GPU Programming Basics

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NUCAR Laboratory

for all

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Hands-on Lab #5

Objective

- Calculate the best operating point for a simple image processing algorithm.
- Study different approaches for a convolutional filter on an image and its performance impact.

First, we need to request an interactive node, we can use the following command. Once a resource is available, you will be connected automatically into the compute node. If you are having trouble with this, go back to Lab 1 and review part 1.

```
srun --pty --export=ALL --reservation=gpu-class --partition=gpu --tasks
-per-node 1 --nodes 1 --mem=2Gb --time=02:00:00 /bin/bash # Reserve the
node
```

Copy the following folder to your scratch directory (or folder of your choosing):

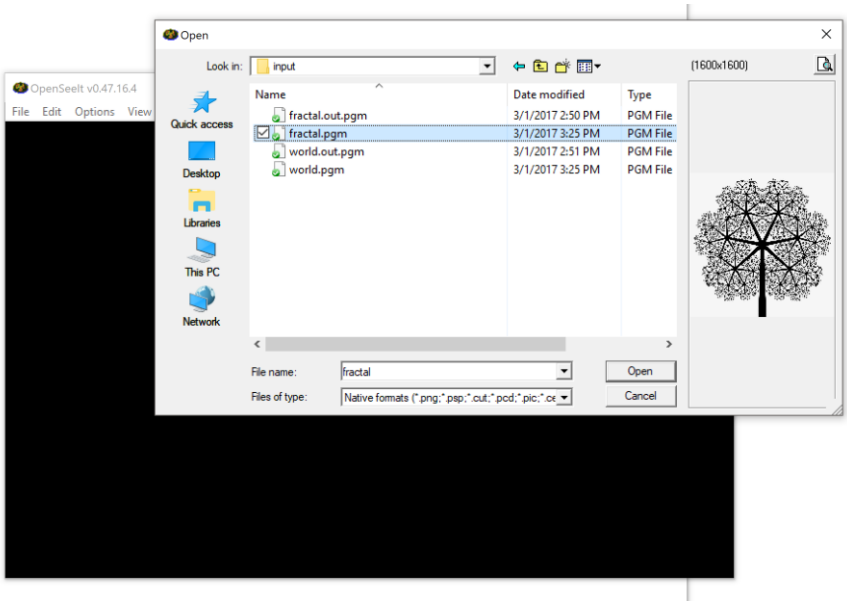
```
cd /scratch/`whoami`/GPUClass18
cp -r /scratch/gutierrez.jul/GPUClass18/HOL5/ .
cd HOL5/
```

Part 1: Brightness

In this lab, we will be modifying images. To visualize the images, we need a program that can view them. Given our connection to the server is through an ssh terminal which doesn't support image displaying, we need to copy the images back to our computer to be able to visualize them (using FileZilla for example). We are using ppm and pgm formatting which means, conventional image tools on Windows don't support this file format. To view them, we will download an open source image viewer called OpenSeeIt.

https://sourceforge.net/projects/openseeit/

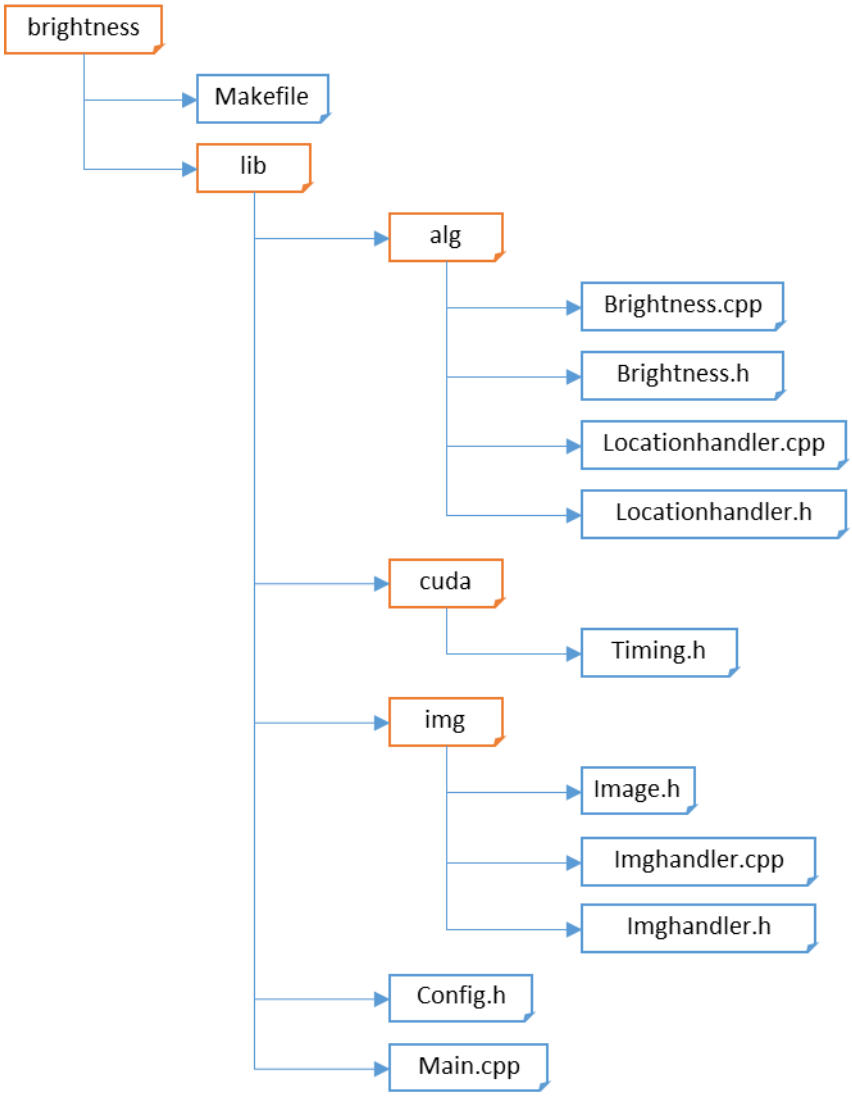
Using it is straight forward, but here is an image to demonstrate the usage:



All the files needed can be found in the following folder on the server:

```
cd ./brightness/
```

File structure:



Read the following files and understand how they work and answer the questions.

- Makefile.
  - Helps automate the process of compiling the code for the project.
  - What could you add in this file that might improve the performance of your code? Look at how the files are compiled.
- Config.h
  - This file oversees the definition of the different variables used in the execution of the code.
  - What changes in this file could significantly affect the performance of the algorithm?

- Main.cpp
  - Main function that calls the function to execute the algorithm on the gpu.
  - Why do we run a warmup function?
  - Extra: How do we read the input image and write the output image? Tip: Look at the files under the img folder.
- Brightness.cu
  - This is the function that controls the GPU and executes the kernel.
  - Look at how the kernel is executed. Grid size, block size, kernel code.
  - Understand how the brightness function and the kernel work.

First, let's run the code to see what it does. To compile the code run the following command:

```
make all
```

To run the code, submit the sbatch script:

```
sbatch exec.bash
```

It will produce an output image called:

```
result.ppm
```

Copy this file with FileZilla to your computer. Use the previous program to open the image.

To compare the input and output, open both inputs. Do you see any differences?

You can change the brightness level by using --brightness <value> in the line of the exec.bash script which executes the program. Try writing a negative value. Remember pixel values go from 0 to 255. This is an example of the input arguments to the program (Don't run it directly on the terminal).

```
./brightness --image ../input/fractal.pgm --brightness -100
```

Resubmit the script.

Your job is to find which block size performs best by modifying it on the `lib/config.h` file. Test it with the `fractal.pgm` image and the `world.pgm` separately. NOTE: Sometimes execution time might vary a lot, so doing a couple of test runs and averaging the result is encouraged (you can execute the same command multiple times inside the `exec.bash` script and then average the results).

Note: Every time you change the block size you must recompile the code using make.

- Which block size is the best one for each input?
- Could these values be different if the size of the image varies significantly?
- How do you think it affects the performance?
- Why do we use only block sizes with 2^n form?

Block Size	Kernel Execution Time (fractal)	Kernel Execution Time (world)
2		
4		
8		
16		
32		

- What optimization could be done to improve this code?

Run nvprof the same way we did for the second lab. Use the best configuration for the block size based on the smallest kernel execution time for the fractal image. MAKE SURE YOU COMPILE THE CODE AGAIN. NOTE: Also remember that we are running a warmup code which executes the same instructions. You can remove this by setting the WARMUP flag to 0 in the config file (Do it for this test). Use the nvprof.bash script.

```
sbatch nvprof.bash
```

Look at the percentages and decide, is it worth optimizing this code? If yes, where would you optimize?

Now let's look at some of the metrics by looking at the output from the nvprof script where we measured the metrics. You can identify this output with the line METRICS.

Open the output file and look at the results, is there anywhere you think we could further improve the kernel?

Extra: ONLY IF YOU FINISHED THE NEXT PART AS WELL. Test one of your ideas to improve the performance. Did it work?

Part 2: Sobel Algorithm

As shown in class, Sobel algorithm is an edge detection algorithm. It applies a convolution filter on the image and outputs another image highlighting the pixels that are located on borders based on a certain threshold.

In this part, we are going to analyze different implementations of the same algorithm and compare their performance. The structure of the folders is identical to the brightness algorithm we saw on the previous part. Compilation and execution are the same as well.

To compile the codes run the following command inside their respective folders:

```
make all
```

To run the code, use the exec.bash scripts:

```
./sobel --image ../../input/fractal.pgm
```

It will produce an output image called:

```
result.ppm
```

We have 5 different versions of the code:

1. Basic
2. Opt1
3. Opt2
4. Opt3
5. Opt4

"Basic" is a naïve implementation of the Sobel algorithm (we saw in class). The other versions have different improvements done to the code to try and achieve better performance. The idea is to fill out the following table with the execution times by running each code on both inputs (no need to change the block size, though this might give you an idea).

Version	**Kernel Execution Time (fractal)**	**Total Execution Time (fractal)**	**Kernel Execution Time (world)**	**Total Execution Time (world)**
Basic				
Opt1				
Opt2				
Opt3				
Opt4				

- Note: To understand what they're doing, look at the sobel.cu files inside the alg folder.

After recollecting the data, answer these questions:

- Explain what each optimization version does.
- Which one works best and why?
- Which one is the easiest to implement?
- Extra: Choose one of the optimized versions and run nvprof. What metrics change compared to the basic implementation?
- Extra: Change the algorithm by changing the filter to something you want and don't use a threshold for the value. How does the output look?

Note: Please remember to ask as many questions as possible. I am here to help as much as we can.