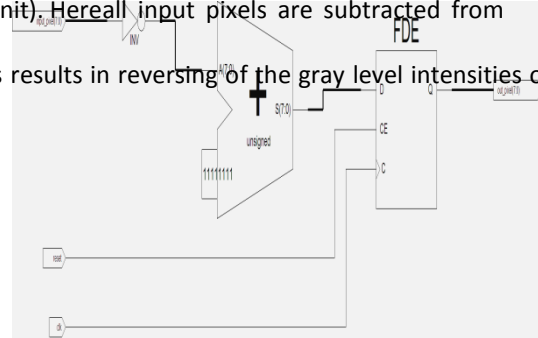


Fig. 4. RTL schematic of negative transformation algorithm Thresholding RTL schematic has D flip-flop and comparator. Comparator compares the input pixel with threshold value .each pixel below or equals that threshold value given to 0(minimum) and above threshold value given to 255(maximum). Resulting of Thresholding image is a black and white image, this have only two gray level values.

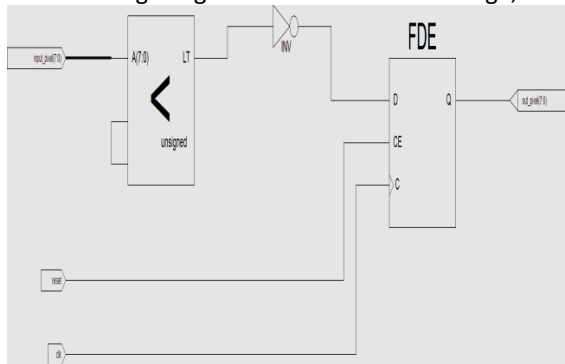


Fig. 5. RTL schematic of thresholding algorithm

IV. RESULTS

The hardware based implementation of image enhancement algorithm is carried out on single Spartan-3E family of fpga. The software development tool used for developing and verifying the design is the Xilinx ISE 10.1 version. The image size considered for testing is a 100x100 pixel resolution gray level image. The reason for considering a 100x100 resolution image is because of the limited memory size of fpga.

Fig.6 to Fig.9 shows MODELSIM simulation results for image enhancement algorithms implemented for brightness control, contrast stretching, negative transform and threshold algorithms respectively. Table1 shows the results at different stages of an algorithm.

Here simulation results for brightness, contrast, negative transform and threshold respectively:

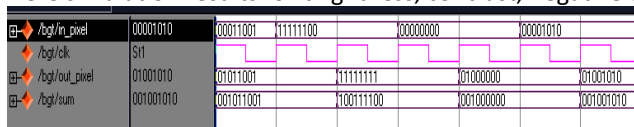


Fig.6. Simulation result for brightness control

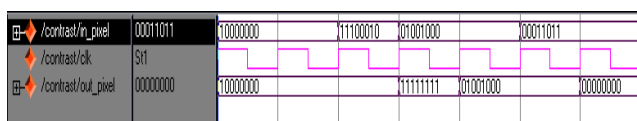


Fig.7. Simulation result for contrast stretch

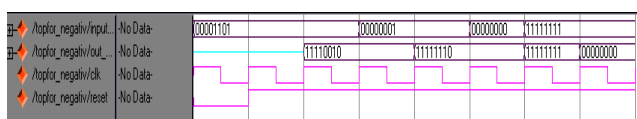


Fig.8. Simulation result for negative transform



Fig.9. Simulation result for thresholding

V. CONCLUSION

This paper implemented for high speed image enhancement applications using fpga. The image enhancement techniques such as brightness and contrast adjustment are important especially in medical images. This paper explains implementation of Brightness control, Contrast stretching, Negative transform and Thresholding algorithms on fpga. The algorithms were implemented on Spartan-3E fpga development kit. This gives digital images with good brightness/contrast and it improves quality of images. This techniques used for different applications depends on requirement and need. These techniques used in digital x-ray, digital mammography, CT scans, MRI etc. The same image enhancement techniques can be applied to RGB color images instead of gray scale images for manual and automatic color correction.

Table1: output results at different stage of algorithm

A	
B	
C	
d	



a) Original image, b) Image for Brightness control
c) Image for contrast stretch, d) Image for negativetransform, e) Image for thresholding.

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