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Convolutional neural network for bio-medical image segmentation with hardware acceleration

M. Vardhana [a], N. Arunkumar [b,*], Sunitha Lasrado [c], Enas Abdulhay [d], Gustavo Ramirez-Gonzalez [e]

[a] *NMAM Institute of Technology, Nitte, India*
[b] *Sastra University, Tanjore, India*
[c] *Dept. of ECE, NMAM Institute of Technology, Nitte, India*
[d] *Jordan University of Science and Technology, Jordan*
[e] *Universidad del Cauca, Colombia*

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Abstract

Application of artificial intelligence in Bio-Medical image processing is gaining more and more importance in the field of Medical Science. The bio medical images, has to go through several steps before the diagnosis of the disease. Firstly, the images has to be acquired and preprocessing has to be done and the data has to be stored in memory. It requires huge amount of memory and processing time. Among the preprocessing steps, edge detection is one of the major step. Edge detection filters the unwanted details in the image, and preserves the edges of the image, which describe the boundary of the image. In biomedical application, for the detection of the diseases, it is very essential to have the boundary detail of the acquired image of the organ under observation. Thus it is very essential to extract the edges of the images. Power is one of the main parameters that have to be considered while dealing with biomedical instruments. The biomedical signal processing instruments should be capable of operating at low power and also at high speed. In order to segregate the images into different levels or stage, we use convolutional neural networks for classification. By having a hardware architecture for image edge detection, the computational time for pre-processing of the image can be reduced, and the hardware can be a part of acquisition device itself. In this paper a low-power architecture for edge detection to detect the biomedical images are presented. The edge detection output are given to the system, which will diagnose the diseases using image classification using convolutional neural network. In this paper, Sobel and Prewitt, algorithms are used for edge detection using 180 nm technology. The edge detection algorithms are implemented using VLSI, and digital IC design of the architecture is presented. The algorithms for edge detection is co-simulated using MATLAB and Modelsim. The architecture is first simulated using CMOS logic and new method using domino logic is presented for low power consumption.

Keywords: Sobel; Prewitt; Domino; RTL; Convolutional neural network

1. Introduction

Edge detection is one of the main step in the image processing. The edges are due to the change in the intensity level at the transition between the boundaries. These edges convey great detail about the image under observation.

* Corresponding author.
E-mail addresses: vardhana619@gmail.com (M. Vardhana), arun.nura@gmail.com (N. Arunkumar), sunithadsouza@nitte.edu.in (S. Lasrado), ewabdulhay@just.edu.jo (E. Abdulhay), gramirez@unicauca.edu.co (G. Ramirez-Gonzalez).

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Edge detection finds its application in various fields, and the major area is in biomedical application. In biomedical application, in order to find the detail of the images, it is necessary to process the images. Edge detection is one of the operation of identifying the boundaries which help in diagnosing the disease in biomedical application. Thus there is a need for low power image processing architectures. The power is one of the major issue, which has to be minimized. In this paper, we present domino CMOS logic for building the image processing algorithm. We employ two major edge detection algorithms that are widely used. The Sobel and Prewitt algorithms are implemented using CMOS logic at 180 nm technology, and power analysis of the design is carried out and domino CMOS architecture is presented. With the use of domino CMOS logic, the power consumption and also the area of the chip can be greatly reduced. The design is applied for various CT scan images of lungs, MR images of brain, X-ray images, etc. the edge detected image can be used for identification of the disease.

2. Literature review

Research work has been carried out in various fields of biomedical image processing, for the identification of brain tumors, etc... Image processing techniques for enhancement of brain tumor patterns are discussed in Verma, Mehrotra, Pandey, and Singh (2013).It presents the various techniques used for identification of the brain tumor. Comparative study on different edge detection techniques has been discussed in Panigrahi, Mahakud, Samantaray, and Mohapatra (2014). It presents the result of various edge detection algorithms, simulated using MATLAB. The various images are taken and analyzed using various algorithms of edge detection. An efficient technique for visualization and segmentation of lung CT scan images has been discussed in Aggarwal, Sardana, and Vig (2010). It provides a complete details regarding the diagnosis of lung cancer, with the help of segmentation. A new approach for edge detection, based on Ant Colony, is presented in Rahebi and Tajik (2011). Ant colony optimization is an algorithm based on behavior of ants (Rahebi & Tajik, 2011). Introduces this algorithm for edge detection of bio medical images. It proposes a new technique, where artificial neural network with supervised learning along with momentum to improve edge detection based on ant colony optimization. The various operators used for boundary extraction of biomedical images have been presented in Gupta and Tiwari (2015).It presents the study of most commonly used edge detection algorithms. Paper (Gupta & Tiwari, 2015) also presents a new edge operator using gray code for image segmentation. All the simulation is carried out using MATLAB. In bio medical application, image processing plays a very important role in detecting the brain tumors (Dhanwani & Bartere, 2014; Joshi & Shah, 2015), stones in the kidney and several other diseases. The problem comes when it actually gets mapped into hardware. In this paper we develop a synthesizable architecture for edge detection. The graphical user interface is developed using matlab, and the processing of the image is carried out using VLSI architecture. The comparative study on Sobel and Prewitt architecture is also presented.

3. System design

The system design is carried out in two stages of development. First stage includes the development of graphical user interface to acquire the biomedical images and for the visualization of the edge detected images. The second stage of development includes the VLSI core developed using Verilog. The two main algorithms that we use for edge detections are Sobel and Prewitt. These algorithms are briefed in the following subsections.

3.1. Sobel edge detection

Sobel edge detection (Al-Tamimi & Sulong, 2014) is introduced in the year 1970 by Sobel. It finds the edges by using Sobel approximation to the first order derivative. Sobel operator also relies on central differences. This equivalent to the first derivative of the Gaussian blurring, obtained by applying the mask to the image. The size of the mask can vary. 3×3 is the one which is widely used. Convolution is commutative and associative, and is given as in (1).

$$\frac{\partial}{\partial x}(f * G) = f * \frac{\partial}{\partial x}(G) \tag{1}$$

In this paper we use 3×3 mask, which is applied to the set of pixels of image under consideration. Digital approximation of Sobel operator is given as in (2).

$$\nabla f \equiv |(z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)| + |(z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)| \tag{2}$$

The 3×3 mask can be represented as follows.

$$M_x = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad and \quad M_y = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

The above masks are applied to the image for identification of the edges. From the mask it is very clear that it is very essential to have the adders and subtractors in the system core. Subtraction is implemented as 2′s compliment addition. These masks are applied to the image pixels and gradient is calculated as in Eq. (1). The final resulting pixel value is replaced with the central pixel of the image under consideration. This process is continued until the whole image is covered.

3.2. Prewitt edge detection

Prewitt operator is similar to that of the Sobel operator, with the difference in the mask values. It takes the central