# Lab3 CUDA Basic

*Oct, 2024 Parallel Programming*

# Overview

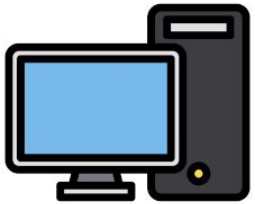
- Platform guide
- Tools
- Assignment

# Platform Guide

# The GPU Cluster

- Host: **`apollo-gpu.cs.nthu.edu.tw`**
- Account & Password: Check your email

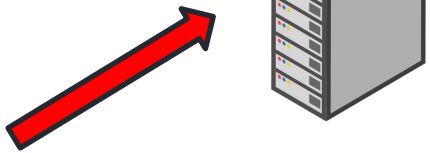
Client
(Your computer)

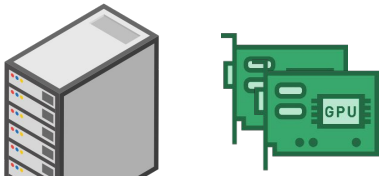


Frontend Server
without GPU
(apollo-login)

ssh apollo-gpu.cs.nthu.edu.tw

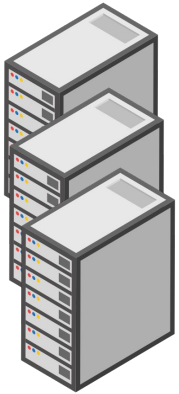
ssh nv-test

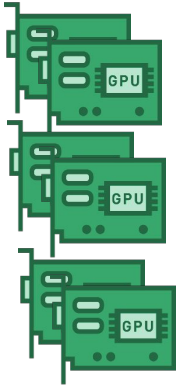




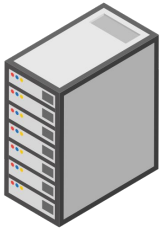

srun -p nvidia

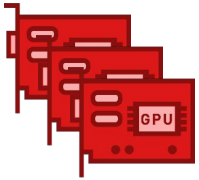
nv-vm[1-7]





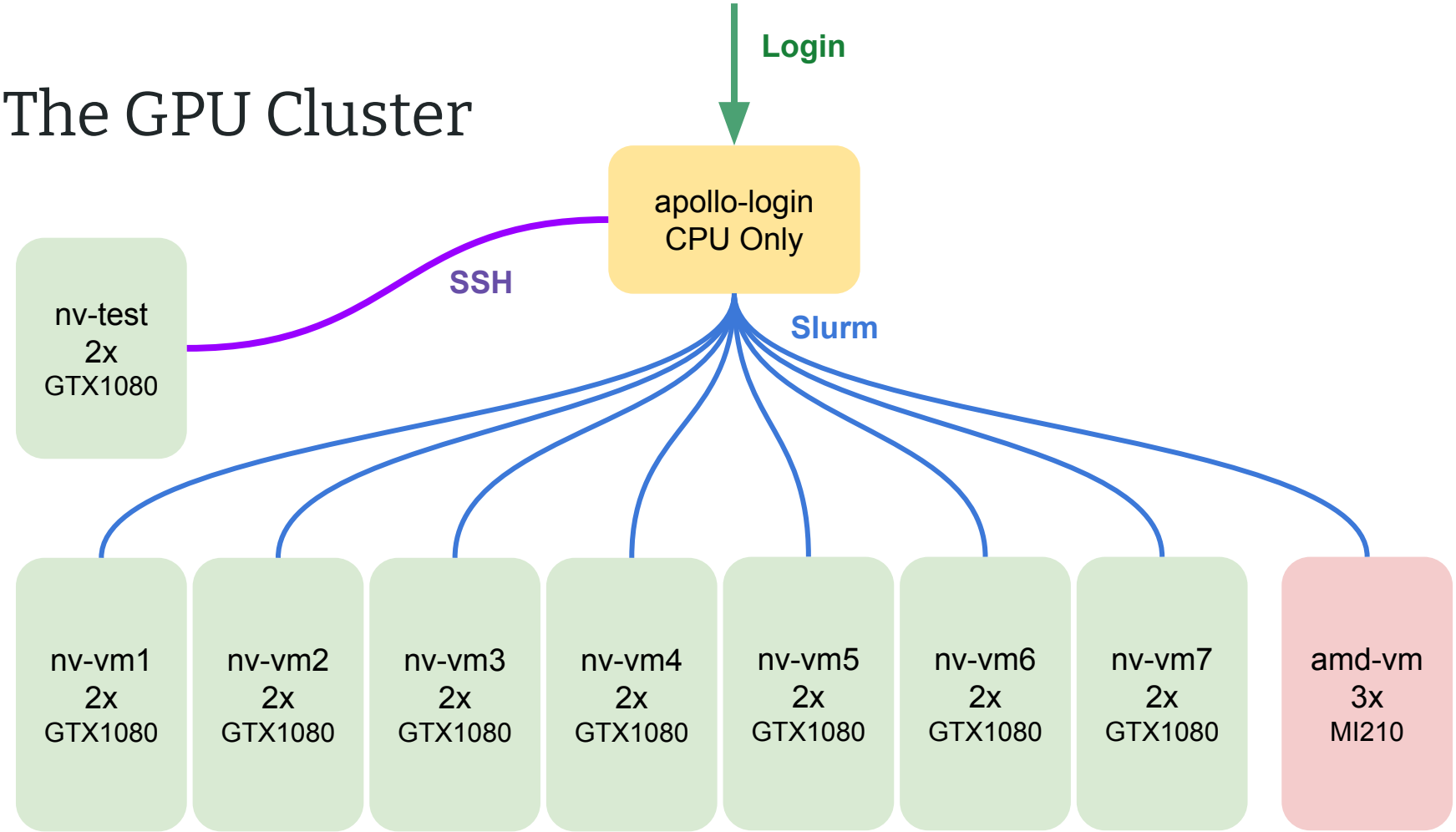

srun -p amd
amd-vm






**8 NVIDIA GPU VMs: each with 2x GTX 1080 GPUs**
**1 AMD GPU VM: with 3x AMD Instinct MI210 GPUs**

# The GPU Cluster



# Job Scheduler

- Slurm
- Partitions: **nvidia** for NVIDIA GPUs (default), **amd** for AMD GPUs

```
yi@apollo-login:~$ sinfo
PARTITION   AVAIL  TIMELIMIT  NODES  STATE NODELIST
nvidia*        up       5:00      7   idle apollo-nv-vm[1-7]
amd            up       5:00      1   idle apollo-amd-vm
```

- Limitations
  - 1GPU or 2 GPUs per Job
  - 2 CPU cores per GPU (i.e. 1 GPU -> 2 cores, 2 GPUs -> 4 cores)
  - 2 Jobs per User
  - Wall time: 5 minutes

# Instructions to compile a CUDA program

- Compile
  - `nvcc -arch=sm_61 [other options] <inputfile>`
  - e.g.,

    ```
    nvcc cuda_code.cu -o cuda_executable
    ```
  - `sm_61` is Compute Capability 6.1, which is what GTX 1080 supports
    - If you are using your own GPU, find your GPU's compute capability here

- If you have a Makefile, simply
  - `make`

# Instructions to run a CUDA program

- apollo-nv-test
  - **`ssh apollo-nv-test`** or **`ssh nv-test`**
  - If you want to specify which GPU to use.
    - `export CUDA_VISIBLE_DEVICES=<gpu id>`
    - eg. `export CUDA_VISIBLE_DEVICES=1`
    - eg. `export CUDA_VISIBLE_DEVICES=0,1`

- apollo-nv-vm[1-7]
  - Slurm
  - Access gpus with the flag: `--gres=gpu:<number of gpu>`
    - eg. `srun -n 1 --gres=gpu:1 ./executable`
    - eg. `srun -n 1 --gres=gpu:2 ./executable`
  - If two GPUs are requested, they will be on the same node.

# Practice

- In this practice, try to run the **`deviceQuery`**
- Steps:
  - `cp -r /home/pp24/share/deviceQuery $HOME`
  - `cd $HOME/deviceQuery`
  - `nvcc deviceQuery.cpp -o deviceQuery`
- Run it
  - on apollo-nv-test
  - with Slurm scheduler on apollo-nv-vm[1-7]
- How many CUDA cores on NVIDIA GTX 1080?

# Tools

# nvidia-smi

- NVIDIA System Management Interface program
- You can query details about
  - gpu type
  - gpu utilization
  - memory usage
  - temperature
  - clock rate
  - ...

# nvidia-smi example

```
# michael1017 @ hades02 in ~ [15:08:34]
$ nvidia-smi
Thu Nov 12 15:08:36 2020
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 450.57       Driver Version: 450.57       CUDA Version: 11.0     |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  GeForce GTX 1080    On   | 00000000:4B:00.0 Off |                  N/A |
|  0%   37C    P8     7W / 200W |      1MiB /  8119MiB |      0%      Default |
|                               |                      |                  N/A |
+-------------------------------+----------------------+----------------------+
|   1  GeForce GTX 1080    On   | 00000000:4D:00.0 Off |                  N/A |
|  0%   44C    P8    14W / 200W |      1MiB /  8117MiB |      0%      Default |
|                               |                      |                  N/A |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
|  No running processes found                                                 |
+-----------------------------------------------------------------------------+
```

# cuda-memcheck

- This tool checks memory errors of your program, and it also reports hardware exceptions encountered by the GPU. These errors may not cause program to crash, but they could result in unexpected program behavior and memory misusage.
- Error types
  - cuda-memcheck

# cuda-memcheck

```
cudaFree(device_t);
cudaFree(device_t); // free an address twice, error
```

```
[mewtwo@hades02 HW4_cuda_sobel]$ cuda-memcheck ./sobel input/candy.bmp out.bmp
========= CUDA-MEMCHECK
========= Program hit cudaErrorInvalidDevicePointer (error 17) due to "invalid device pointer" on CUDA API call to cudaFre
e.
=========     Saved host backtrace up to driver entry point at error
=========     Host Frame:/usr/lib64/nvidia/libcuda.so.1 [0x32f6a3]
=========     Host Frame:./sobel [0x454c0]
=========     Host Frame:./sobel [0x356f]
=========     Host Frame:/usr/lib64/libc.so.6 (__libc_start_main + 0xf5) [0x21b35]
=========     Host Frame:./sobel [0x36ff]
=========
========= ERROR SUMMARY: 1 error
```

# cuda-gdb

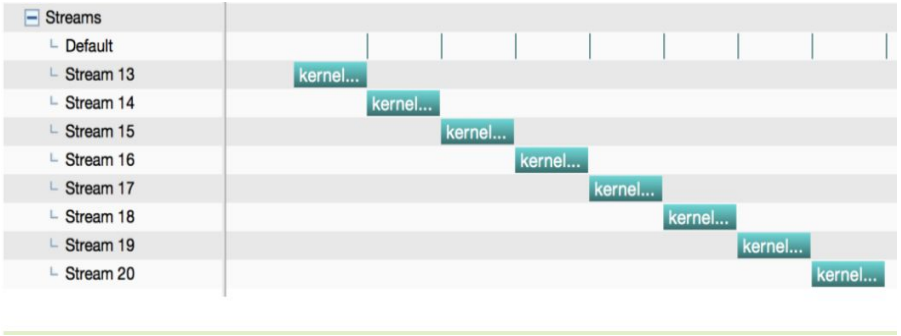
- cuda-gdb tutorial

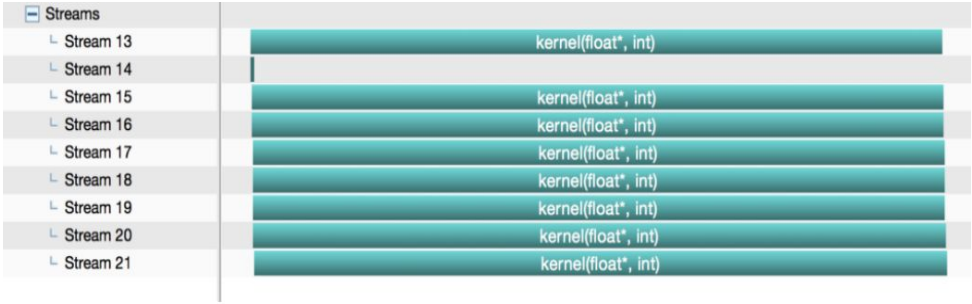
# nvprof

- nvprof  provide you feedback about how to optimize CUDA programs
  - `nvprof <CUDA executable>`
  - `-o <FILE>` to save result to a file
  - `-i <FILE>` to read result from a file

# nvvp

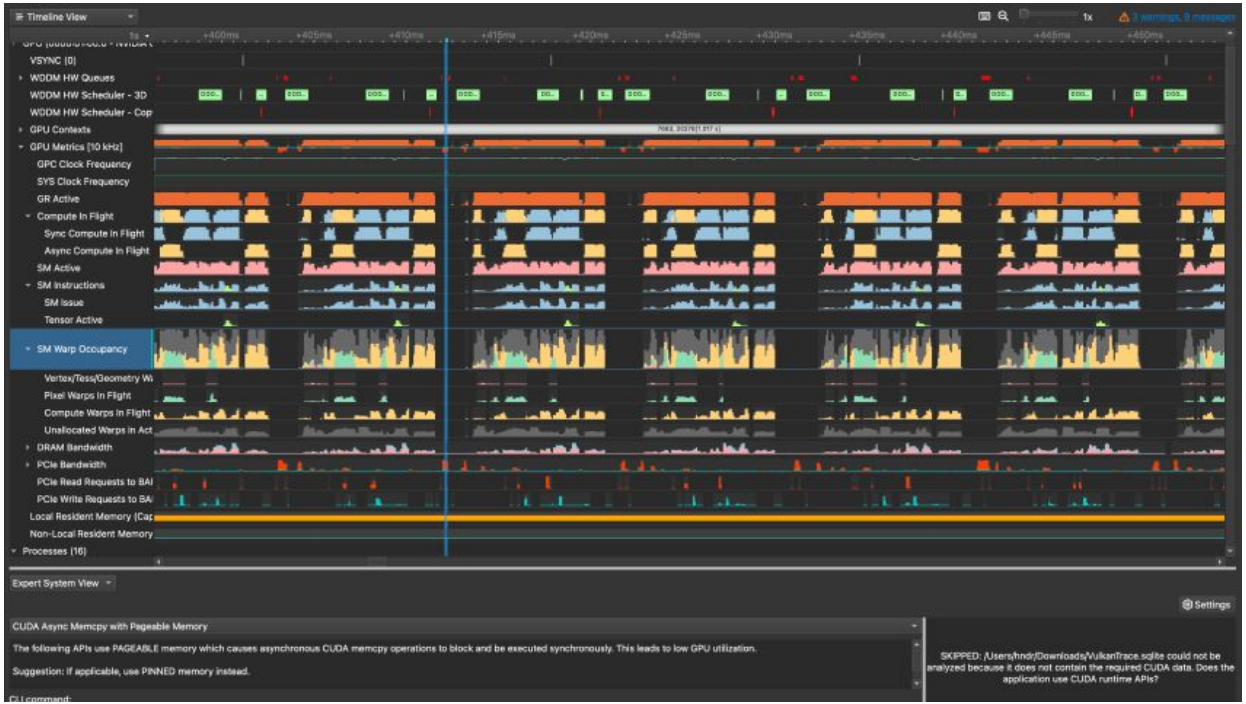
- [nvvp-tutorial]
- GUI version of nvprof
- Useful for the stream optimization
  - Timeline




*nvvp is useful for checking the concurrency of stream*

# NSight Systems (nsys)

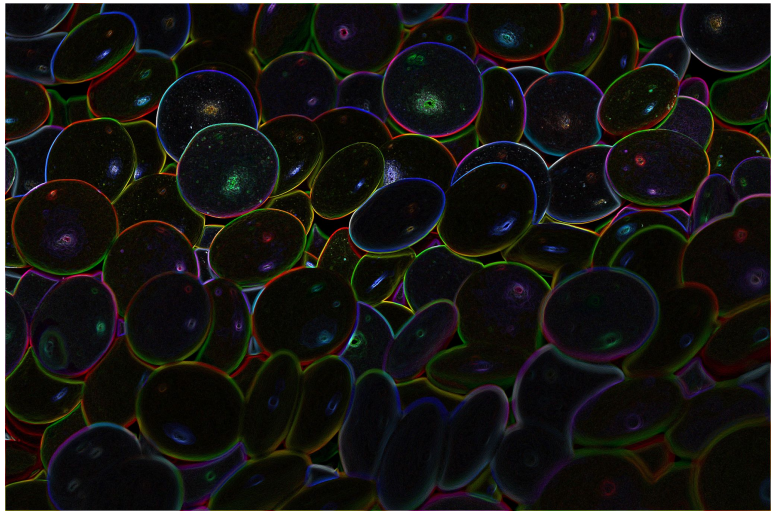



- `nsys profile` **`-t cuda`** `...`

# Lab3 Assignment

# Problem Description

- Edge Detection: Identifying points in a digital image at which the image brightness changes sharply



# Sobel Operator

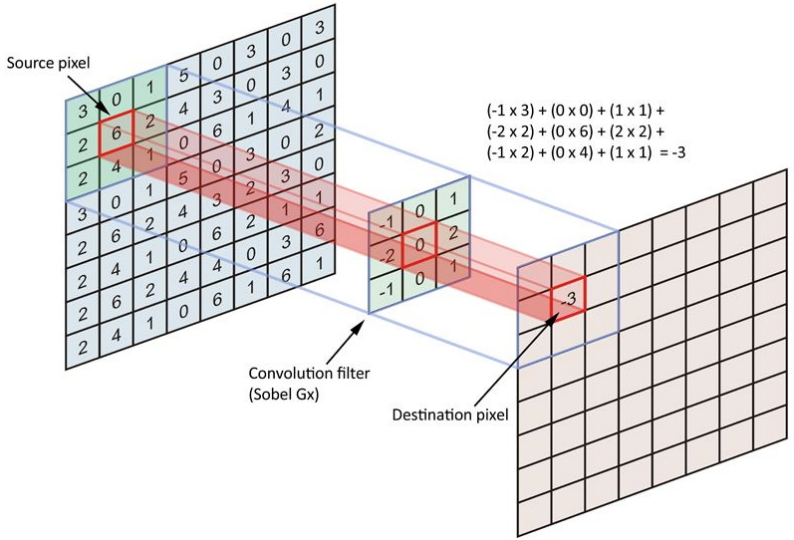
- Used in image processing and computer vision, particularly within **edge detection algorithms**.
- Uses two **3x3 filter matrix gx, gy** which are **convolved with the original image** to calculate approximations of the derivatives - one for horizontal changes, and one for vertical.
- In this lab, we use **5x5 kernels**

$$g_x = \begin{pmatrix} -1 & -2 & 0 & 2 & 1 \\ -4 & -8 & 0 & 8 & 4 \\ -6 & -12 & 0 & 6 & 12 \\ -4 & -8 & 0 & 8 & 4 \\ -1 & -2 & 0 & 2 & 1 \end{pmatrix},$$

$$g_y = \begin{pmatrix} -1 & -4 & -6 & -4 & -1 \\ -2 & -8 & -12 & -8 & -2 \\ 0 & 0 & 0 & 0 & 0 \\ 2 & 8 & 12 & 8 & 2 \\ 1 & 4 & 6 & 4 & 1 \end{pmatrix}$$

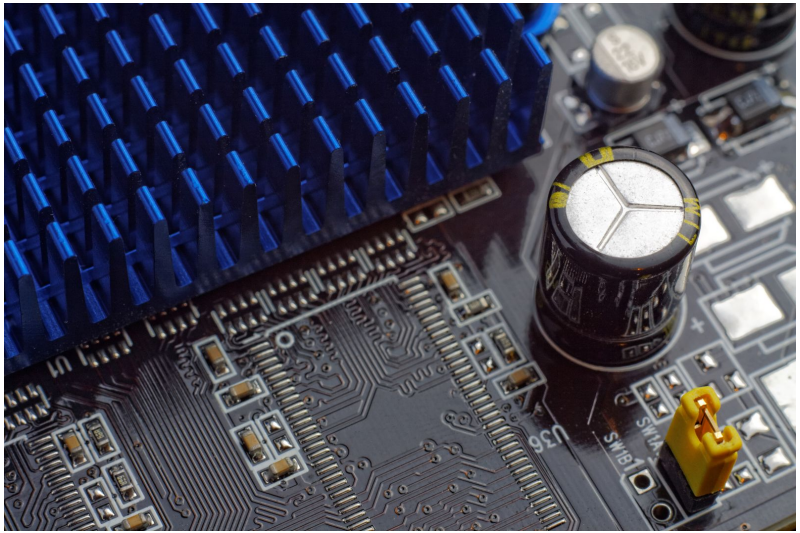
# Convolution Calculation

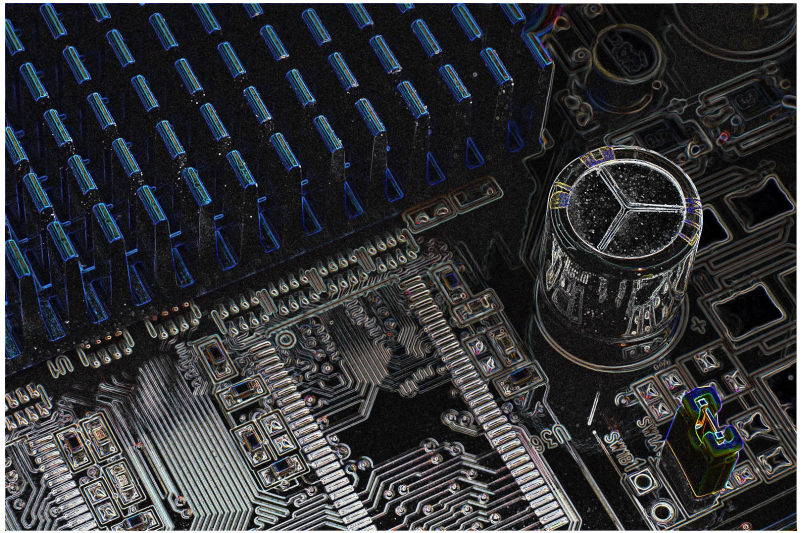
- Iterate through the width and height of the image
- For each pixel, multiply the filter matrix with original image element-wisely and sum them up.




Credit: https://soubhihadri.medium.com/image-processing-best-practices-c-part-2-c0988b2d3e0c

# Sample Result





# Preparation

- TA provided CPU version, Makefile, and hint
- Files are located at `/home/pp24/share/lab-sobel`
- Please do not copy the testcases
- `sobel.cu` is cpu version(you need to rewrite it with cuda!)
- Follow hints
- After you finish the code using CUDA, try it on AMD GPU

# Workflow

1. cp -r /home/pp24/share/lab-sobel ~/lab_sobel
2. module load rocm cuda
3. Finish the hints
4. Compile the program : make sobel
5. Run the program : srun --gres=gpu:1 ./sobel testcases/candy.png candy.out.png
6. Check the diff : png-diff testcases/candy.out.png candy.out.png
7. Judge: lab-sobel-judge
8. Scoreboard: sobel

# Workflow for AMD GPU

We ask you to test your code on AMD GPU as well.

No need to rewrite the code, just use “Hipify”

1. `module load rocm cuda`
2. Hipify your CUDA code: `hipify-clang sobel.cu`
   Generates `sobel.cu.hip`
3. Inspect the code and learn how HIP works
4. Rename the file to sobel.hip
5. Compile the program
   `make sobel-amd`
6. Run : srun -p amd --gres=gpu:1 ./sobel-amd testcases/candy.png candy.out.png
7. Judge: lab-sobel-amd-judge
8. Scoreboard: sobel-amd

# How to run

- apollo-nv-test
  - `./sobel <input> <output>`
  - `CUDA_VISIBLE_DEVICES=0 ./sobel <input> <output>`
- apollo-nv-vm[1-7]
  - `srun -n 1 --gres=gpu:1 ./sobel <input> <output>`
- apollo-amd-vm
  - `srun -p amd -n 1 --gres=gpu:1 ./sobel-hip <input> <output>`

# Check the correctness

- `png-diff <result_file> <answer_file>`
  - It verifies the correctness of your output result
  - `result_file` is the output file from your CUDA program.
  - `answer_file` is the provided file for correctness checking.
    - If your input_file is "`~/lab_sobel/testcases/candy.png`", your answer_file is "`~/lab_sobel/testcases/candy.out.png`"

```
[kswang@hades02 lab]$ png-diff testcases/candy.out.png test.png
ok, 100.00% 🙂
```

  - Your code is correct if you see "`ok, 100.00%`"

# Hints

- Malloc memory on GPU
- Copy the original image to GPU
- Put filter matrix on device memory (or declare it on device)
- Parallelize the sobel computing
- Copy the results from device to host
- Free unused address

# Submission

- Judge will execute your code with single process, single GPU
- Submit your code and Makefile (optional) to eeclass before 10/31 23:59
- Use lab-sobel and lab-sobel-amd to judge
- Get started as soon as possible to avoid heavy queueing delay

- sobel.cu
- sobel.hip
- Makefile (Optional)