EEP524
Homework #2
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Questions

1)

Assume that a kernel is launched with 1000 thread blocks each of which has 512 threads. If a variable is declared as a shared memory variable, how many versions of the variable will be created through the lifetime of the execution of the kernel?

There will be 1,000 versions of the variable, or one per block. Since shared memory is shared between all threads of the same block, it doesn't matter how many threads are in each block, the number of versions of the variable will be the same as the number of blocks.

2)

For our tiled matrix-matrix multiplication kernel, if we use a 32X32 tile, what is the reduction of memory bandwidth usage for input matrices A and B?

The reduction in bandwidth usage will be 1/32 of the original usage. Each row and column stored in shared memory will be reused 32 times, reducing the global DRAM traffic by the same factor.

3)

For the tiled single-precision matrix multiplication kernel as shown in lecture, assume that the tile size is 32X32 and the system has a DRAM burst size of 128 bytes. How many DRAM bursts will be delivered to the processor as a result of loading one A-matrix tile by a thread block?

There will be 32 DRAM bursts delivered to the processor. Each single-precision value is 4 bytes, so each burst delivers 32 values, or one row of the tile. So, it will take 32 bursts to deliver the whole tile.

12b.ii)

How many warps are running? Based on the Tesla T4 hardware, can you explain this number in terms of hardware resources?

I am not using the Tesla T4 hardware, but rather a GTX 3070 on my own machine. There are 2048 warps allocated. The grid dimension is 16x16 and the block dimension is 16x16. With 32 threads per warp, there are 8 warps per block. With 16x16 blocks, there are 16x16x8=2048 total warps.

Timing Results

	Test Image 1		Test Image 2		Test Image 3		Test Image 4	
	Timer 1 (ms)	Timer 2 (ms)	Timer 1 (ms)	Timer 2 (ms)	Timer 1 (ms)	Timer 2 (ms)	Timer 1 (ms)	Timer 2 (ms)
Global Mem	9.086	0.245	35.785	0.951	86.110	1.625	1497.504	25.022
Static Mem	8.927	0.367	35.111	1.007	86.581	2.510	1499.965	40.648
Dynamic Mem	9.700	0.358	35.428	0.705	86.245	2.976	1501.708	26.906

NSight Compute Profile

Parameter	Kernel	Test Image 1	Test Image 2	Test Image 3	Test Image 4
Kernel Execution Time (seconds)	Global Memory	1.82E-06	2.14E-06	1.89E-06	1.79E-06
	Shared Memory	3.07E-06	2.75E-06	3.39E-06	2.72E-06
Kernel Instruction Intensity (Inst/Byte)	Global Memory	1.38E-03	7.18E-03	1.25E-02	1.23E-02
	Shared Memory	7.52E-03	1.52E-02	1.61E-02	4.12E-03

Appendix A: Result Images

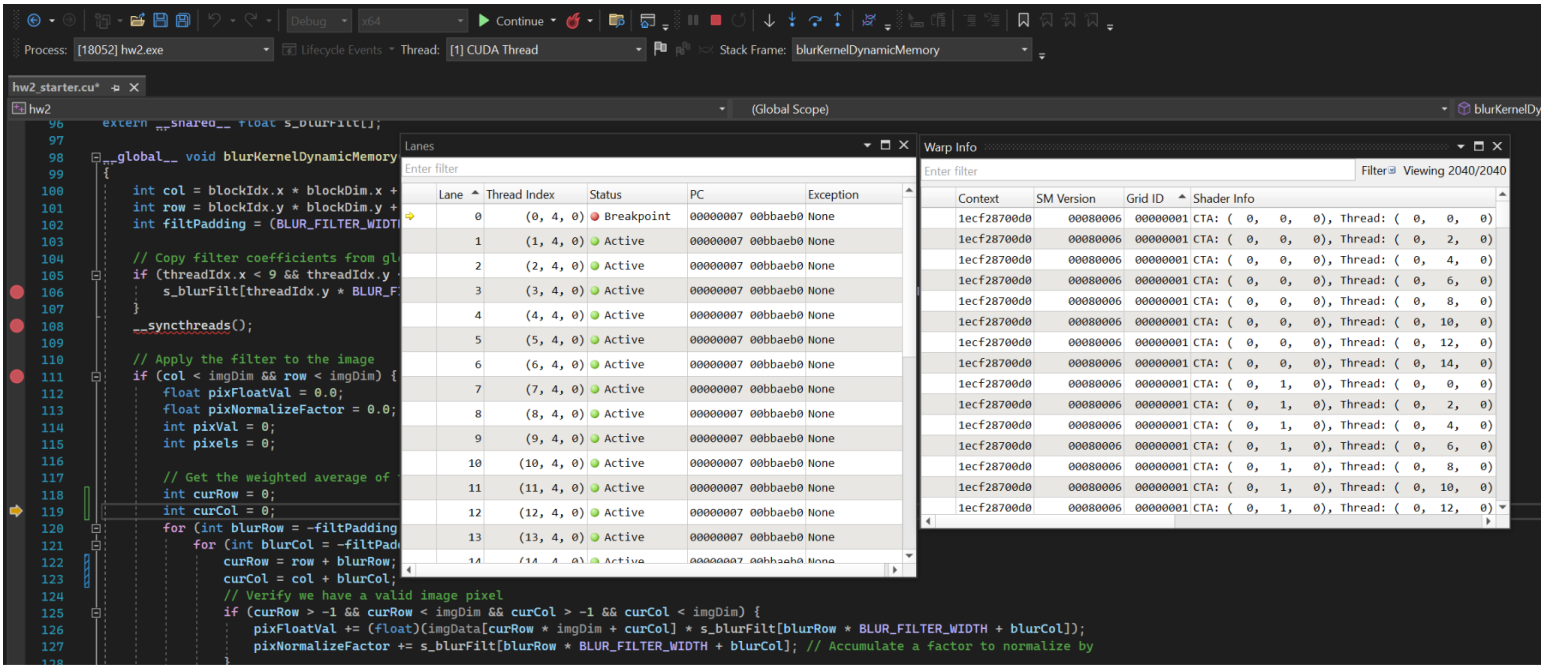
Image 1

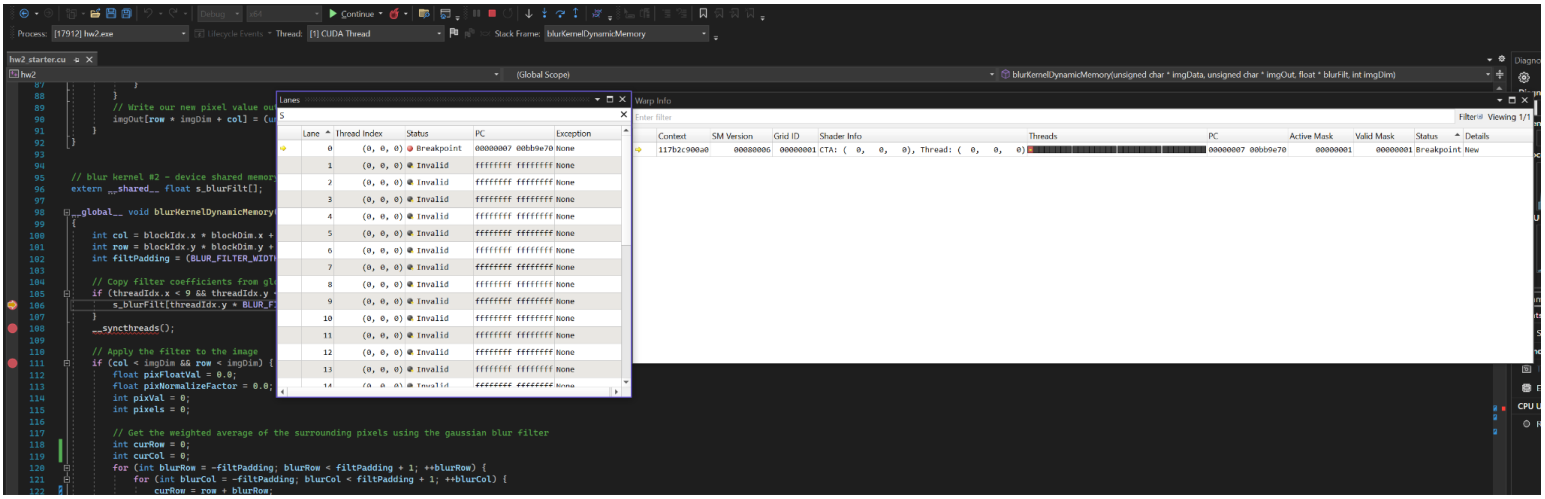
Image 2

Image 3

Image 4

Appendix B: CUDA Kernel Debug





Appendix C: NSight Metrics

Global Memory Kernel

```
[7864] image1_global.exe@127.0.0.1
  blurKernelGlobalMemory(unsigned char *, unsigned char *, float *, int, int), 2022-Oct-25 16:54:28, Context 1, Stream 7
    Section: Command line profiler metrics
    ------------------------------------------------------------------------ --------------- ------------------------------
    dram__bytes.sum                                                                   Kbyte                          21.38
    dram__sectors_read.sum                                                           sector                            668
    dram__sectors_write.sum                                                          sector                              0
    smsp__cycles_elapsed.sum                                                          cycle                        491,296
    smsp__cycles_elapsed.sum.per_second                                         cycle/nsecond                         269.35
    smsp__inst_executed.sum                                                            inst                             80
    ------------------------------------------------------------------------ --------------- ------------------------------
```

```
[7916] image2_global.exe@127.0.0.1
  blurKernelGlobalMemory(unsigned char *, unsigned char *, float *, int, int), 2022-Oct-25 17:06:17, Context 1, Stream 7
    Section: Command line profiler metrics
    ------------------------------------------------------------------------ --------------- ------------------------------
    dram__bytes.sum                                                                   Kbyte                          11.14
    dram__sectors_read.sum                                                           sector                            308
    dram__sectors_write.sum                                                          sector                             40
    smsp__cycles_elapsed.sum                                                          cycle                        577,768
    smsp__cycles_elapsed.sum.per_second                                         cycle/nsecond                         269.48
    smsp__inst_executed.sum                                                            inst                             80
    ------------------------------------------------------------------------ --------------- ------------------------------
```

```
[23020] image3_global.exe@127.0.0.1
  blurKernelGlobalMemory(unsigned char *, unsigned char *, float *, int, int), 2022-Oct-25 17:08:32, Context 1, Stream 7
    Section: Command line profiler metrics
    ------------------------------------------------------------------------ --------------- ------------------------------
    dram__bytes.sum                                                                   Kbyte                           6.40
    dram__sectors_read.sum                                                           sector                            200
    dram__sectors_write.sum                                                          sector                              0
    smsp__cycles_elapsed.sum                                                          cycle                        508,304
    smsp__cycles_elapsed.sum.per_second                                         cycle/nsecond                         269.23
    smsp__inst_executed.sum                                                            inst                             80
    ------------------------------------------------------------------------ --------------- ------------------------------
```

```
[5604] image4_global.exe@127.0.0.1
  blurKernelGlobalMemory(unsigned char *, unsigned char *, float *, int, int), 2022-Oct-25 17:11:30, Context 1, Stream 7
    Section: Command line profiler metrics
    ------------------------------------------------------------------------ --------------- ------------------------------
    dram__bytes.sum                                                                   Kbyte                           6.53
    dram__sectors_read.sum                                                           sector                            204
    dram__sectors_write.sum                                                          sector                              0
    smsp__cycles_elapsed.sum                                                          cycle                        485,816
    smsp__cycles_elapsed.sum.per_second                                         cycle/nsecond                         271.10
    smsp__inst_executed.sum                                                            inst                             80
    ------------------------------------------------------------------------ --------------- ------------------------------
```

Shared Memory Kernel

```
[7576] image1_shared.exe@127.0.0.1
  blurKernelStaticMemory(unsigned char *, unsigned char *, float *, int, int), 2022-Oct-25 17:14:08, Context 1, Stream 7
    Section: Command line profiler metrics
    ------------------------------------------------------------------------ --------------- ------------------------------
    dram__bytes.sum                                                                   Kbyte                          20.22
    dram__sectors_read.sum                                                           sector                            620
    dram__sectors_write.sum                                                          sector                             12
    smsp__cycles_elapsed.sum                                                          cycle                        831,232
    smsp__cycles_elapsed.sum.per_second                                         cycle/nsecond                         270.58
    smsp__inst_executed.sum                                                            inst                            152
    ------------------------------------------------------------------------ --------------- ------------------------------
```

```
[10932] image2_shared.exe@127.0.0.1
  blurKernelStaticMemory(unsigned char *, unsigned char *, float *, int, int), 2022-Oct-25 17:15:42, Context 1, Stream 7
    Section: Command line profiler metrics
    ------------------------------------------------------------------------ --------------- ------------------------------
    dram__bytes.sum                                                                    Kbyte                           9.98
    dram__sectors_read.sum                                                            sector                            284
    dram__sectors_write.sum                                                           sector                             28
    smsp__cycles_elapsed.sum                                                           cycle                        745,816
    smsp__cycles_elapsed.sum.per_second                                          cycle/nsecond                         271.01
    smsp__inst_executed.sum                                                             inst                            152
    ------------------------------------------------------------------------ --------------- ------------------------------
```

```
[4672] image3_shared.exe@127.0.0.1
  blurKernelStaticMemory(unsigned char *, unsigned char *, float *, int, int), 2022-Oct-25 17:16:44, Context 1, Stream 7
    Section: Command line profiler metrics
    ------------------------------------------------------------------------ --------------- ------------------------------
    dram__bytes.sum                                                                    Kbyte                           9.47
    dram__sectors_read.sum                                                            sector                            288
    dram__sectors_write.sum                                                           sector                              8
    smsp__cycles_elapsed.sum                                                           cycle                        852,472
    smsp__cycles_elapsed.sum.per_second                                          cycle/nsecond                         271.83
    smsp__inst_executed.sum                                                             inst                            152
    ------------------------------------------------------------------------ --------------- ------------------------------
```

```
[2416] image4_shared.exe@127.0.0.1
  blurKernelStaticMemory(unsigned char *, unsigned char *, float *, int, int), 2022-Oct-25 17:17:52, Context 1, Stream 7
    Section: Command line profiler metrics
    ------------------------------------------------------------------------ --------------- ------------------------------
    dram__bytes.sum                                                                    Kbyte                          36.86
    dram__sectors_read.sum                                                            sector                          1,112
    dram__sectors_write.sum                                                           sector                             40
    smsp__cycles_elapsed.sum                                                           cycle                        740,896
    smsp__cycles_elapsed.sum.per_second                                          cycle/nsecond                         272.39
    smsp__inst_executed.sum                                                             inst                            152
    ------------------------------------------------------------------------ --------------- ------------------------------
```