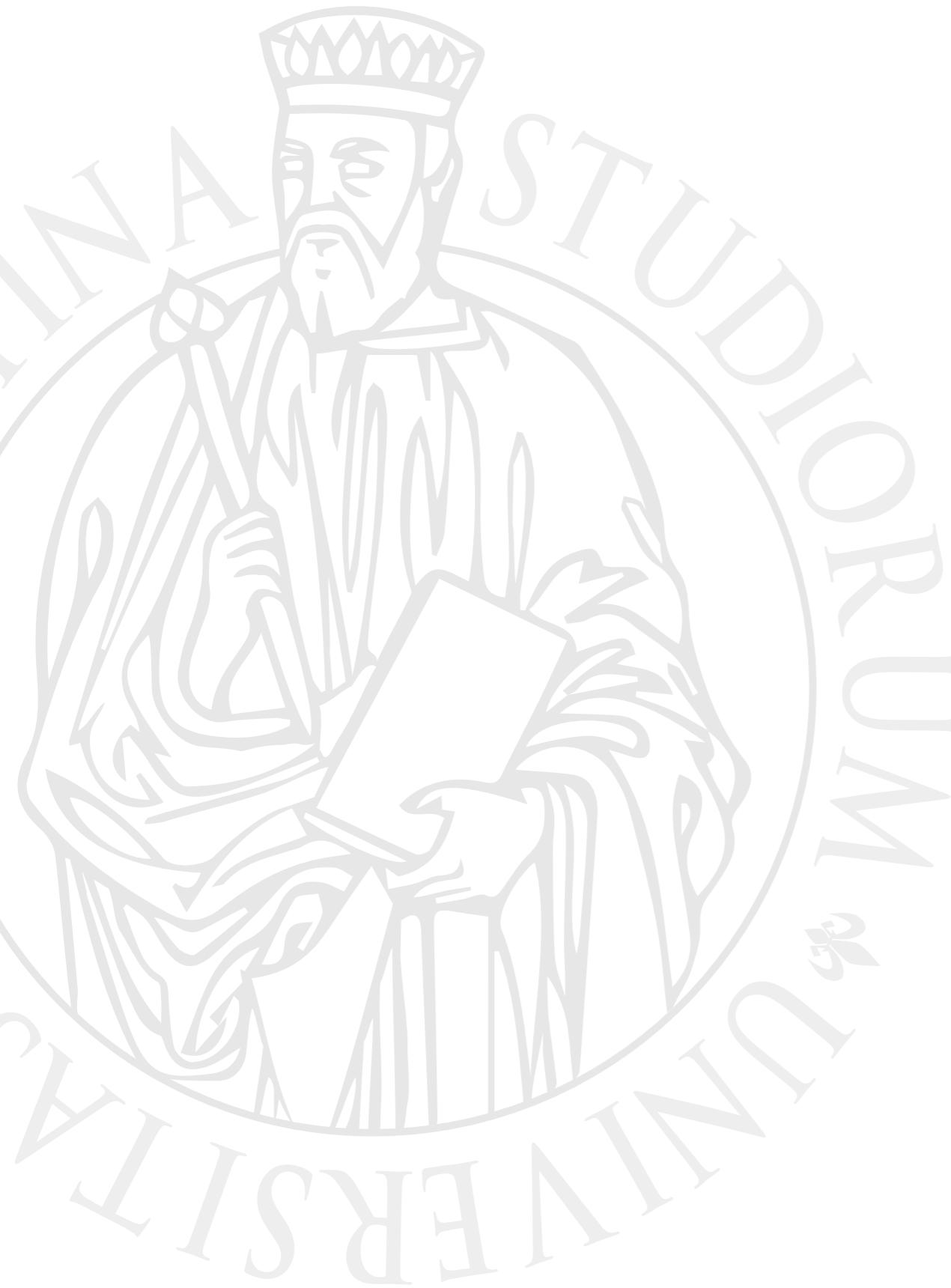




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# Histogram Equalization

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# Abstract

- Histogram equalization is a method used in Image Processing through which the contrast can be calibrated using the image histogram.
- An **image histogram** is a type of histogram that acts as a graphical representation of the tonal distribution in a digital image. It plots the number of pixels for each tonal value.
- This method usually increases the global **contrast** of many images, especially when the usable **data** of the image is represented by close contrast values.
- Through this adjustment, the **intensities can be better distributed on the histogram**. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values.



# Math

- The *probability* of an occurrence of a pixel  $x$  of level  $k$  in the image is:

$$p_x(k) = p(x = k) = \frac{n_k}{n} \quad 0 \leq k < L$$

- *cumulative distribution function*

$$cdf_x(k) = \sum_{l=0}^k p_x(l)$$

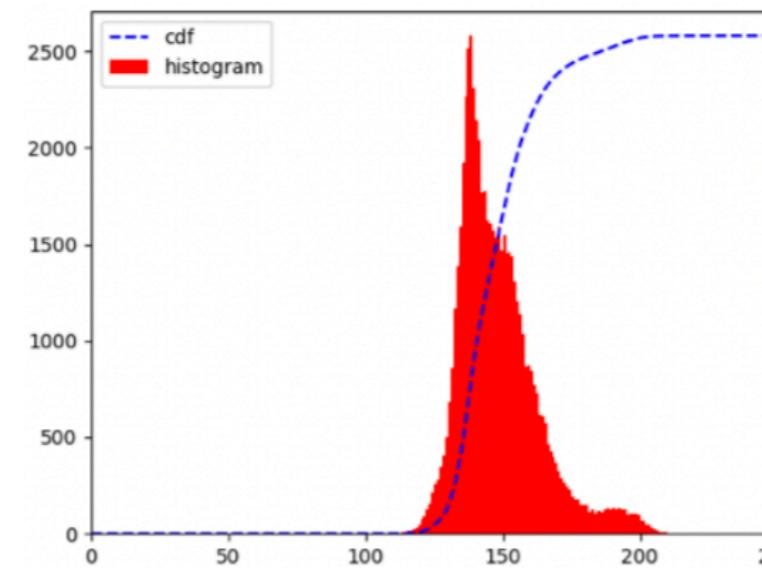
- *normalize* it such that the maximum value is 255:

$$y(i, j) = h(x(i, j)) = \text{round}\left(\frac{cdf(x(i, j)) - cdf_{min}}{(M \cdot N) - cdf_{min}} \cdot (L - 1)\right)$$

# Example

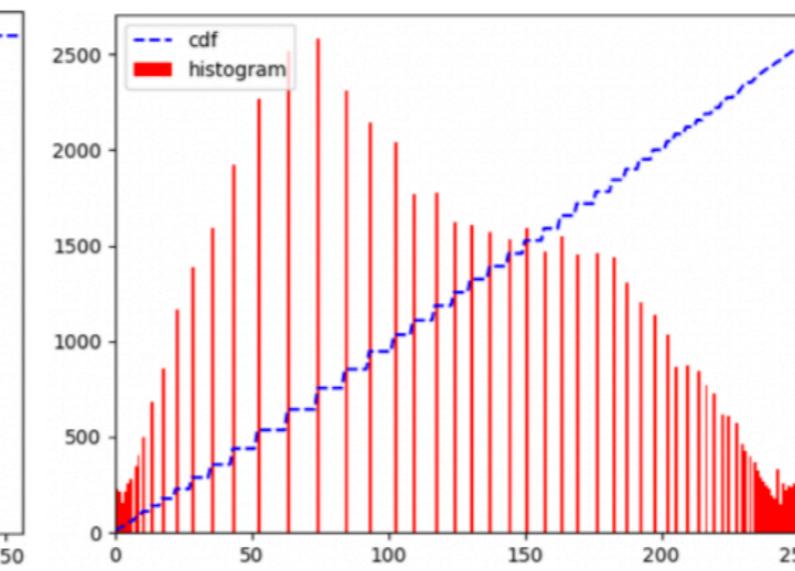


(a) Original Image



(c) Original Histogram

(b) Equalized Image



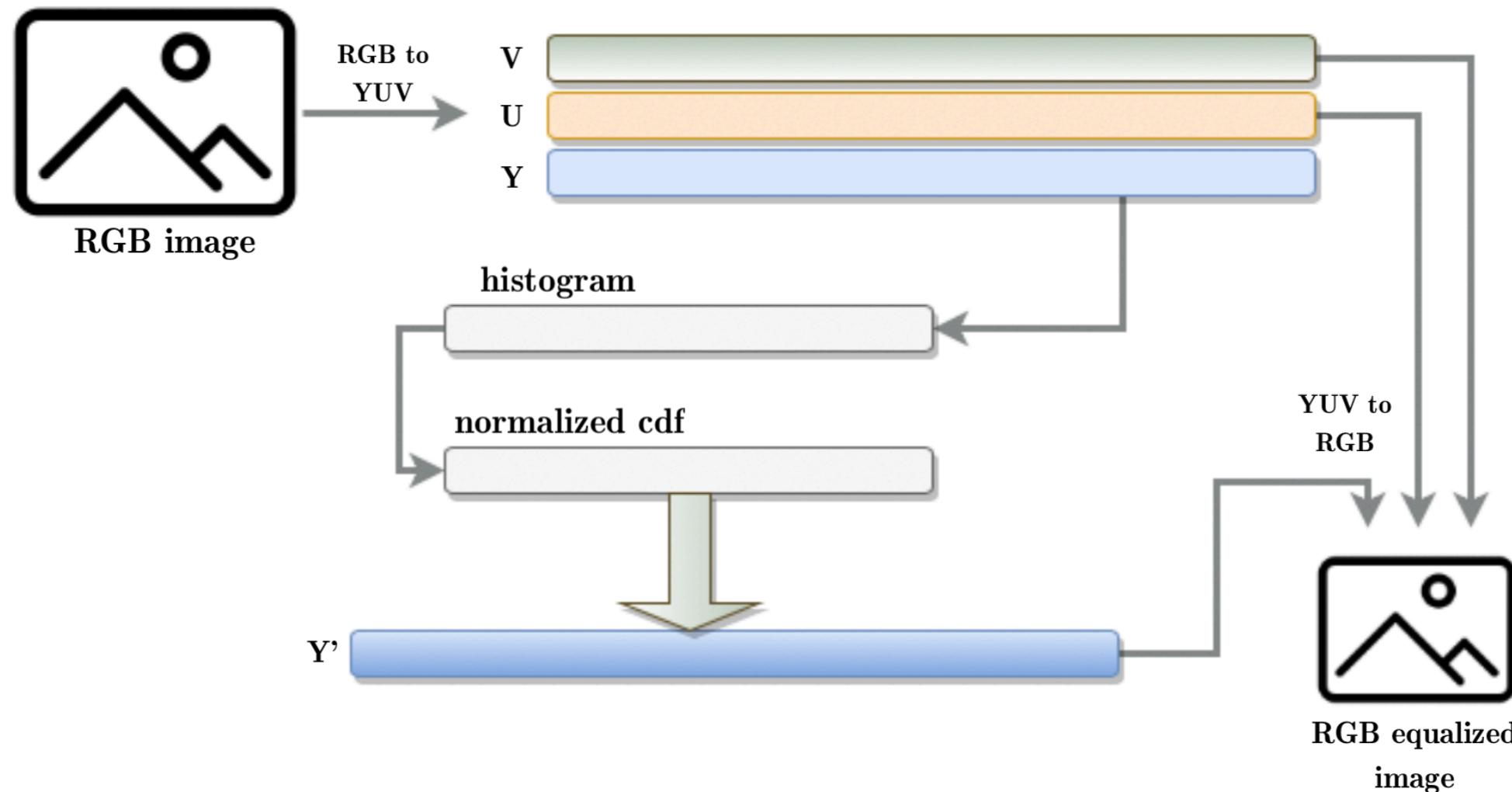
(d) Equalized Histogram

# Technologies

- Sequential Implementation: C++
- Parallel Implementation 1: OpenMP
- Parallel Implementation 2: CUDA



# Serial



- $\text{RGB} \Rightarrow \text{YUV}$



# Parallel : OpenMP

OpenMP is a multi-platform API for the creation of parallel applications on shared memory system

OpenMP version has been implemented reusing the sequential code and entrusting the **for loop** computation to an OMP specific structure:

```
#pragma omp parallel default(shared)
{
    #pragma omp for schedule(static)

    for (int i = 0; i < image.rows; i++) {

        for (int j = 0; j < image.cols; j++) {
            /* code here */
        }
    }
}
```



# Parallel : CUDA

CUDA is a parallel computing platform and API created by NVIDIA that allows to use a GPU (CUDA-enabled) for parallel calculation.

To implement CUDA version some characteristic functions have been used:

- `cudaMalloc()` to allocate arrays in the GPU
- `cudaMemcpy()` to copy arrays from CPU to GPU and vice versa
- `cudaFree()` to free GPU

The CUDA kernels have been implemented are:

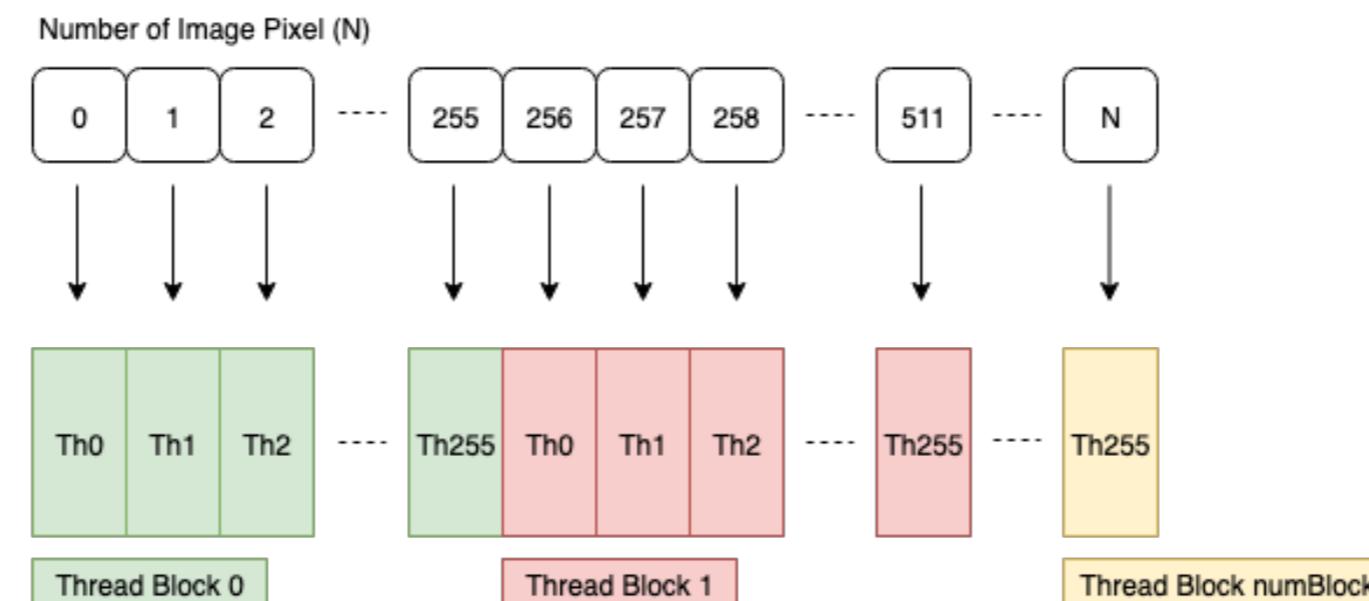
- `make_histogram()`
- `normalizeCdf()`
- `equalize()`



# Parallel : CUDA

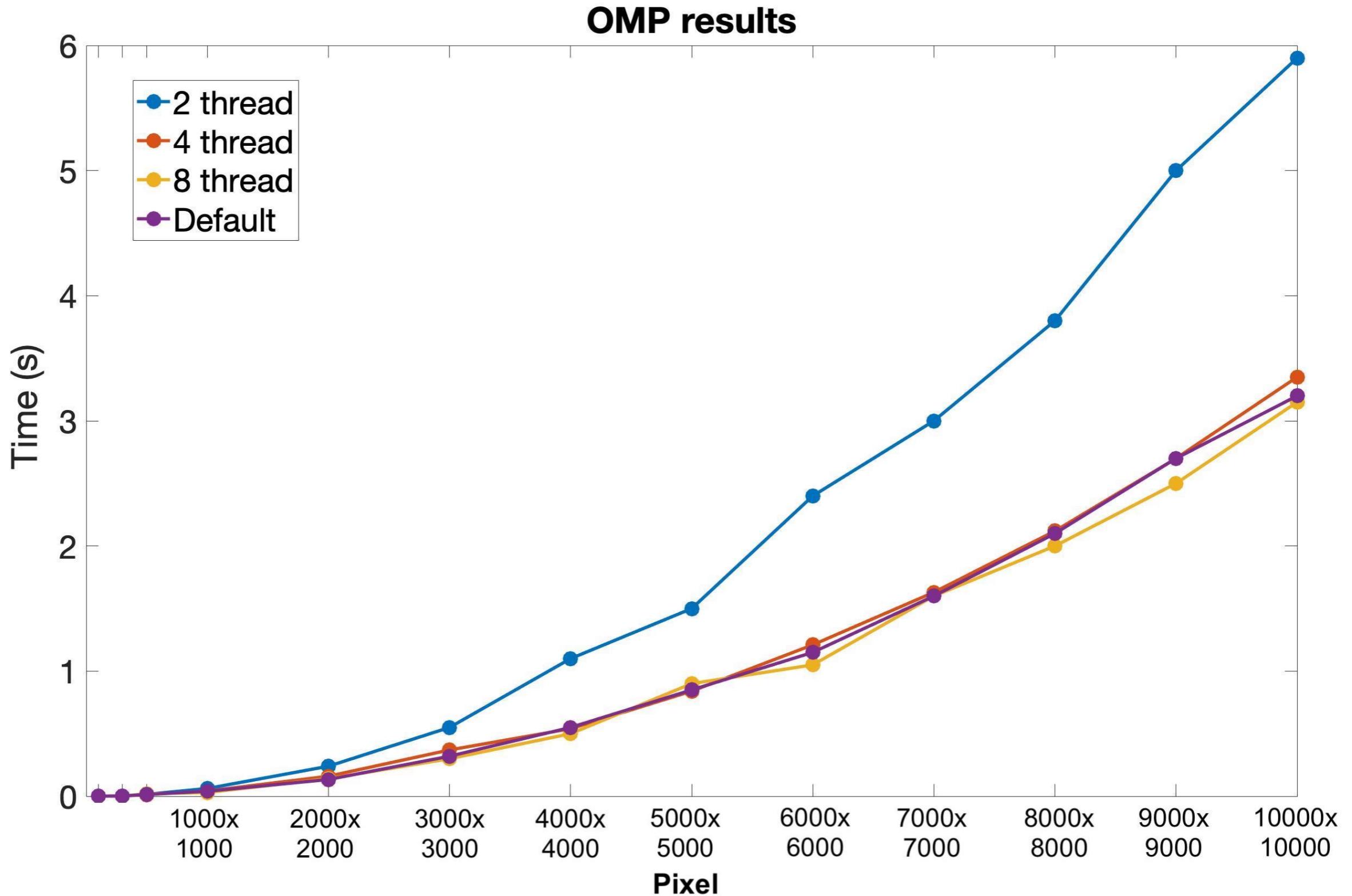
In order to implement CUDA version we have paid special attention on image's pixels management:

- Images have been computed assigning one thread for each pixel
- The thread blocks contain 256 threads

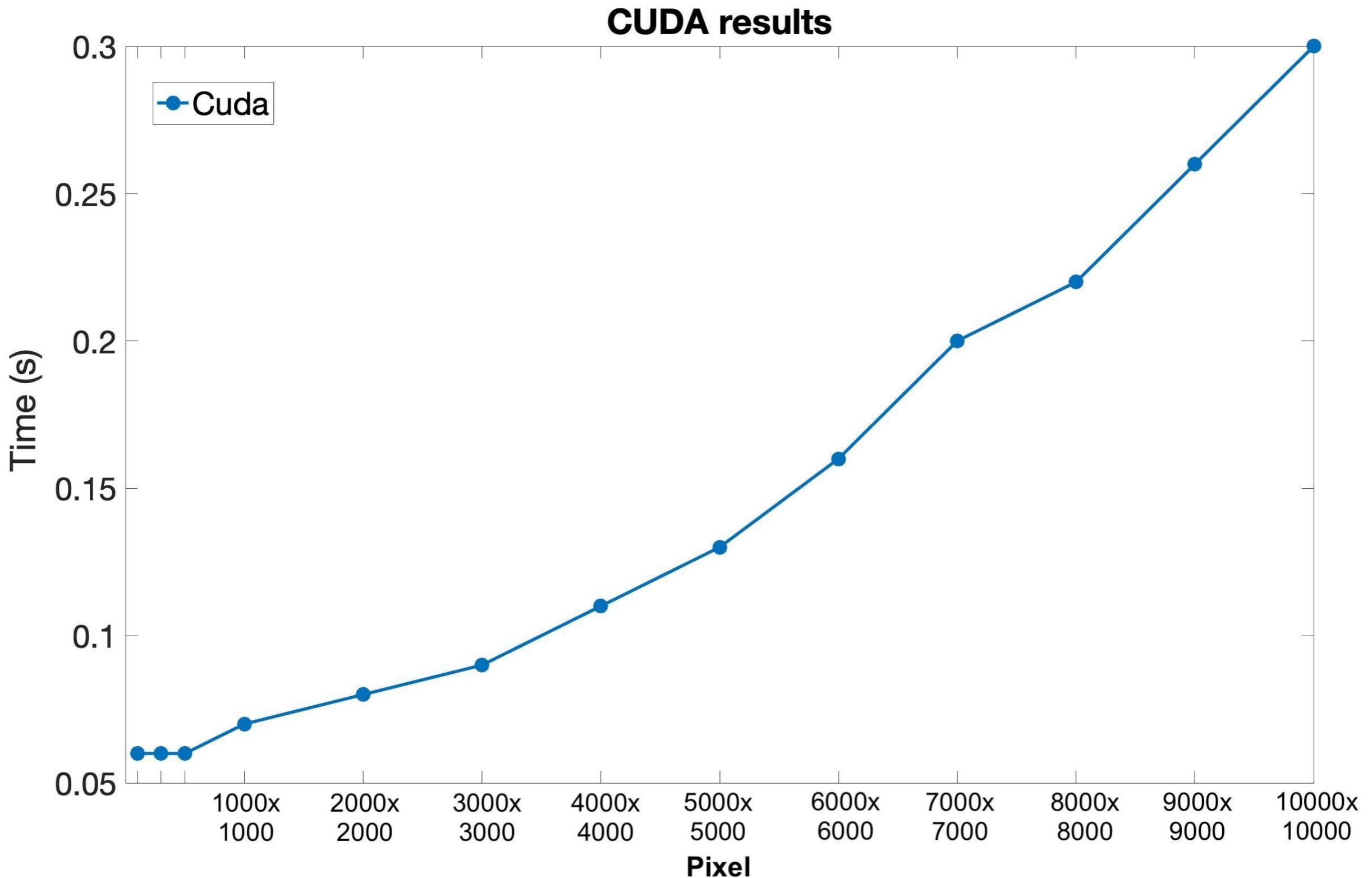


$\text{numBlocks} = (\text{N} + \text{blockSize} - 1) / \text{blockSize}$

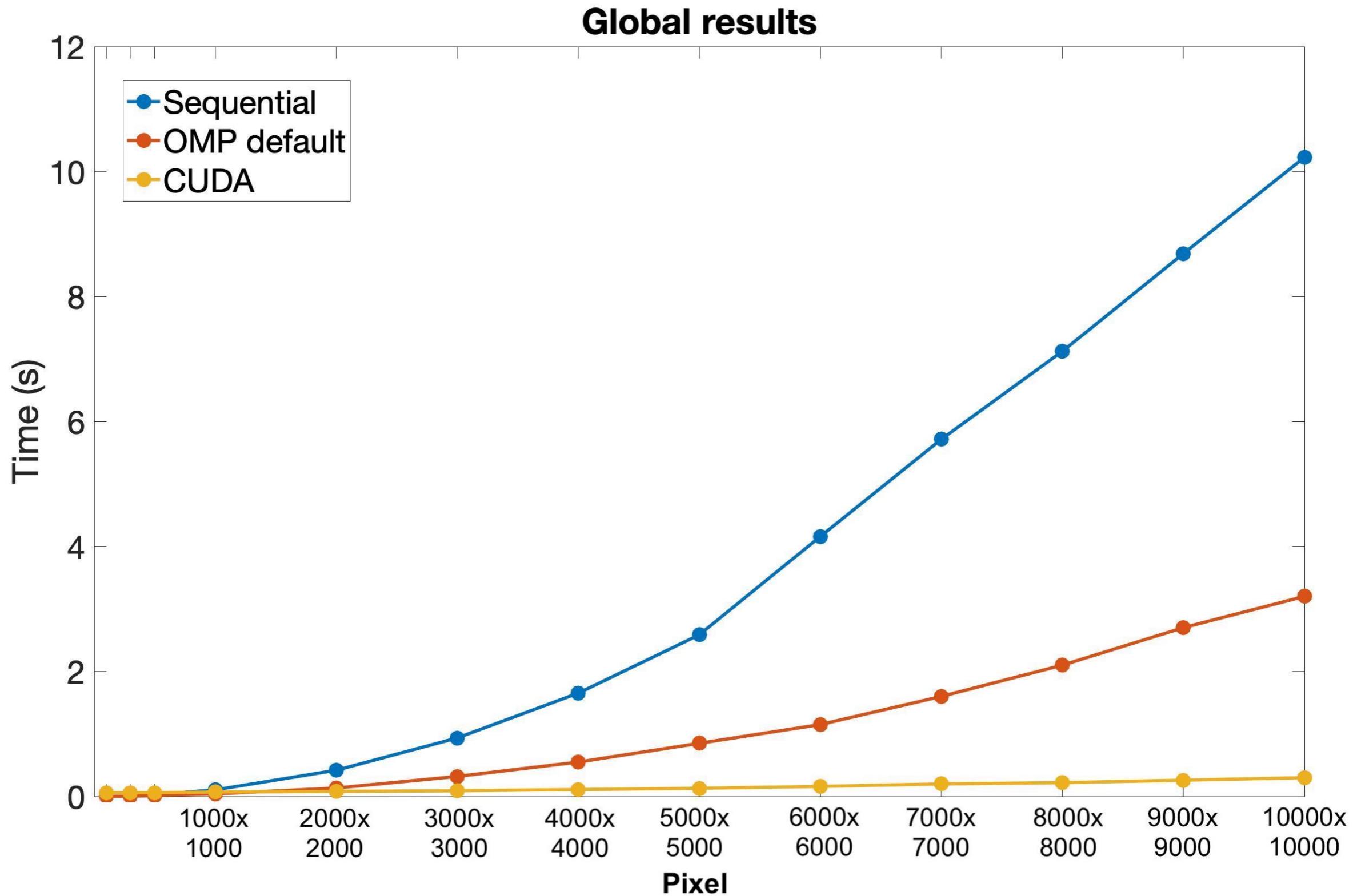
# Results



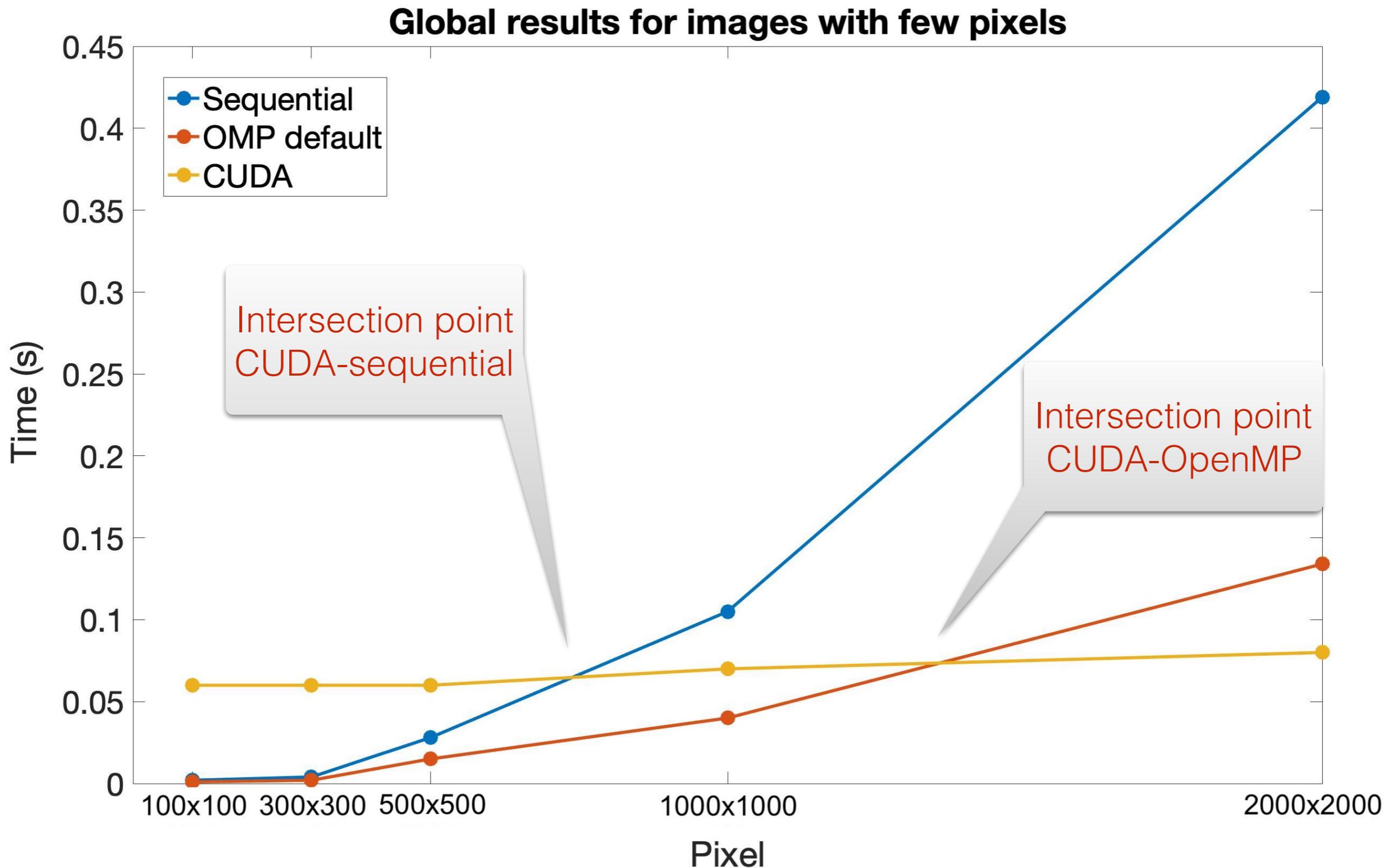
# Results



# Results

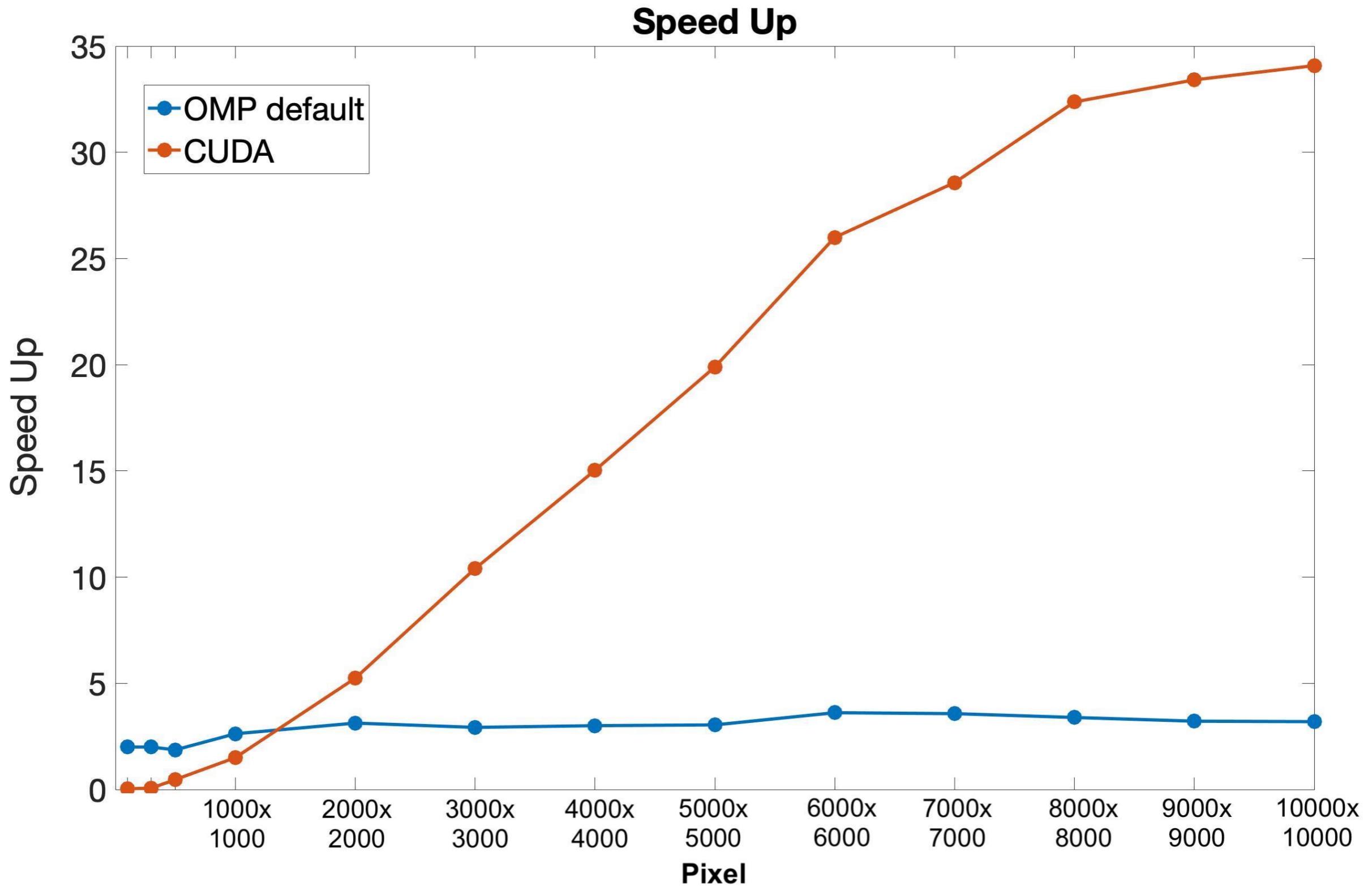


# Results





# Speed Up





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