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Assignment #4

Part 1: Sobel Filter

The results of various image sizes (both squared and non-squared image sizes) were ran for the OpenCV, CPU, and GPU implementation of the Sobel Filter.

From the results, at larger image sizes, the GPU far out performs the CPU and OpenCV. GPU is 16.23x faster than CPU and 17.71x faster than the OpenCV function from a 2048x2048 image. There is better parallelization with larger data sets in the GPU compared to the CPU and OpenCV functions. The GPU is able to run multiple cores to calculate the Sobel image with much more efficiency than the CPU unrolled algorithm and OpenCV function.

The ideal grid/block sizes were 32x32 for our implementation since the execution times are faster. It is ideal to have a max number of threads in the streaming multiprocessors (SM). Since our limit is 2048 threads, the 32x32 is the most optimal since we are utilizing 1024 threads within the SM.

Using GPU @ 1024x1024 Image = 32x32 Threads and 32x32 blocks

Execution time (ms) = 26.2073
Execution time (ms) = 27.2308
Execution time (ms) = 27.1049
Execution time (ms) = 26.9143
Execution time (ms) = 24.6562
Execution time (ms) = 26.2835
Execution time (ms) = 23.3389
Execution time (ms) = 22.6419
Execution time (ms) = 25.1037

Using GPU @ 1024x1024 Image = 16x16 Thread and 64x64 blocks

Execution time (ms) = 39.1022
Execution time (ms) = 23.2307
Execution time (ms) = 22.6168
Execution time (ms) = 23.1532
Execution time (ms) = 26.009
Execution time (ms) = 26.5414
Execution time (ms) = 26.5534
Execution time (ms) = 26.8432
Execution time (ms) = 26.6392

Using GPU @ 1024x1024 Image = 8x8 Threads and 128x128 blocks

Execution time (ms) = 42.0883
Execution time (ms) = 24.1766
Execution time (ms) = 26.6643
Execution time (ms) = 25.0864
Execution time (ms) = 26.6403
Execution time (ms) = 26.6832
Execution time (ms) = 26.5511

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GPU @ 4096 x 4096

Using GPU
Execution time (ms) = 21.5259
Execution time (ms) = 21.1551
Execution time (ms) = 20.6803
Execution time (ms) = 20.254
Execution time (ms) = 20.7842
Execution time (ms) = 20.4777
Execution time (ms) = 22.9037

CPU @ 4096 x 4096

Using CPU
Execution time (ms) = 362.395
Execution time (ms) = 361.671
Execution time (ms) = 361.139
Execution time (ms) = 360.913
Execution time (ms) = 359.247
Execution time (ms) = 358.526
Execution time (ms) = 357.932

OpenCV @ 4096 x 4096

Using OpenCV
Execution time (ms) = 446.405
Execution time (ms) = 438.898
Execution time (ms) = 436.117
Execution time (ms) = 436.85
Execution time (ms) = 436.058
Execution time (ms) = 435.946
Execution time (ms) = 437.825

GPU @ 2048 x 2048

Using GPU
Execution time (ms) = 6.43117
Execution time (ms) = 6.32376
Execution time (ms) = 6.29688
Execution time (ms) = 6.18555
Execution time (ms) = 5.36325
Execution time (ms) = 5.49134
Execution time (ms) = 5.30633

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CPU @ 2048 x 2048

Using CPU
Execution time (ms) = 104.384
Execution time (ms) = 102.943
Execution time (ms) = 103.024
Execution time (ms) = 102.529
Execution time (ms) = 103.481
Execution time (ms) = 103.194
Execution time (ms) = 100.986
Execution time (ms) = 103.871

OpenCV @ 2048 x 2048

Using OpenCV
Execution time (ms) = 113.922
Execution time (ms) = 113.281
Execution time (ms) = 111.102
Execution time (ms) = 113.17
Execution time (ms) = 113.876
Execution time (ms) = 111.769
Execution time (ms) = 112.913
Execution time (ms) = 113.921

GPU @ 512 x 512

Using GPU
Execution time (ms) = 24.1407
Execution time (ms) = 15.9074
Execution time (ms) = 15.9987
Execution time (ms) = 14.5108
Execution time (ms) = 12.438
Execution time (ms) = 11.9116
Execution time (ms) = 11.8376

CPU @ 512 x 512

Using CPU
Execution time (ms) = 7.32685
Execution time (ms) = 7.14825
Execution time (ms) = 7.99167
Execution time (ms) = 6.82963
Execution time (ms) = 7.54825
Execution time (ms) = 7.53889
Execution time (ms) = 7.19396

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OpenCV @ 512 x 512

Using OpenCV
Execution time (ms) = 8.87823
Execution time (ms) = 11.1214
Execution time (ms) = 8.62905
Execution time (ms) = 9.12885
Execution time (ms) = 8.28516
Execution time (ms) = 9.28894
Execution time (ms) = 8.5478

OpenCV @ 512 x 256

Using OpenCV
Execution time (ms) = 3.94123
Execution time (ms) = 4.14427
Execution time (ms) = 4.31702
Execution time (ms) = 4.02262
Execution time (ms) = 4.33681
Execution time (ms) = 4.28476
Execution time (ms) = 4.11339

CPU @ 512 x 256

Using CPU
Execution time (ms) = 3.46553
Execution time (ms) = 3.42754
Execution time (ms) = 3.10499
Execution time (ms) = 3.5484
Execution time (ms) = 3.27436
Execution time (ms) = 3.21757
Execution time (ms) = 3.20001

GPU @ 512 x 256

Using GPU
Execution time (ms) = 7.24699
Execution time (ms) = 8.12897
Execution time (ms) = 7.53261
Execution time (ms) = 7.52036
Execution time (ms) = 7.28859
Execution time (ms) = 7.38909
Execution time (ms) = 7.51074

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OpenCV @ 256 x 512

Using OpenCV
Execution time (ms) = 4.38672
Execution time (ms) = 4.19362
Execution time (ms) = 4.11551
Execution time (ms) = 4.21417
Execution time (ms) = 4.15467
Execution time (ms) = 4.30502
Execution time (ms) = 4.23876

CPU @ 256 x 512

Using CPU
Execution time (ms) = 3.13304
Execution time (ms) = 3.5507
Execution time (ms) = 3.44486
Execution time (ms) = 3.28706
Execution time (ms) = 3.16833
Execution time (ms) = 3.15314
Execution time (ms) = 3.14623

GPU @ 256 x 512

Using GPU
Execution time (ms) = 15.9188
Execution time (ms) = 8.85356
Execution time (ms) = 10.0358
Execution time (ms) = 9.4375
Execution time (ms) = 9.73894
Execution time (ms) = 9.18146
Execution time (ms) = 9.08784

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Part2: Matrix Multiplication

Comments:
The GPU performance improves as the image size increases because of more parallel thread execution and shared memory access between threads.

Matrix Multiplication Stats

Block Size @ 16x16
IMAGE Size @ 16x16
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 16 16
Time CPU = 0.10ms, Time GPU = 0.19ms, Speedup = 0.55x, RMSE = 0.00000

Block Size @ 16x16
IMAGE Size @ 32x32
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 32 32
Time CPU = 1.16ms, Time GPU = 0.28ms, Speedup = 4.09x, RMSE = 0.00000

Block Size @ 16x16
IMAGE Size @ 64x64
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 64 64
Time CPU = 1.15ms, Time GPU = 0.26ms, Speedup = 4.37x, RMSE = 0.00000

Block Size @ 16x16
IMAGE Size @ 256x256
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 256 256
Time CPU = 27.19ms, Time GPU = 4.74ms, Speedup = 5.74x, RMSE = 0.00001

Block Size @ 16x16
IMAGE Size @ 512x512
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 512 512
Time CPU = 207.77ms, Time GPU = 34.84ms, Speedup = 5.96x, RMSE = 0.00004

Block Size @ 16x16
IMAGE Size @ 1024x1024
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 1024 1024
Time CPU = 1633.99ms, Time GPU = 100.55ms, Speedup = 16.25x, RMSE = 0.00011

Block Size @ 16x16
IMAGE Size @ 256x512
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 256 512
Time CPU = 101.02ms, Time GPU = 18.25ms, Speedup = 5.53x, RMSE = 0.00001

Block Size @ 16x16
IMAGE Size @ 512x256
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 512 256
Time CPU = 56.78ms, Time GPU = 9.20ms, Speedup = 6.17x, RMSE = 0.00004

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Block Size @ 32x32
IMAGE Size @ 16x16
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 16 16
Time CPU = 0.16ms, Time GPU = 0.26ms, Speedup = 0.62x, RMSE = 4.06680

Block Size @ 32x32
IMAGE Size @ 32x32
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 32 32
Time CPU = 0.15ms, Time GPU = 0.22ms, Speedup = 0.71x, RMSE = 0.00000
Block Size @ 32x32
IMAGE Size @ 64x64
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 64 64
Time CPU = 1.16ms, Time GPU = 0.25ms, Speedup = 4.63x, RMSE = 0.00000

Block Size @ 32x32
IMAGE Size @ 256x256
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 256 256
Time CPU = 26.80ms, Time GPU = 4.58ms, Speedup = 5.85x, RMSE = 0.00001

Block Size @ 32x32
IMAGE Size @ 512x512
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 512 512
Time CPU = 218.36ms, Time GPU = 34.03ms, Speedup = 6.42x, RMSE = 0.00004

Block Size @ 32x32
IMAGE Size @ 1024x1024
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 1024 1024
Time CPU = 1728.77ms, Time GPU = 81.58ms, Speedup = 21.19x, RMSE = 0.00011

Block Size @ 32x32
IMAGE Size @ 256x512
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 256 512
Time CPU = 103.41ms, Time GPU = 17.46ms, Speedup = 5.92x, RMSE = 0.00001

Block Size @ 32x32
IMAGE Size @ 512x256
wes237b@wes237b-jtx2:~/Documents/share_test/HW4/code/matrix$ ./mm 512 256
Time CPU = 53.97ms, Time GPU = 8.76ms, Speedup = 6.16x, RMSE = 0.00004