

```
!apt-get update
!apt-get install -y libopencv-dev pkg-config
```

Show hidden output

```
!pkg-config --modversion opencv4
```

```
4.5.4
```

```
from google.colab import files
files.upload()
```

Show hidden output

```
!ls
```

```
input.jpg  sample_data
```

```
%writefile grayscale.cu
#include <opencv2/opencv.hpp>
#include <cuda_runtime.h>
#include <iostream>
#include <chrono>

using namespace std;
using namespace cv;

/* ===== CUDA KERNEL ===== */
__global__ void grayscaleKernel(unsigned char* input,
                                unsigned char* output,
                                int width, int height)
{
    int idx = blockIdx.x * blockDim.x + threadIdx.x;

    if (idx < width * height)
    {
        int i = idx * 3; // BGR image
        unsigned char b = input[i];
        unsigned char g = input[i + 1];
        unsigned char r = input[i + 2];

        output[idx] = (r + g + b) / 3;
    }
}

/* ===== CPU FUNCTION ===== */
void grayscaleCPU(Mat& input, Mat& output)
{
    for (int y = 0; y < input.rows; y++)
        for (int x = 0; x < input.cols; x++)
        {
            Vec3b p = input.at<Vec3b>(y, x);
            output.at<uchar>(y, x) =
                (p[0] + p[1] + p[2]) / 3;
        }
}

int main()
{
    Mat img = imread("input.jpg");
    if (img.empty())
    {
        cout << "Image not found!" << endl;
        return -1;
    }

    int width = img.cols;
    int height = img.rows;

    Mat grayCPU(height, width, CV_8UC1);
    Mat grayGPU(height, width, CV_8UC1);
```

```

// ... grayGPU(height, width, cv_8UC1);

size_t imgSize = width * height * 3;
size_t graySize = width * height;

unsigned char *d_input, *d_output;
unsigned char *h_output = new unsigned char[graySize];

cudaMalloc(&d_input, imgSize);
cudaMalloc(&d_output, graySize);

cudaMemcpy(d_input, img.data, imgSize, cudaMemcpyHostToDevice);

/* ----- CPU TIME ----- */
auto cpuStart = chrono::high_resolution_clock::now();
grayscaleCPU(img, grayCPU);
auto cpuEnd = chrono::high_resolution_clock::now();

/* ----- GPU TIME ----- */
cudaEvent_t start, stop;
cudaEventCreate(&start);
cudaEventCreate(&stop);

cudaEventRecord(start);

int threads = 256;
int blocks = (width * height + threads - 1) / threads;
grayscaleKernel<<<blocks, threads>>>(d_input, d_output, width, height);

cudaEventRecord(stop);
cudaEventSynchronize(stop);

cudaMemcpy(h_output, d_output, graySize, cudaMemcpyDeviceToHost);
memcpy(grayGPU.data, h_output, graySize);

float gpuTime;
cudaEventElapsedTime(&gpuTime, start, stop);

auto cpuTime =
    chrono::duration_cast<chrono::milliseconds>(cpuEnd - cpuStart);

cout << "CPU Time: " << cpuTime.count() << " ms" << endl;
cout << "GPU Time: " << gpuTime << " ms" << endl;

imwrite("gray_cpu.jpg", grayCPU);
imwrite("gray_gpu.jpg", grayGPU);

delete[] h_output;
cudaFree(d_input);
cudaFree(d_output);

return 0;
}

```

Writing grayscale.cu

```
!nvcc grayscale.cu -o grayscale `pkg-config --cflags --libs opencv4`
```

```

/usr/include/opencv4/opencv2/stitching/detail/warpers.hpp(235): warning #611-D: overloaded virtual function "cv::detail::PlaneWarper::warpImage"
class AffineWarper : public PlaneWarper
    ^

```

Remark: The warnings can be suppressed with "-diag-suppress <warning-number>"

```

/usr/include/opencv4/opencv2/stitching/detail/warpers.hpp(235): warning #611-D: overloaded virtual function "cv::detail::PlaneWarper::warpImage"
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```

/usr/include/opencv4/opencv2/stitching/detail/blenders.hpp(100): warning #611-D: overloaded virtual function "cv::detail::Blender::blend"
class FeatherBlender : public Blender
    ^

```

```

/usr/include/opencv4/opencv2/stitching/detail/blenders.hpp(127): warning #611-D: overloaded virtual function "cv::detail::Blender::blend"
class MultiBandBlender : public Blender
    ^

```

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```

```
!./grayscale
```

```

CPU Time: 719 ms
GPU Time: 48.6945 ms

```

```
!rm -f grayscale gray_gpu.jpg gray_cpu.jpg
!ls
```

```
grayscale.cu  input.jpg  sample_data
```

```
!ls
```

```
grayscale.cu  input.jpg  sample_data
```

```

from PIL import Image
import matplotlib.pyplot as plt

img = Image.open("input.jpg")
plt.imshow(img)
plt.axis("off")

```

```
(np.float64(-0.5), np.float64(3583.5), np.float64(5375.5), np.float64(-0.5))
```



```

%%writefile grayscale.cu
#include <opencv2/opencv.hpp>
#include <cuda_runtime.h>
#include <iostream>
#include <chrono>

using namespace std;
using namespace cv;

/* ===== CUDA KERNEL ===== */
__global__ void grayscaleKernel(unsigned char* input,
                                unsigned char* output,

```

```

        int width, int height)
    {
        int idx = blockIdx.x * blockDim.x + threadIdx.x;
        if (idx < width * height)
        {
            int i = idx * 3;
            unsigned char b = input[i];
            unsigned char g = input[i + 1];
            unsigned char r = input[i + 2];
            output[idx] = (r + g + b) / 3;
        }
    }

int main()
{
    /* ----- Load image safely ----- */
    Mat img = imread("input.jpg", IMREAD_COLOR);
    if (img.empty())
    {
        cout << "Image not found!" << endl;
        return -1;
    }

    if (img.type() != CV_8UC3)
        img.convertTo(img, CV_8UC3);

    int width  = img.cols;
    int height = img.rows;

    Mat grayGPU(height, width, CV_8UC1);

    size_t imgSize  = width * height * 3;
    size_t graySize = width * height;

    unsigned char *d_input, *d_output;
    unsigned char *h_output = new unsigned char[graySize];

    memset(h_output, 255, graySize); // proof buffer

    cudaMalloc(&d_input, imgSize);
    cudaMalloc(&d_output, graySize);

    cudaMemcpy(d_input, img.data, imgSize, cudaMemcpyHostToDevice);

    /* ----- Launch kernel ----- */
    int threads = 256;
    int blocks  = (width * height + threads - 1) / threads;

    grayscaleKernel<<<blocks, threads>>>(d_input, d_output, width, height);

    /* ----- HARD SYNC + ERROR CHECK ----- */
    cudaDeviceSynchronize();
    cudaError_t err = cudaGetLastError();
    if (err != cudaSuccess)
    {
        cout << "CUDA ERROR: " << cudaGetErrorString(err) << endl;
        return -1;
    }

    cudaMemcpy(h_output, d_output, graySize, cudaMemcpyDeviceToHost);
    memcpy(grayGPU.data, h_output, graySize);

    imwrite("gray_gpu.jpg", grayGPU);

    cudaFree(d_input);
    cudaFree(d_output);
    delete[] h_output;

    cout << "GPU grayscale DONE" << endl;
    return 0;
}

```

Overwriting grayscale.cu

```
!nvcc -arch=sm_75 grayscale.cu -o grayscale `pkg-config --cflags --libs opencv4`
```

```
/usr/include/opencv4/opencv2/stitching/detail/warpers.hpp(235): warning #611-D: overloaded virtual function "cv::detail::PlaneWarper"
class AffineWarper : public PlaneWarper
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Remark: The warnings can be suppressed with "-diag-suppress <warning-number>"

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/usr/include/opencv4/opencv2/stitching/detail/blenders.hpp(100): warning #611-D: overloaded virtual function "cv::detail::Blender"
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class MultiBandBlender : public Blender
^
```

```
!./grayscale
```

```
GPU grayscale DONE
```

```
!!s
```

```
gray_gpu.jpg grayscale grayscale.cu input.jpg sample_data
```

```
!nvcc grayscale.cu -o grayscale \
  -arch=sm_75 \
  --std=c++14 \
  `pkg-config --cflags --libs opencv4`
```

```
/usr/include/opencv4/opencv2/stitching/detail/warpers.hpp(235): warning #611-D: overloaded virtual function "cv::detail::PlaneWarper"
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class MultiBandBlender : public Blender
^
```

```
!./grayscale
```

```
GPU grayscale DONE
```

```
from PIL import Image
import numpy as np
import matplotlib.pyplot as plt

img = Image.open("gray_gpu.jpg")
arr = np.array(img)

print("MIN:", arr.min(), "MAX:", arr.max())

plt.imshow(img, cmap="gray", vmin=0, vmax=255)
plt.axis("off")
```

```
MIN: 0 MAX: 255
(np.float64(-0.5), np.float64(3583.5), np.float64(5375.5), np.float64(-0.5))
```



Day 2 code

```
%writefile sobel.cu
#include <opencv2/opencv.hpp>
#include <cuda_runtime.h>
#include <iostream>

using namespace std;
using namespace cv;

/* ===== CUDA SOBEL KERNEL ===== */
__global__ void sobelKernel(unsigned char* input,
                           unsigned char* output,
                           int width, int height)
{
    int x = blockIdx.x * blockDim.x + threadIdx.x;
    int y = blockIdx.y * blockDim.y + threadIdx.y;

    if (x > 0 && x < width-1 && y > 0 && y < height-1)
    {
        int idx = y * width + x;

        int gx =
            -input[(y-1)*width + (x-1)] + input[(y-1)*width + (x+1)] +
            -2*input[y*width + (x-1)] + 2*input[y*width + (x+1)] +
            -input[(y+1)*width + (x-1)] + input[(y+1)*width + (x+1)];
```

```

        int gy =
            -input[(y-1)*width + (x-1)] -2*input[(y-1)*width + x] -input[(y-1)*width + (x+1)] +
            input[(y+1)*width + (x-1)] +2*input[(y+1)*width + x] +input[(y+1)*width + (x+1)];

        int edge = abs(gx) + abs(gy);
        if (edge > 255) edge = 255;

        output[idx] = edge;
    }
}

/* ===== MAIN FUNCTION ===== */
int main()
{
    Mat gray = imread("input.jpg", IMREAD_GRAYSCALE);
    if (gray.empty())
    {
        cout << "Image not found!" << endl;
        return -1;
    }

    int width = gray.cols;
    int height = gray.rows;

    Mat edges(height, width, CV_8UC1);

    size_t size = width * height;

    unsigned char *d_input, *d_output;
    cudaMalloc(&d_input, size);
    cudaMalloc(&d_output, size);

    cudaMemcpy(d_input, gray.data, size, cudaMemcpyHostToDevice);

    dim3 threads(16, 16);
    dim3 blocks((width + 15) / 16, (height + 15) / 16);

    sobelKernel<<<blocks, threads>>>(d_input, d_output, width, height);
    cudaDeviceSynchronize();

    cudaMemcpy(edges.data, d_output, size, cudaMemcpyDeviceToHost);

    imwrite("edges_gpu.jpg", edges);

    cudaFree(d_input);
    cudaFree(d_output);

    cout << "Edge detection completed" << endl;
    return 0;
}

```

Writing sobel.cu

```
!nvcc sobel.cu -o sobel -arch=sm_75 `pkg-config --cflags --libs opencv4`
```

```
/usr/include/opencv4/opencv2/stitching/detail/warpers.hpp(235): warning #611-D: overloaded virtual function "cv::detail::PlaneWarper"
class AffineWarper : public PlaneWarper
^
```

Remark: The warnings can be suppressed with "-diag-suppress <warning-number>"

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/usr/include/opencv4/opencv2/stitching/detail/warpers.hpp(235): **warning** #611-D: overloaded virtual function "cv::detail::PlaneWarper::warpImage" in class AffineWarper : public PlaneWarper

/usr/include/opencv4/opencv2/stitching/detail/blenders.hpp(100): **warning** #611-D: overloaded virtual function "cv::detail::Blender::blendImage" in class FeatherBlender : public Blender

/usr/include/opencv4/opencv2/stitching/detail/blenders.hpp(127): **warning** #611-D: overloaded virtual function "cv::detail::Blender::blendImage" in class MultiBandBlender : public Blender

!./sobel

Edge detection completed

```
from PIL import Image
import matplotlib.pyplot as plt

img = Image.open("edges_gpu.jpg")
plt.imshow(img, cmap="gray")
plt.axis("off")
```

```
(np.float64(-0.5), np.float64(3583.5), np.float64(5375.5), np.float64(-0.5))
```

