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TEXAS
The University of Texas at Austin

Edge Detection using Sobel Filters on Zynq Ultra-96

EE382N-4 Advanced Embedded Systems

Final Project

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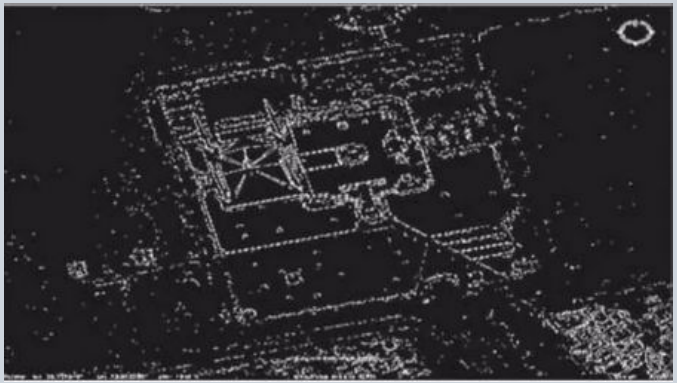
Agenda

- Motivation
- Implementation Details
- Results
- Future Work

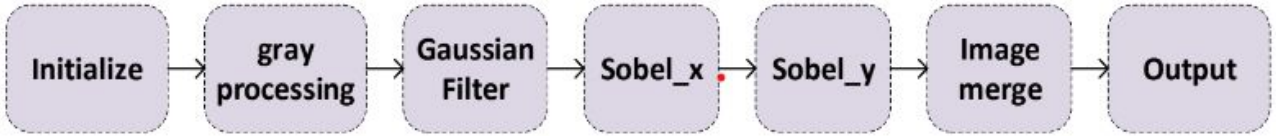
Motivation

- Edge detection involves convolution operations to detect edges.
- Expensive in software.
- We built an *efficient* hardware implementation to accelerate this application which is *flexible* enough to run on multiple image sizes without generating new bitstream.



https://www.slideshare.net/NareshBiloniya/application-of-edge-detection-96942725

Methodology



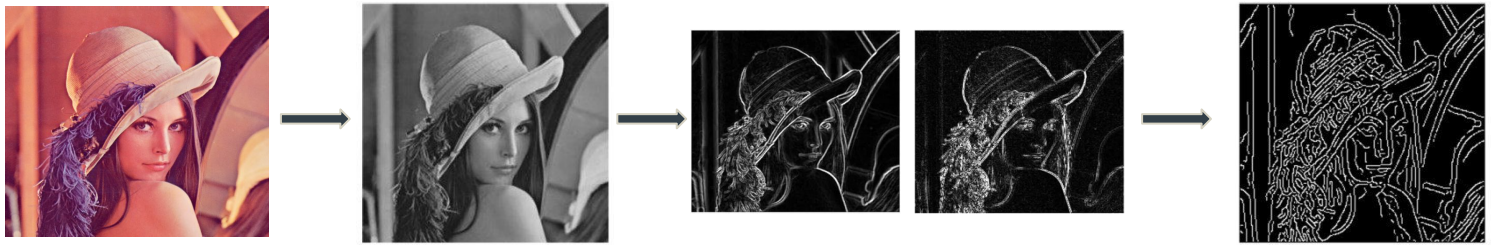
X – Direction Kernel

-1	0	1
-2	0	2
-1	0	1

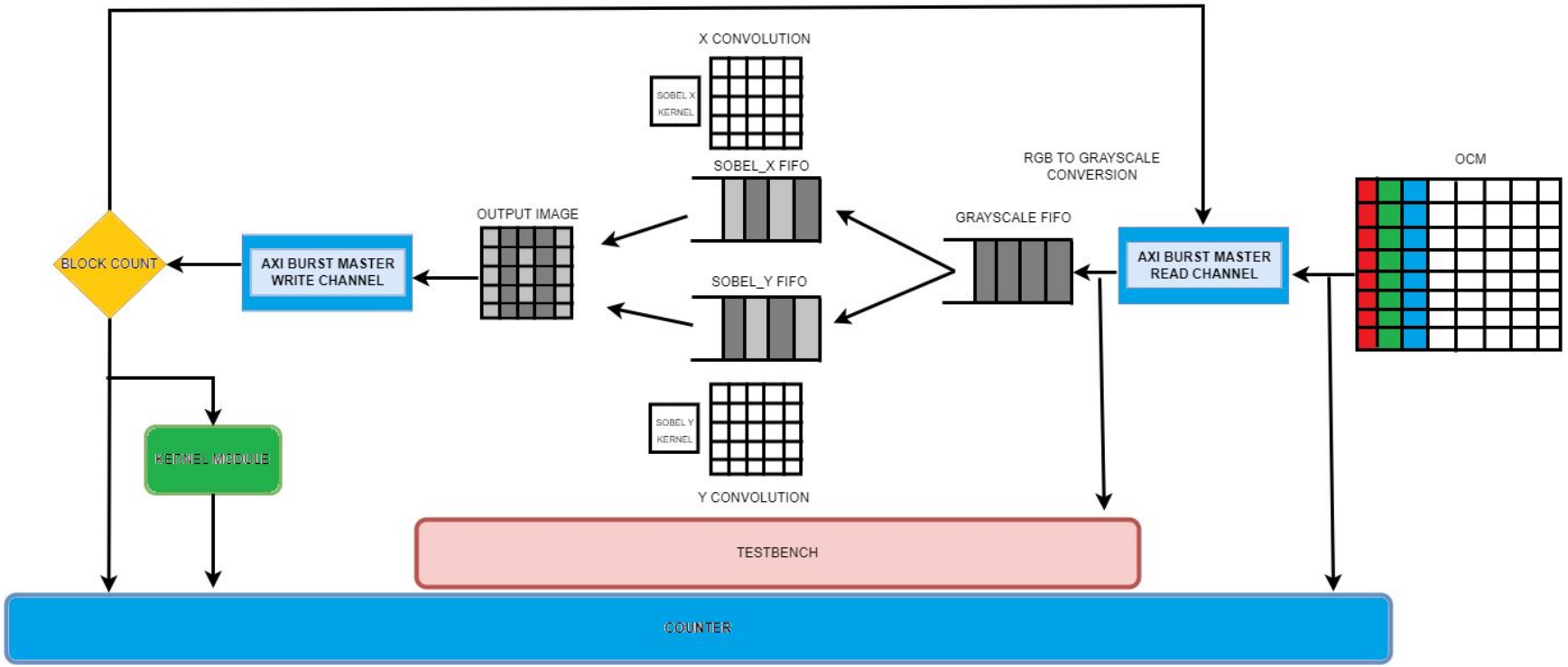
Y – Direction Kernel

-1	-2	-1
0	0	0
1	2	1

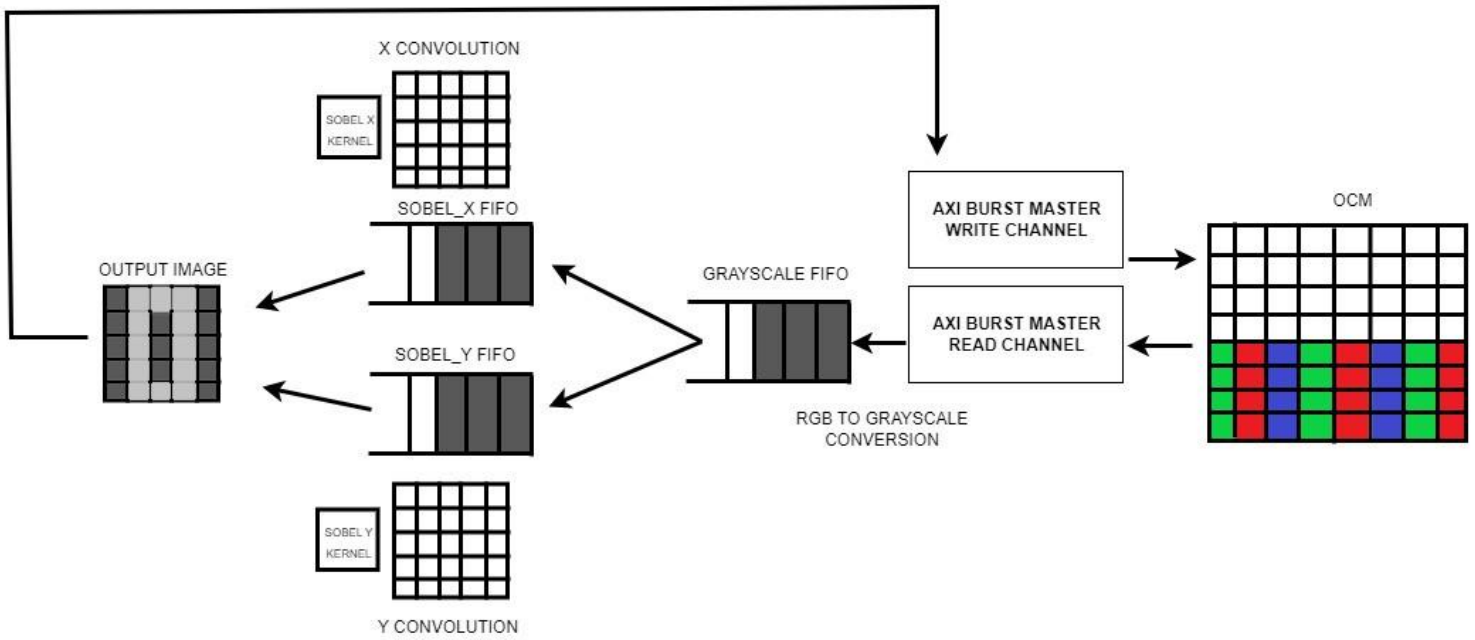
$$\mathbf{G} = \sqrt{\mathbf{G}_x{}^2 + \mathbf{G}_y{}^2}$$



Hardware Implementation Overview



- **AXI Burst Read/Write in the parallel**

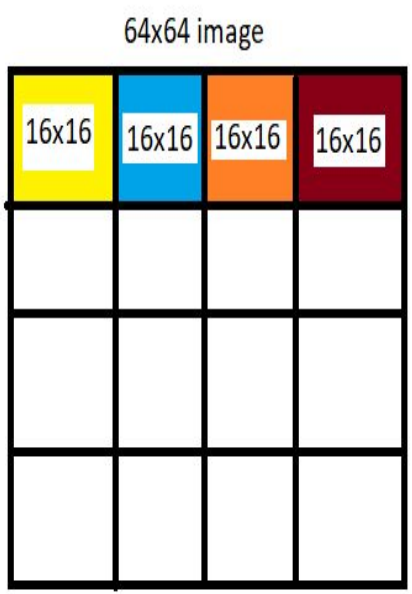


Design Optimisations

NxN image divided into 16x16 blocks

- Perform convolution operations on **smaller blocks** at at time. Reduce LUT load by using smaller fifo depths, lesser logic to store and manipulate pixels

- Taking advantage of locality in OCM by **storing image in 16x16 Blocks** instead of row-major/column major.



- **LUT Savings using mathematical optimisations**
  - Multiplication to Shift
  - Square Root
    - LUT with SQRT - 77519
    - LUT available - 70560
    - Square Root approximated from $\sqrt{(x^2 + y^2)}$ to abs(x) +abs(y).
- Use of **AXI burst master** to read and write data from OCM memory.
  - Burst length - 64
- **Parallelising Independent operations.**
  - Per pixel RGB to grayscale calculation
  - Convolution on Sobel X and Sobel Y filters

Results

Hardware generated

Software generated

Software Implementation (Optimizations)

Function	Percentage of Total Time Spent				
	O0	O1	O2	O3	O4
RGB to Gray	7.46%	12.65%	13.11%	13.95%	14.63%
Sobel X	41.88%	41.77%	40.98%	41.86%	41.46%
Sobel Y	41.23%	39.24%	37.70%	32.55%	34.14%
Contour	9.415%	6.329%	8.196%	11.62%	9.756%
Total Time (us)	462	250	226	202	225

Hardware vs Software Comparison

Image Size	Execution Time in Hardware (us)			Software (us)	Speedup
	Burst Size 64	Burst Size 1	Parallel Read/Write		
128 x 128	151.7	999.5	124.47	2170	**17.44**
64 x 64	37.93	249.85	31.37	679	**21.64**
32 x 32	9.5	62.48	8.18	281	**34.35**
16 x 16	2.37	15.62	2.36	202	**85.59**

Software run with O3 optimization level

Future Work

- Read 18x18 matrices from the OCM to improve the quality of the resulting image
- Streamline the design and improve resource utilization
- Setting up simulation environment to offset validation time is not difficult

THANK YOU