HPC Programming Project - 2023/2024

This project has to be done during the week 45 (from 4/11 to 12/11).

1. Main objective

This project concerns **image contrast enhancement** using some *histogram equalization* techniques. During this project, you have to implement various methods on the GPU to solve this problem, using the following techniques :

- HE : classical Histogram Equalization (see google or old labwork 4).
- AHE : Adjusted Histogram Equalization (see [1]).
- WHE : Weighted Histogram Equalization (see [1]).
- EIHE : (see [2]).
- MMSICHE : (see [3]).
- CLAHE : Contrast Local Adaptive Histogram Equalization (see [4] or google).
- ACLAHE : Automatic Contrast Local Adaptive Histogram Equalization (see [4]).

1.1. Metrics

To study the efficiency of the algorithms, you will use two different metrics:

- AME which is the sum of the absolute value of the difference per pixel. This is a *reduction* made from the transform of two images. Easy to do onto Cuda.
- Entropy (see [1]) : it relies on the global histogram of the image.

1.2. Atomic operations

The histogram's calculation requires the usage of **atomic operations**. The documentation can be found here. You will need the `numba.cuda.atomic.add(array, idx, value)` to add one to the histogram at position V, where V is the value of the pixel.

Notice that atomic operations are more efficient using the shared memory... You **must** use shared memory to compute local histogram, that will be merged into the global one with a final `numba.cuda.atomic.add(array, idx, value)` per thread. This means that the kernel that computes that should contains exactly `L` threads for images having `L` values (in practice, 256).

2. Organization

This is a proposed planning.

- Day 1:
  - Create a `Colaboratory` file, import `Pilow` for image manipulation, add some images from Internet (permanent link) or copy them directly in the Jupiter file.
  - Add a first kernel to extract the Value (*i.e.* the maximum of the red/green/blue component) of each pixel.
  - Add a second kernel to transform an image with a given value (using the transformation RGB->HSV->RGB).

    - Then add the first algorithm (HE) and the metrics.
- Day 2:
    - Starts the report.
    - Add the AHE method, complete the report.
    - Add the WHE method, complete the report.
- Day 3:
    - Add the EIHE method.
    - Complete the report.
- Day 4:
    - Add the MMSICHE method.
    - Complete the report.
- Day 5:
    - Add the CLAHE method.
    - Complete the report.
- Day 6:
    - Add the ACLAHE method.
    - Complete the report.
- Day 7:
    - Check your report, correct last bug, and send me the email before 12pm!

3. Expected work

Your work must be sent by email including the following files.

1. A Colab file containing the different algorithms in a first part, then the metrics, and some example of usage. The image should be included, or downloaded from Internet with permanent links.
2. A short report that recaps your work, and the result obtained onto different images for the different algorithm, including the metric and the computation times.

The email is expected to be received the **Sunday 12 November, before 12pm**. Any delay is not allowed. If you miss the delay, then 0 mark will be automatically given.

4. Bibliography

[1] T. Arici, S. Dikbas, and Y. Altunbasak, **A histogram modification framework and its application for image contrast enhancement**, IEEE Trans. Image Process., vol. 18, no. 9, pp. 1921–1935, Sep. 2009.

[2] K. Singh and R. Kapoor, **Image enhancement using exposure based sub-image histogram equalization**, Pattern Recognition Letters, vol. 36, no. 1, pp. 10–14, Jan. 2014.

[3] K. Singh and R. Kapoor, **Image enhancement via median-mean based sub-image-clipped histogram equalization**, Opt.-Int. J. Light Electron Opt., vol. 125, no. 17, pp. 4646–4651, Sep. 2014.

[4] Chang, Y., Jung, C., Ke, P., Song, H., & Hwang, J. (2018). Automatic Contrast-Limited Adaptive Histogram Equalization With Dual Gamma Correction. IEEE Access, 6, 11782-11792.