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CUDA PROJECT REPORT

Sobel Filter

Lien Colab : Sobel_Filter_CUDA_KHENE_Soraya

Lien Dataset : dataset

Scope :

A **filter** in image processing is an operation applied to an image to extract specific features. One common use of filters is edge detection, which highlights the boundaries of objects within an image by identifying regions with a sudden change in intensity (brightness).
Among the many filters used for edge detection, the **Sobel filter** is widely recognized.

How does it work :

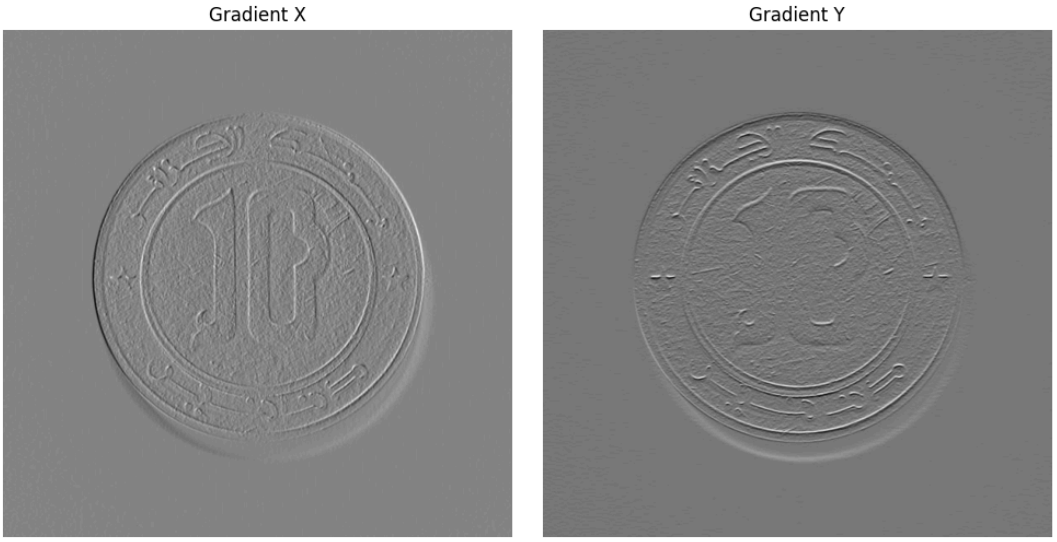
Inputs:

1. **Grayscale Image**: An image of dimensions x×y, represented in grayscale.
2. **Kernels**: Both are usually 3×3 matrices.
    - **Sobel_x_kernel**: Detects vertical edges.
    - **Sobel_y_kernel**: Detects horizontal edges.

Convolution:

Perform a **convolution operation** between the image and each kernel:

1. Convolution of the image with sobel_x_kernel : this is performed to detect edges in horizontal direction resulting Horizontal gradient image Gx
2. Convolution of the image with sobel_y_kernel : this is performed to detect edges in vertical direction resulting Vertical gradient image Gy



Gradient Magnitude Calculation: For each pixel, calculate the gradient magnitude G using the formula: $\sqrt{Gx^2 + Gy^2}$

Thresholding (optional): Use a **threshold** (value to be fixed experimentally) to decide the edge strength. For each pixel in G:

- If pixel value > threshold, set pixel value to **min(magnitude, 255)**.
- Otherwise, set the pixel value to **0** (black, no edge).

Output: The final output is a binary image highlighting the edges detected by the Sobel filter.

when threshold = 120	when threshold = 200
	

Dataset :

I've created a dataset containing 12 images of different objects, including glass, flowers, apples, coins..... The images have varying sizes, with the largest dimension being 2250x1500 pixels and smallest 612x612 pixels.

Sobel Filter on CPU :

I've used the predefined python function from the opencv library.
I tried to do it from scratch, but it was really slow.

Sobel Filter on GPU :

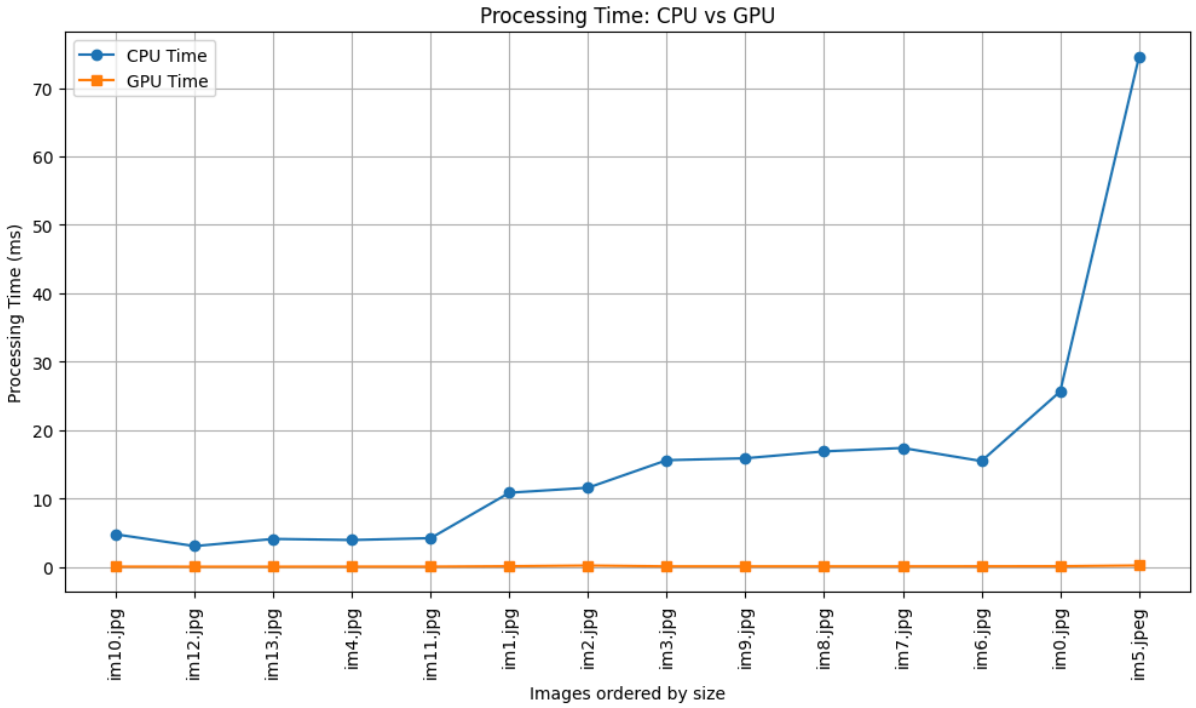
To achieve parallelism, the image is divided into **blocks of threads**, and each thread is responsible for processing a single pixel, ensuring simultaneous computation of edge detection across the entire image.

Workflow

1. **Initialization**: The host function loads the input image and allocates memory on both the CPU and GPU.
2. **Data Transfer**: The input image data is copied from the CPU memory to the GPU memory.

3. **Kernel Launch**: The Sobel filter kernel is launched, with the grid and block dimensions specified to cover all pixels in the image.
4. **Parallel Processing**: Each thread on the GPU executes the kernel function, calculating the magnitude for its assigned pixel, and applying threshold.
5. **Synchronization**: The CPU waits for the GPU to finish processing before continuing.
6. **Data Retrieval**: The processed image data, containing the magnitudes, is copied from the GPU memory back to the CPU memory.
7. **Output**: The host function saves the processed image to a file.

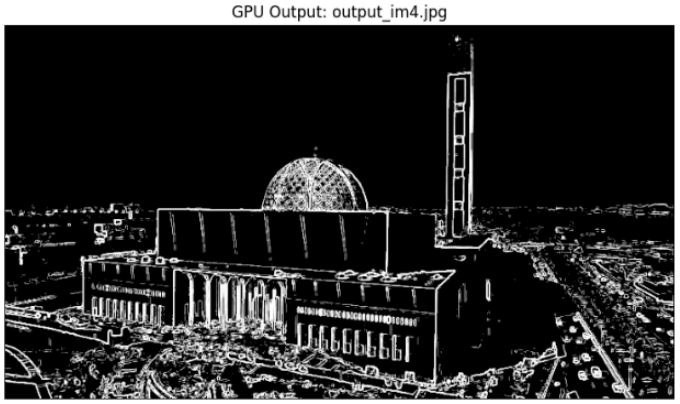
CPU vs GPU :



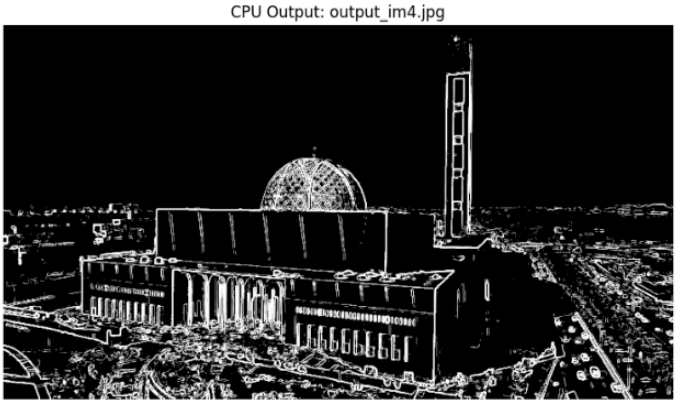
- The **CPU** processing times are consistently **higher** compared to the GPU
- The **CPU** processing time **increases** as the image size grows.
- The **GPU** processing time remains **nearly constant** across all images, demonstrating its ability to handle tasks efficiently regardless of image complexity.
- The **GPU's** performance indicates **better scalability** for large images compared to the CPU.

Examples :

GPU Output: output_im4.jpg

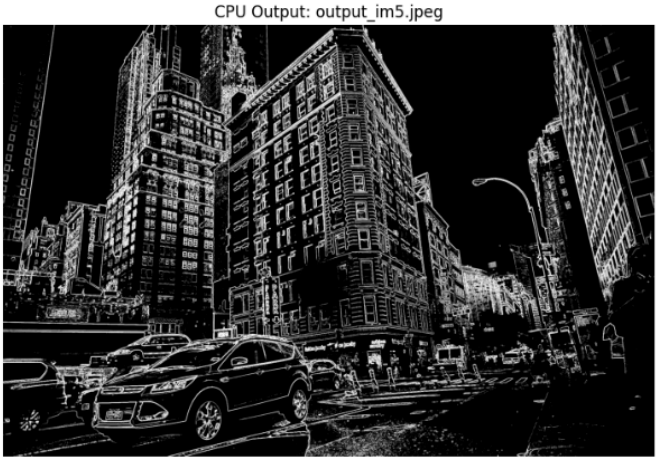


CPU Output: output_im4.jpg



GPU Output: output_im5.jpeg

CPU Output: output_im5.jpeg



GPU Output: output_im9.jpg

CPU Output: output_im9.jpg