

IMPLEMENTATION OF DIGITAL IMAGE PROCESSING ALGORITHM FOR BLUR, SOBEL AND SHARPEN FILTER ON FPGA HARDWARE

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ABSTRACT

Digital image processing is the use of algorithms and mathematical models to process and analyze digital images. The goal of digital image processing is to enhance the quality of images, extract meaningful information from images, and automate image-based tasks. This field has many useful applications in our life. Various image processing algorithms help us to clearly view the image and able to recognise different characteristics of the image. In our research, Blur, Sobel and Sharpen filters are used for this image processing project. Each filter has its own application and is performed by convolution of pixel values. This method of image processing is quite popular because it is convenient to use, it enhances image quality, and their different combinations can yield more useful processing algorithms. In this paper, image processing algorithms are implemented based on Xilinx Spartan 6 FPGA hardware. Implementation on FPGA hardware is quite popular because of its efficiency in speed, complexity and flexibility in processing.

Keyword: *FPGA, image processing, Sobel filtering, Blur filtering, Sharpen filtering, Matlab*

1. INTRODUCTION

The FPGA family of chips was created due to the necessary requirements posed in the field of IC design. It needs to have a hardware testing system to verify and test the designs. FPGAs are currently used mainly in the field of digital signal processing, aeronautical systems, ASIC prototype design, image analysis and recognition, speech recognition, cryptography, computer hardware model. Due to the high flexibility in the design process, FPGA chips allow to solve complex problems which previously only performed by computer software. In addition, thanks to the large density of logic gates, FPGAs are applied used for problems that require a large amount of computation and used in systems working in real time.

Applying the knowledge in digital integrated circuit design course, a group of students from the Department of Electronics, Thai Nguyen University of Technology has launched a study to implement the digital image filtering algorithm based on Xilinx's FPGA hardware, Spartan VI. With an input grayscale image, after being fed into a system designed to integrate processing blocks in Verilog hardware description language, the output image will match the filter's requirements. The algorithm used to put into the processing blocks is the convolution of the image matrix and the filter matrix with the program writing tool ISE design.

The results obtained when using three filters: Sobel, Blur and sharpen filter all qualified the set targets. It is equivalent to image processing with those three filters using Matlab.

2. OVERVIEW OF IMAGE PROCESSING

Image processing is a method to perform some operations on an image, in order to get an enhanced image or to extract some useful information from it. It is a type of signal processing in which input is an image and output may be image or characteristics/features associated with that image. In recent years, image processing have many applications in the various fields of medical imaging, meteorology, traffic system, computer vision, digital photography, microscopy, Human Resources Management etc.

Image processing basically includes the following three steps:

- Importing the image via image acquisition tools;
- Analysing and manipulating the image;
- Output in which result can be altered image or report that is based on image analysis.

2.1 Digital Image

a) Image element

A picture element is the smallest possible quantitative part of an image, whether it is one that is printed or a digital image on a monitor or television screen. Images in nature are spatially continuous signals and luminance values. For storing and representing images by computers, humans have to convert those continuous signals into a finite number of discrete signals through the process of quantizing and sampling the value components brightness.

An picture element has a value representing the gray level or image intensity at a location after transforming the image into a finite number of discrete signals.

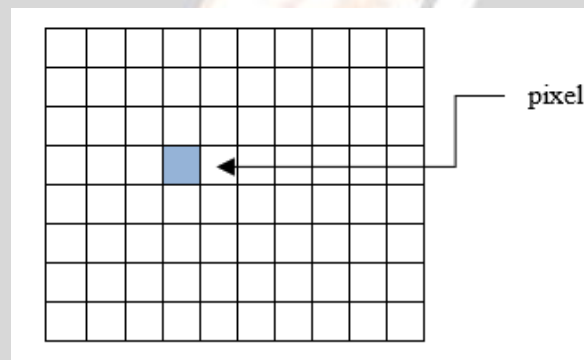


Fig -1 : Pixel image element description

b) Gray level

Gray levels refers to the total number of discrete tonal variations that can be recorded on film or paper. It is the result of the corresponding transformation of the luminance value of a pixel with a positive integer value. Depend on the number of values representing of gray level, each pixel will be represented on 1, 4, 8, 24 or 32 bits. The larger number of bits representing the gray level, the higher the image quality, but it takes more memory space to store and requires a more powerful system to process.

c) Digital image

Digital image is composed of a finite number of elements, each of which elements have a particular value at a particular location. A digital image is a finite set of pixels with a suitable gray level used to describe the image as similar to the real image. Thus every digital image is a matrix, with a pixel being a value in the matrix.

Binary image (black and white): The binary image is an image whose gray level value of pixels is represented by 1 bit (0 represents black entirely and 1 represents white). This image is also known as Monochrome.

0	1	1	0
1	1	1	0
0	0	1	1
0	1	1	1



Fig -2: Binary image example

Grayscale image: the gray level value of pixels is represented by 8 bits (values from 0 to 255). Zero is entirely black, and 255 is white. Gray falls around 127 leading to the white color. These images are also known as 8-bit color format images.

0	5	12	0
15	94	21	0
0	0	156	9
0	11	245	12



Fig -3: Gray image example

Color image: In RGB images, a pixel consists of three integers, and the value range is 0 to 255. Normally, a color image is made up of 3 grayscale images with background colors RED, GREEN, BLUE (RGB). Therefore, the representation of the color image on the computer above will be represented as a 3-dimensional tensor of size $m * n * 3$ because there are 3 red, green, and blue color matrices (channels) of size $m * n$ overlapping each other. These images are represented in a 3-D matrix or a 3-dimensional array. These images use the high color format known as the 16-bit color format.

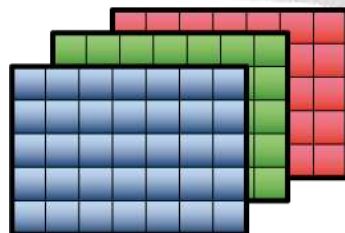


Fig -4: The RGB color image

2.2 Convolution method in image processing

In image processing, a kernel, convolution matrix, or mask is a small matrix used for blurring, sharpening, embossing, edge detection, and more. The general principle of filtering methods is to multiply the image matrix by a filter matrix (kernel). Filter matrix can be called convolution window (in convolutional multiplication), filter window, mask, etc.

For each filter we have different filter matrices. There is no specific rule for determining M. The size of the matrix M is an odd number. For example, 3x3, 5x5 or 3x5 as shown in Figure 5.

When multiplying the corresponding elements (between pixels, neighboring points - components in the kernel), for the elements at the edge, it has some missing pixels, at this time. There are many solutions such as omit, insert one or several rows or columns with the nearest zero or equal value, or create a mirror symmetry at the edge of the image.

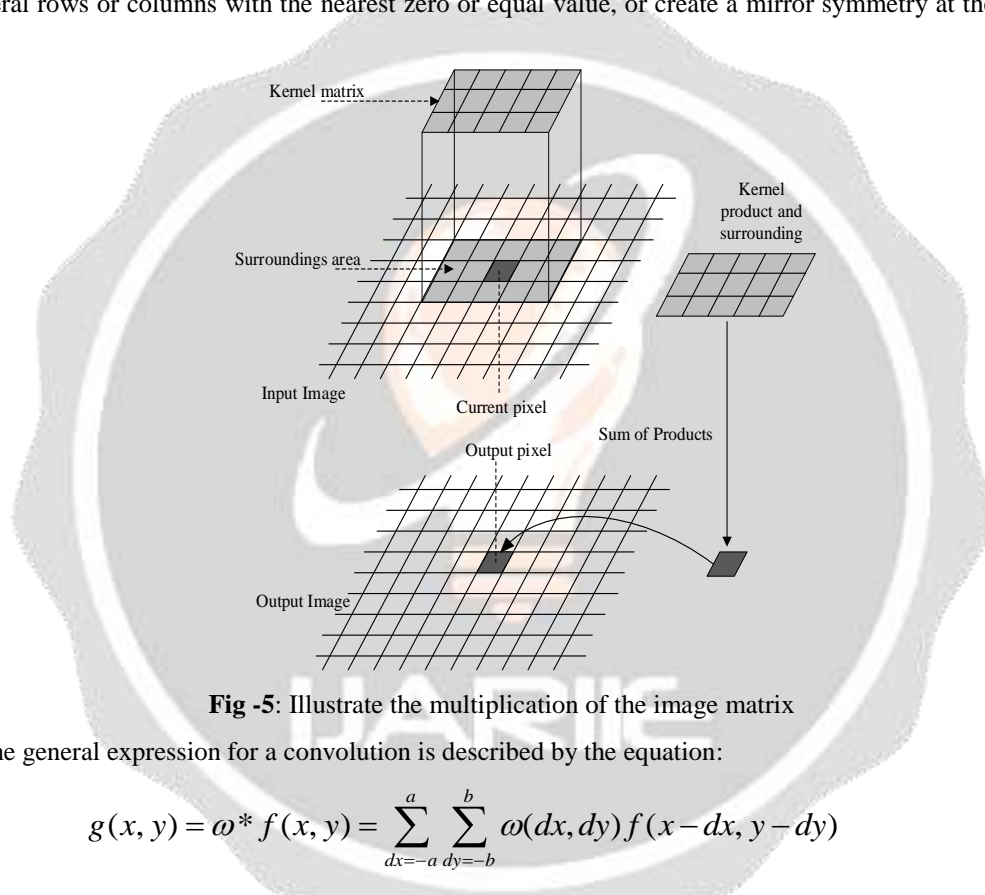


Fig -5: Illustrate the multiplication of the image matrix

The general expression for a convolution is described by the equation:

$$g(x, y) = \omega * f(x, y) = \sum_{dx=-a}^a \sum_{dy=-b}^b \omega(dx, dy) f(x-dx, y-dy) \tag{1}$$

2.3 Using filters for image processing

Average filter (Normalitize Box Blur) with filter matrix:

$$K = \frac{1}{9} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \tag{2}$$

To find the boundary image, using Sobel filter with filter matrix:

$$K_x = \begin{bmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{bmatrix} \quad K_y = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \quad (3)$$

Sharpen filter with filter matrix:

$$K = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix} \quad (4)$$

3. DESIGN AND IMPLEMENTATION

3.1 Block diagram of digital image filtering system

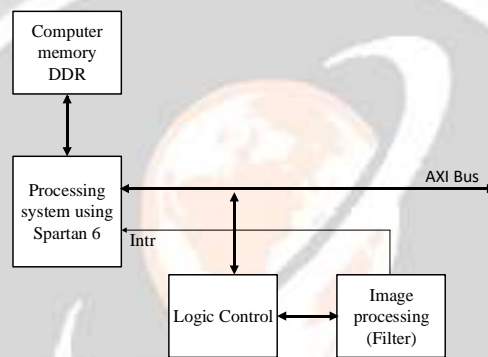


Fig -6: Block diagram of digital image filtering system



Fig -7: 512x512 grayscale input image

3.2 Design description

Defines the FPGA part to be used (Xilinx Spartan-6 FPGA).

Synthesis tool: Specifies the tool to be used to synthesize the design.

Hardware Description Language: Specifies the HDL language to be used for compilation i. e Verilog.

Create testbench.

The line buffer block selects neighborhood pixels from input image data. It handles logic control signals and edge padding, and is pipelined for high-quality image designs. The block outputs one column of the neighborhood at a time.

Design is synthesized and Implemented.

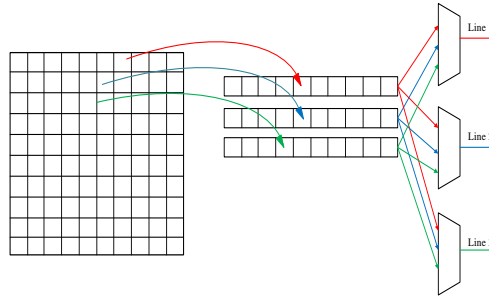


Fig -8: Line buffer description

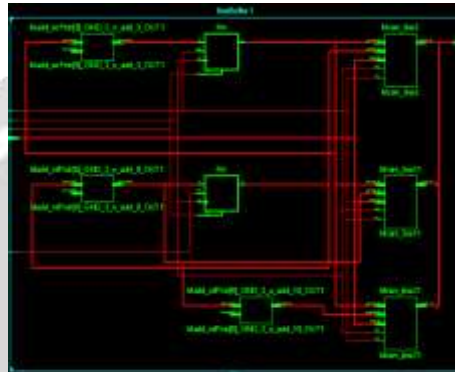


Fig -9: RTL schematic for line buffer

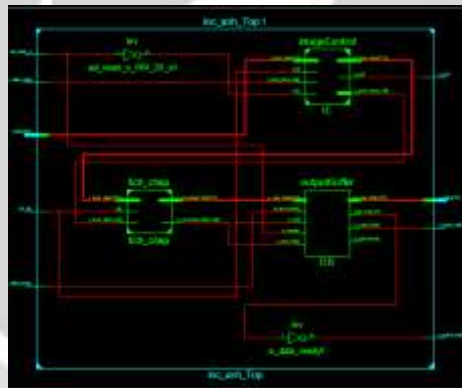


Fig -10: RTL diagram depicting main program

4. SIMULATION RESULTS AND DISCUSSION

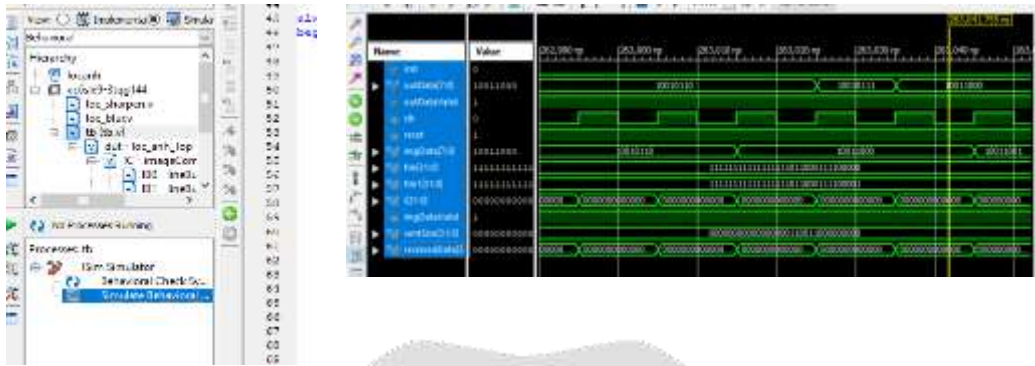


Fig -11: Simulation running interface

- **The result of the Sobel filter:**



Fig -12: Results for image processing using Sobel filter

- **The results of the sharpening and comparison filter when performed on Matlab:**



a) FPGA implementation result

b) image processing using Matlab

Fig -13: Results for image processing using sharpening filter with FPGA implementation (a) and using Matlab (b)

- **Results of Blur filter and comparison with image processing on Matlab**

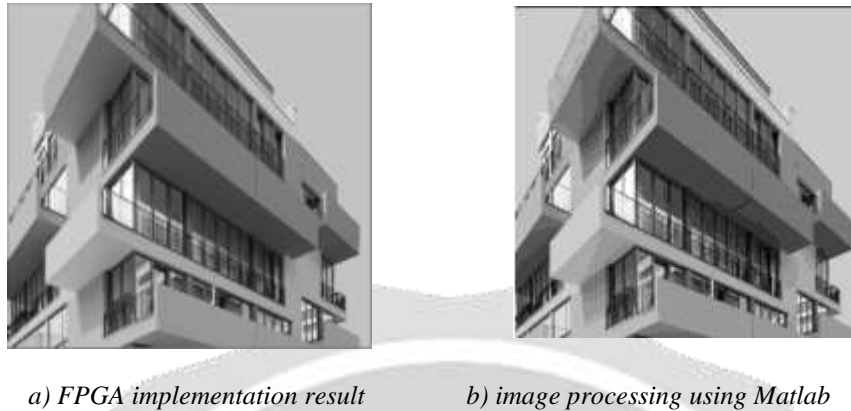


Fig -14: Results for image processing using Blur filter with FPGA implementation (a) and using Matlab (b)

From the results of the output images using Verilog on FPGA platform and in Matlab, it can be seen that the images after filtering between the two tools are similar, with shorter time for image processing when executing on the FPGA platform.

5. CONCLUSIONS

The article has basically presented an overview of digital image processing, basic characteristics of digital images, methods to design a digital image filter. Build algorithms to support image filtering, convolution algorithms, apply digital signal processing knowledge as well as electronic circuit techniques to solve problem. Become familiar with and solve the problem by coding a program using the hardware description language Verilog.

Image processing results when using Sobel, Blur and sharpening filters performed on FPGA hardware are quite good, equivalent to that of Matlab with shorter execution time.

In the future, the research team intends to give the following development directions for the project. It is possible to take input images directly from the webcam, memory card and put on the VGA or HDMI screen interface and perform image filtering loaded the program into the FPGA kit, use the I/O pins on the FPGA to adjust the filter parameters or select the filter. Using the OV7670 CMOS camera with the FPGA Kit enables real-time image and video processing without worrying about the camera interface. Build many different filtering algorithms with different sizes or filter color images.

6. ACKNOWLEDGEMENT

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7. REFERENCES

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