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Sobel Algorithm for Processing Medical Images on FPGA

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***Abstract*—FPGAs are gaining interest in microchip manufacturing due to their high computational power and parallelization capabilities. This makes them suitable for compact, integrated devices handling diverse computational tasks, particularly in the medical field. The Sobel operator is a simple method for determining image contours. It utilizes 2D convolution with kernel matrices to approximate brightness derivatives along horizontal and vertical axes. FPGA implementation allows for easy parallelization. However, as a standalone algorithm, it is not ideal for medical image processing due to limited accuracy and noise sensitivity. Instead, it can be used as an additional filter to enhance edges in conjunction with other algorithms, improving diagnostic detail. FPGA implementation enables rapid edge detection, making it suitable for integration into medical image recognition systems.**

Keywords—Image processing, medical images, optimization, Sobel operator, parallelization

I. Introduction

In modern medicine, the processing and analysis of medical images play a crucial role in diagnosis, treatment planning, and patient monitoring [1-4]. One of the most commonly used algorithms for image processing is the Sobel operator. This operator allows for the detection of edges and contours in images, providing important information for physicians and specialists in the field of medical visualization.

For efficient implementation of the Sobel algorithm in practice, programmable logic devices such as Xilinx FPGAs are widely employed. FPGAs offer high computational power and parallel processing capabilities, which accelerate the processing of medical images. With the flexibility of FPGA configuration, the Sobel algorithm can be optimized to meet the specific requirements and tasks of medical systems, enabling fast and accurate image processing in real-time [5-13].

II. The Sobel Operator

As the field of microchip manufacturing continues to evolve, there is also a growing interest in the use of FPGAs. These platforms currently offer high computational power and parallelization capabilities, making them a great choice for creating integrated devices that handle various computational tasks. Particularly, these devices can be of interest in the medical field, where compact solutions for processing images obtained through various methods are needed.

The Sobel operator is a relatively simple method for determining the contours of images in most types. Let's consider its mathematical essence. The Sobel operator uses two square kernel matrices to perform a 2D convolution on the image. This is done to approximate the derivative values of pixel brightness along the horizontal and vertical axes. The expressions for these operations can be formulated in the form of equations:

$$G_y = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} * A \text{ and } G_x = \begin{bmatrix} -1 & +2 & +1 \\ -2 & 0 & +2 \\ -1 & -2 & +1 \end{bmatrix} * A \quad (1)$$

where A is the input image, G_x, G_y is images where each point represents the approximate derivatives along the x and y axes.

n the formula (1), the symbol "*" represents the operation of two-dimensional convolution. The approximate gradient value of brightness can be obtained by element-wise summation of the resulting images:

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

As can be seen, this operator involves relatively simple calculations: to approximate the gradient vector, only eight pixels around each image point and integer arithmetic are needed. Moreover, the filters (1) can be separated, further reducing the number of required arithmetic operations per pixel.

This is a mathematical description of how the Sobel operator works. It is evident that in its software implementation, it can be easily parallelized across any number of threads. For example, with two computational cores, the upper half-frame can process the first core, while the lower half-frame can process the second core.

All of this enables a simple and fast implementation of the operator on an FPGA, thanks to its inherent parallelization capabilities. Figure 1 shows an example of Sobel operator processing on a medical image.

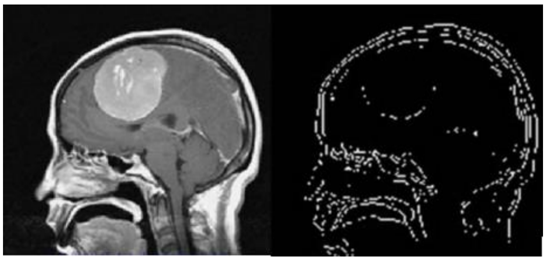

Fig. 1. Head scan before (left) and after (right) applying the Sobel operator.

FPGAs offer several advantages for implementing the Sobel operator [14]:

The ability to process multiple operations simultaneously, enabling parallelism. This accelerates the mathematical operations associated with image processing.

The flexibility to reconfigure the FPGA to optimize the algorithm execution for specific task requirements, allowing hardware optimization according to computational demands.

FPGAs are known for their high speed, making them a good choice for implementing image processing algorithms.

To implement the Sobel operator calculation on an FPGA, the logic and hardware resources need to be configured to perform each stage of the calculations. Additionally, image smoothing using a Gaussian filter can be applied to improve the results.

If we consider the characteristics of the Sobel algorithm, it is not suitable for standalone use in medical image processing [15]. This is due to its relatively low accuracy and the presence of significant amounts of noise. Additionally, if an image has sharp brightness transitions, the algorithm may also detect those transitions as edges.

However, as a standalone algorithm, it can be used as an additional filter to enhance edges in images processed by other algorithms, thereby improving their level of detail. This can be particularly important for medical images obtained through various methods (such as X-rays or positron emission tomography) that contain many fine details crucial for accurate diagnosis [15].

III. Conclusion

In conclusion, implementing the Sobel operator calculation on an FPGA enables fast and easy edge detection. FPGAs provide parallel processing capabilities and compact size, making them attractive for integration into medical image recognition systems that interface with external devices. However, the algorithm utilizing the Sobel operator cannot be used as a standalone tool due to its limitations in accuracy and sensitivity to noise. Instead, it can be employed as an additional filter to enhance edge sharpness in medical images processed by other methods (such as the Canny algorithm). This, in turn, improves the level of detail critical for accurate diagnosis [3].

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