Implementation of Edge Detection Algorithm on FPGA for Brain Tumor Cell Identification

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Abstract

Brain tumors are considered to be a serious kind of disease in medical field. So, it must to required fast and accurate detection of brain tumor. In this paper implementing real time brain tumor edge detection on a field programmable gate array using Xilinx system generator and Matlab. The data of edge detection is very large, so the speed of image processing is a difficult problem. We use hardware software co-simulation time is reduced and accuracy of image increase. For brain tumor edge detection Sobel method is used on FPGA.

Keywords: Brain Tumors, Edge Detection, FPGA, Magnetic resonance image, Sobel operator.

1. Introduction

Modern era is driven by automation. Bio medical industry also experiences the effect of automatic implementation of various diagnostic systems. MRI is one of the powerful means to diagnose the tumors in the brain. MRI is commonly used in the medical field for detection and visualization of details in the internal structure of the body. It is basically used to detect the differences in the body tissues which have a considerably better technique as compared to computed tomography [1]. Thus, this technique becomes a special technique especially for the brain tumor detection and cancer imaging [1]. Basically, for comparison, CT uses ionizing radiation while MRI uses strong magnetic field to align the nuclear magnetization that follows by changes the alignment of the magnetization by radio frequencies that can be detected by the scanner. The signal produced can be further processed later to gain extra information of the body [1].

Edge detection refers to the process of identifying and locating sharp discontinuities in an image.

A brief review of some edge detection methods is presented here. Natarajan P. [2] presents tumor region detection using image subtraction technique. Ghassan [3] various edge detection techniques like Sobel operator, Prewitt operator, Canny operator, Robert operator, Laplacian technique and comparisons of these technique on Matlab software. Sobel is less sensitive to noise compared to other operators but it is not more accurate. So use 4 convolution masks to increase the accuracy of edge detection [4]. The data of edge detection is very large so the speed of image processing is a difficult problem. FPGA can overcome it [5]. FPGA have large number of internal memory banks which can be accessed in parallel that allowed FPGA hardware to execute functions in a few clock cycles [6]. Uses of FPGA in image processing system enables rapid prototyping, minimizes the time to market cost [7]. Then we referred 'digital image processing' book by Gonzalez and woods we studied three gradient based operators i.e. Robert, Prewitt and Sobel. Implemented these algorithms on MATLAB. By comparing the results obtain from MATLAB Sobel operator gives sharpen edges.

The aim of this paper is that, the edge detection of MRI image performed on MATLAB software and Xilinx System Generator. To design efficient Sobel algorithm for edge detection of image and implementing that algorithm System Generator and

achieve overall high performance, low cost and short development time for the MRI images of brain tumor cells.

2. Design Flow

Xilinx System Generator [8], is a system-level modeling tool from Xilinx that facilitates FPGA hardware design. It extends Simulink in many ways to provide a modeling environment well suited for hardware design. The software automatically converts the high level system DSP block diagram to RTL. The result can be synthesized to Xilinx FPGA technology using ISE tools. All of the downstream FPGA implementation steps including synthesis and place and route are automatically performed to generate an FPGA programming file.

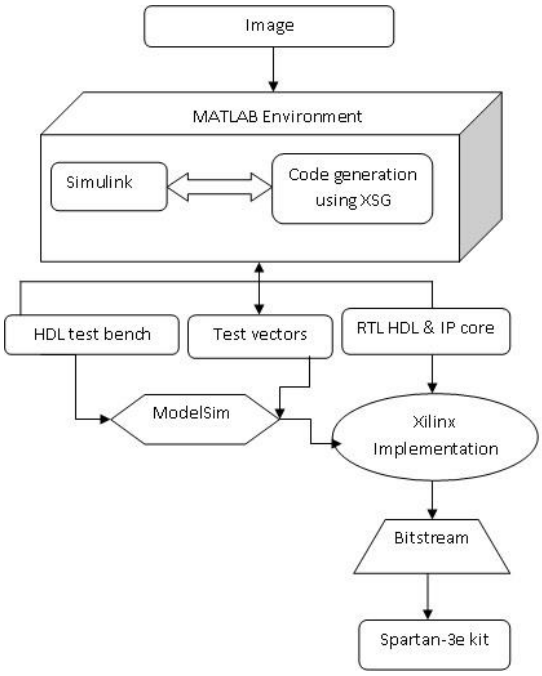


Fig-1 Design flow

"Fig-1" presents the design flow of XSG. System Generator automates the design process, debugs, and implements and verifies the Xilinx-based FPGAs. It provides a high-speed HDL co-simulation interface, system-level resource estimation, and accelerated simulation through hardware in the loop co-simulation interfaces which give up to a 1000x simulation performance increase [9]. It also provides a system integration platform for the design of DSP FPGAs that allows the RTL, Simulink, MATLAB and C/C++ components of a DSP system to come together in a single simulation and implementation environment. System Generator supports a black box block that allows RTL to be imported into Simulink and simulated with either ModelSim or Xilinx ISE Simulator.

3. Algorithm of Edge Detection System

In this project, we will use a modified version of Sobel edge detector algorithm to detect edges in 8-bit gray scale images of 256×256 pixels. The Sobel operator is widely used for edge detection in images. There is an advantage over simple gradient operators because of its property to cancel out the noise sensitivity. It is based on computing an approximation of the gradient of the image intensity function. It uses two 3x3 spatial masks (Hx and Hy) which are convolved with the original image to calculate the approximations of the gradient. The Sobel operator uses two filters.

$$\mathrm{Hx} = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}, \ \mathrm{Hy} = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

Looks for edges in both horizontal and vertical directions, then combine the information into a single metric. These compute the average gradient components across the neighboring lines or columns, respectively. The local edge strength defined as the gradient magnitude given by

$$G(x,y) = \sqrt{Hx^2 + \mathrm{Hy}^2} \qquad (1)$$

The accuracy of Sobel operator for edge detection is comparatively low because it uses two masks which detect the edges in vertical and horizontal directions only. This complication can be addressed by using Sobel compass operator which uses a larger set of masks with narrowly spaced alignment. It uses eight masks (H0, H45, H90, H135, H180, H225, H270, and H315) each provides edge strength along one of the eight possible directions of the compass.

$$\mathrm{H}_0 = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}, \ \mathrm{H}_{45} = \begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix}$$

$$H_{90} = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}, H_{135} = \begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{bmatrix}$$

$$H_{180} = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}, H_{225} = \begin{bmatrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -2 \end{bmatrix}$$

$$H_{270} = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}, H_{315} = \begin{bmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix}$$

3.1 Algorithm in Simulink using Xilinx blocks

The proposed edge detection algorithm is based on Sobel Operator. For edge detection block some pre-processing and post-processing are required on the image while using Xilinx block set. The proposed algorithm consists:

1. Image from file and Frame to Serial Conversion (2-D to 1-D)
2. Gateway in
3. Rgb2gray scale Conversion
4. Sobel Edge Detection Horizontal (Gx) and Vertical (Gy) masking
5. Thresholding
6. Gateway out
7. Serial to Frame Conversion (1-D TO 2-D) and Display

3.2 Flow diagram of Sobel Edge Detection system

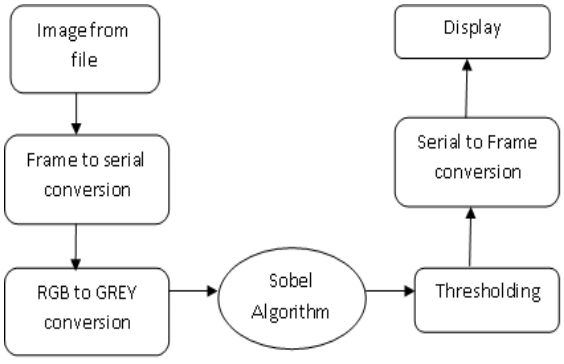


Fig-2 Flow diagram of Edge detection

3.3 Block diagram of Sobel based edge detection

Give the color image which should be of 255 x 255 pixels. Acquisition of image from is done using "Image from file" Matlab Simulink block. Each separate color signal is given to 2-D to 1-D conversion subsystem. These process called image pre-processing.

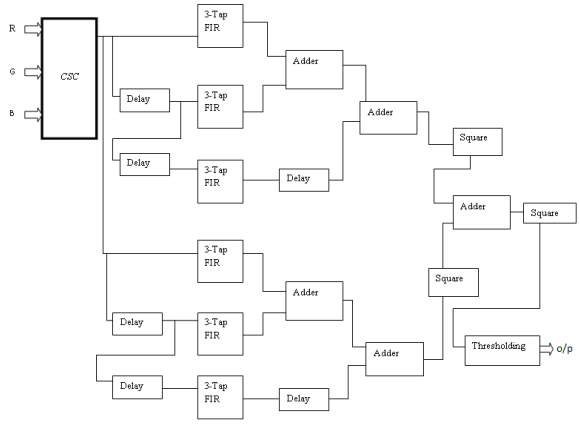


Fig-3 Block diagram of Sobel based edge detection

Gateway In block provides the bridge of communication between Simulink and Xilinx Block set. The Xilinx Gateway In blocks are the inputs to the Xilinx portion of Model. These blocks convert Simulink integer, double and fixed-point data types into the System Generator fixed-point type.

In rgb2gray scale, accurate conversion from red, green, blue color space to grayscale, or intensity. The intensity of a pixel represents how much power it is emitting, and it is correlated to a shade of gray. A pixel of zero intensity is black and a pixel of intensity value 255 is white.

for detecting the edge of MRI Image, Sobel method is used. Horizontal and vertical masking used for detecting the edges. Edge detection model in Xilinx system generator 14.2, FIR compiler used for horizontal and vertical masking. Xilinx system generator used because easily change the matrix value.

Thresholding block used to convert intensity image to binary image. Model input values compare with a fixed threshold 20 (this value is not a fixed value, through over and over again for comparing to choose the best value), if greater than 20 is set to 255, while if less than or equal to 0.

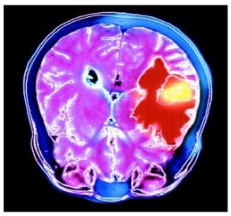
The output of the Thresholding system is given to gateway out. The gateway out block provides Communication Bridge between Xilinx and Simulink block set. Xilinx Gateway Out blocks are the output to Xilinx portion of Simulink Model. This block converts the System Generator fixed-point data type into Simulink Double.

The output of the gateway out is given to buffer and reshape block because the image is 1-D image so, we have to convert it to 2-D image. To display the final image using video viewer.

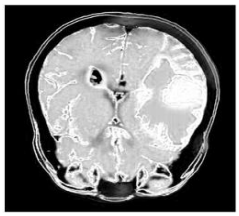
4. Simulation and Results

4.1Matlab Simulation

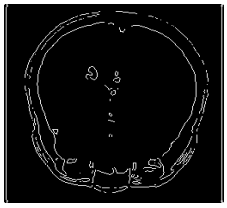
Here Matlab Simulink model for Sobel, Canny, Robert, Prewitt operators. Performed edge detection on Matlab we get accurate edge detection using Sobel method. Sobel based edge detection is less complex compare to other methods.



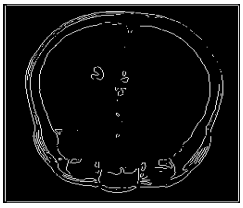
(a)Original



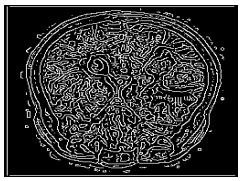
(b)Grayscale



(c) Sobel



(d) Prewitt



(e) Canny

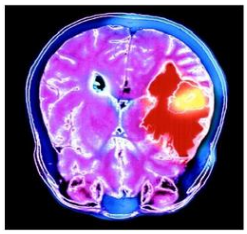
Fig-4 Matlab Results

Fig shows Sobel and Prewitt results almost same but Sobel have better noise suppression. Canny has more time consuming methods compare to other methods. So, we use sobel method for more accurate edge detection on xilinx system generator.

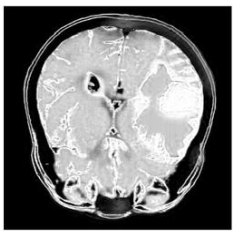
4.2Xilinx Simulation

Xilinx model first image convert into grayscale. Input image size is 256x256 pixel. FIR complier block used for masking. Sobel edge detection in Xilinx system generator takes few seconds.

For achieving high accuracy we use hardware software co-simulation on spartan-3e kit. Sobel edge detection perform on these kit and edge detected image shown in matlab using image video viwer block.



(a)Original



(b) grayscale

(c) Sobel using two 3x3 mask

(d) Sobel using four 3x3 mask

(e) Sobel using four 5x5 mask

Fig-5 Xilinx system generator simulation results

Here we use two performance parameter for comparing original image and edge detected image.

$$MSE = \frac{1}{MN} \sum_{m=1}^{M} \sum_{n=1}^{N} \left(I_1(m,n) - I_2(m,n) \right)^2 \quad (2)$$

$$PSNR = 10 \log \frac{R^2}{MSE} \quad (3)$$

Table-1 Parameters comparisons of edge detection

Methods	PSNR	MSE
Sobel	26.3376	152.3078
Prewitt	26.3269	152.6815
Canny	26.7165	139.5819
Sobel on XSG (Two 3x3 mask)	27.7471	110.0954
Sobel on XSG (Four 3x3 mask)	28.4206	94.2793
Sobel on XSG (Four 5x5 mask)	28.6811	88.7902

5.Conclusion

In this project implement Sobel based edge detection on FPGA. Sobel operator is used because it is insensible to noise and reduces system complexity. It performed on Spartan-3e development board achieve high accuracy and reduced time. Compare performance parameters MSE and PSNR, we get high accuracy using Sobel four 3x3 convolution mask and four 5x5 convolution mask on XSG.

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