Sobel Filter for Edge Detection using VHDL

Ali Alipour, *University of Tehran*

This project implements the Sobel Filter, an edge detection algorithm, using VHDL to process images efficiently. Edge detection is a crucial step in image processing, often used to highlight significant changes in intensity, which correspond to object boundaries within an image. The Sobel Filter is well-known for its ability to detect vertical and horizontal edges.

Filter Design

The Sobel Filter was designed to detect both horizontal and vertical edges by applying two 3x3 kernels to the input image. One kernel detects horizontal changes in intensity, while the other detects vertical changes. The convolution process outputs a new image highlighting areas with significant intensity shifts. (See Figure 1 for the process of edge detection).

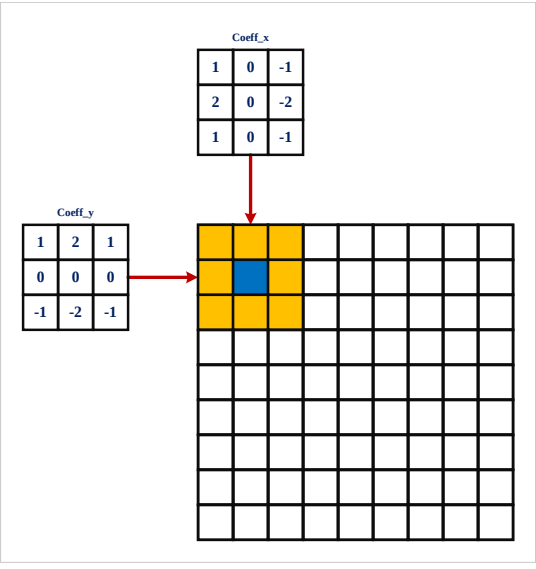

Figure 1: *Figure 1*

Hardware Integration

The hardware design includes the following components:

- **VHDL Modules:** The core modules of the filter, including the convolution operator and gradient calculations, were implemented in VHDL. These modules are responsible for calculating the Sobel Filter's output by processing each pixel in the input image.
- **Memory Management:** The memory read and write modules ensure that the input image is fetched from memory, processed by the filter, and then the output image is written back to memory. This data flow is crucial for real-time image processing.

Methodology

Input pixels are sequentially read from memory, and once 9 pixels are retrieved, the matrix mapping operation is executed. The calculated result is then output, followed by the write command to store it back into memory. Figure 1 illustrates how the module receives the input, while Figure 2 displays the state machine designed for this filter.

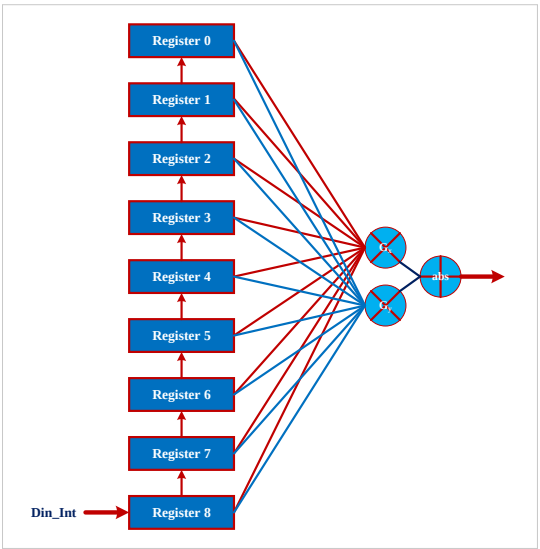

Figure 2: *Figure 2*

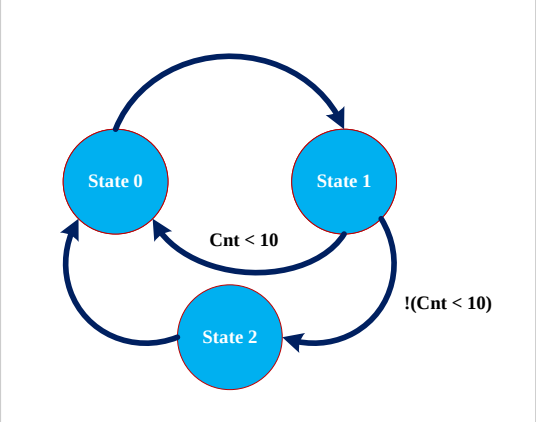

Figure 3: *Figure 3*

Conclusion

The Sobel Filter implemented in VHDL and synthesized on an FPGA demonstrates the effectiveness of hardware-based edge detection. By leveraging hardware acceleration, this project achieves fast, real-time processing of images, making it ideal for applications that require quick and accurate edge detection, such as object recognition or automated vision systems.

References

[Alipour Fraydani, 2024] Alipour Fraydani, A. (2024). Homework on Methodology and automatic design algorithms of digital systems, University of Tehran. *Unpublished Manuscript*, Department of Electrical Engineering, University of Tehran.