Analyzing Performance of Spatial-Domain Linear Filtering on Multi-Channel Images using OpenMP

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Abstract

Typically, Image Processing Algorithms are massively parallelizable and are performed on specialized hardwares such as Graphics Processing units(GPUs) that offer high-throughput. This experiment aims to analyze the performance of parallelized Spatial-Domain linear filtering for multi-channel images using OpenMP.

1 Theory

1.1 Spatial-Domain Linear Filtering

Linear Filtering is neighborhood operation, in the which the value of any given pixel in the output image is represented as a linear function of the pixel values in the neighborhood of the corresponding input pixel. Linear filtering in spatial domain is performed using **convolution**.

Mean Filtering is a linear filtering in which value of any given pixel in the ouput image is the mean of values of pixel in a kxk window centered at the corresponding input pixel (where k is an odd number).

1.2 Sections in OpenMP

The section construct in OpenMP is a way of distributing different independent blocks of codes (each performing a task) to different threads. The sytax of the sections construct is:

```
#pragma omp parallel
{
  #pragma omp sections
  {
    #pragma omp section
    {
      //structured block 1
    }

    #pragma omp section
    {
      //structured block 2
    }

    #pragma omp section
    {
      //structured block 3
    }

    ...
  }
}
```

2 Results [1]

The experiments were conducted on a three-channel (red, green and blue) image of size 384x512 for varying size of filter kernels. Each section block performed mean filtering of one channel of the image.

Number of Threads	Execution Time (in seconds)					
	Without Sections			With Sections		
	3x3 filter	5x5 filter	7x7 filter	3x3 filter	5x5 filter	7x7 filter
1	0.019927	0.054407	0.105519	0.012785	0.021406	0.040657
2	0.010053	0.027356	0.053044	0.008516	0.021233	0.040614
4	0.007793	0.015653	0.032042	0.009176	0.021220	0.040507
6	0.007935	0.020113	0.038913	0.008530	0.021251	0.040530
8	0.007302	0.015856	0.030059	0.008977	0.021224	0.040493
12	0.007650	0.016432	0.034132	0.008535	0.021301	0.040629
16	0.007699	0.017675	0.031378	0.008656	0.021210	0.040533
20	0.007568	0.019941	0.033236	0.008595	0.021234	0.040508
24	0.009263	0.020189	0.031605	0.008533	0.021246	0.040567
28	0.007752	0.025205	0.033459	0.008351	0.021210	0.043062
32	0.008162	0.022908	0.032675	0.010023	0.021207	0.043040

Note: The actual number of concurrently executing threads for the programs with sections is thrice the indicated number since the three sections are executed in parallel, with each section executing the indicated number of threads.

3 Calculation

The parallel fraction of the algorithm can be computed using the following equation:

$$f = \frac{(1 - T_p/T_1)}{(1 - 1/p)} \tag{1}$$

For Mean Filtering using 3x3 filter (without sections),

$$f = \frac{(1 - 0.007793/0.019927)}{(1 - 1/4)} = \mathbf{0.811896756\ (81.19\ \%)}$$

For Mean Filtering using 5x5 filter (without sections),

$$f = \frac{(1 - 0.015653/0.054407)}{(1 - 1/4)} = \mathbf{0.949730733\ (94.97\ \%)}$$

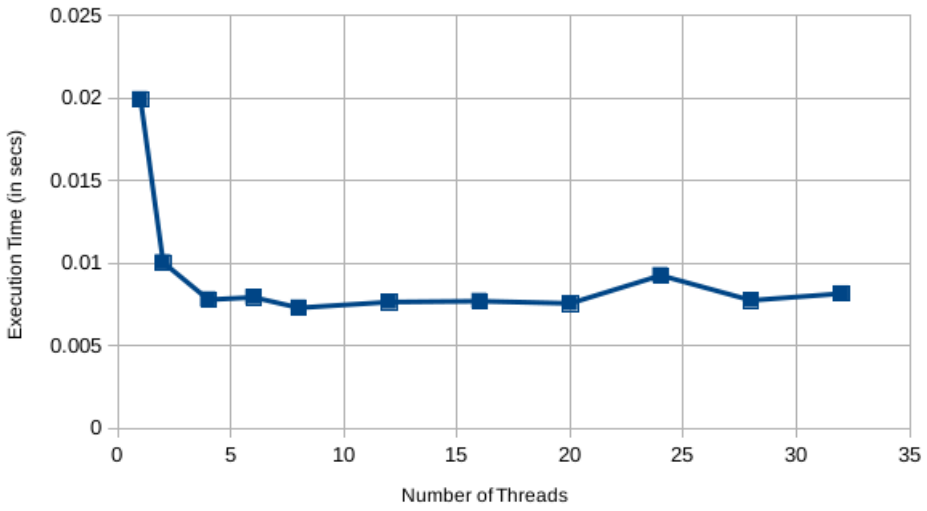
For Mean Filtering using 7x7 filter (without sections),

$$f = \frac{(1 - 0.032042/0.105519)}{(1 - 1/4)} = \mathbf{0.928452064\ (92.85\ \%)}$$

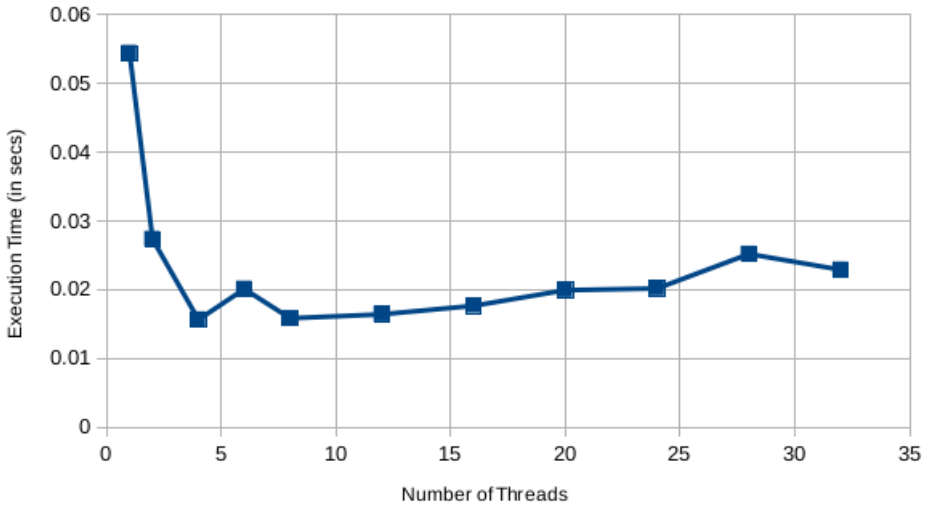
4 Inference

1. Mean Filtering Algorithm for kernel sizes of 3x3, 5x5 and 7x7 has parallel fractions of **81.19 %**, **94.97 %** and **92.85 %** respectively.
2. The program with sections outperforms the program without sections because the sections are executed parallely.
3. The sudden spike in execution time for mean filtering using 7x7 kernel size with sections in OpenMP can be attributed the overheads associated with creation, switching and scheduling of large number of threads.

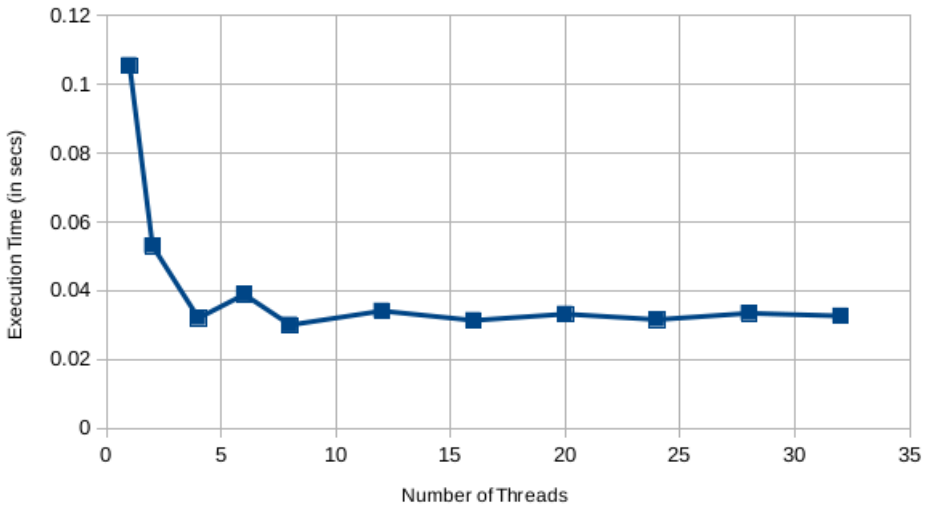
[1] The experiments were conducted on a computer with 6^{th} Generation Intel(R) Core(TM) i7-6500U Processor (4M Cache, upto 3.10 GHz) and 4GB Single Channel DDR3L 1600M Hz (4GBx1) RAM.



(a) Performance of Mean Filtering for 3x3 Filter (without sections)

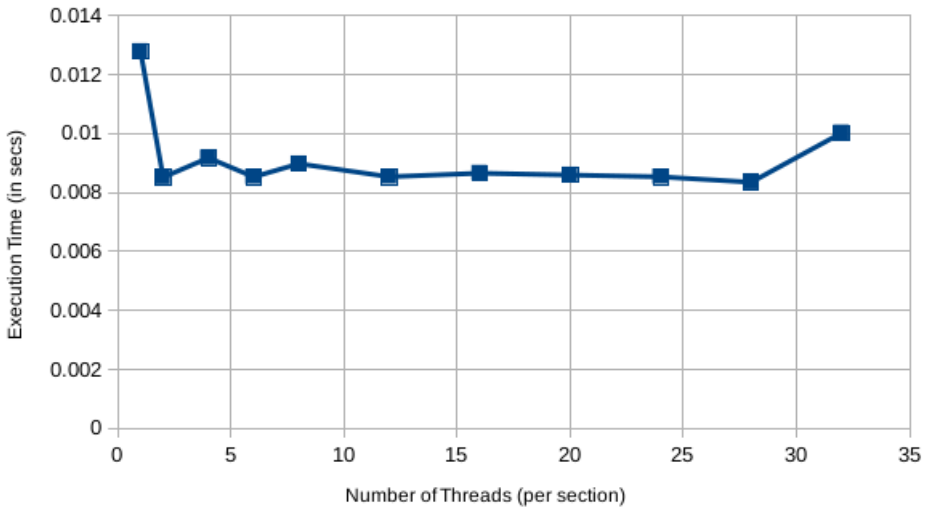


(b) Performance of Mean Filtering for 5x5 Filter (without sections)

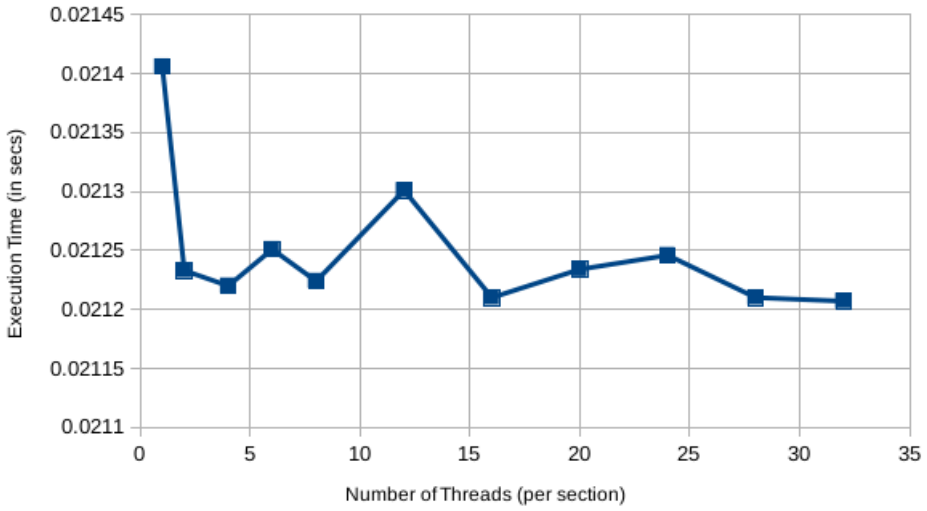


(c) Performance of Mean Filtering for 7x7 Filter (without sections)

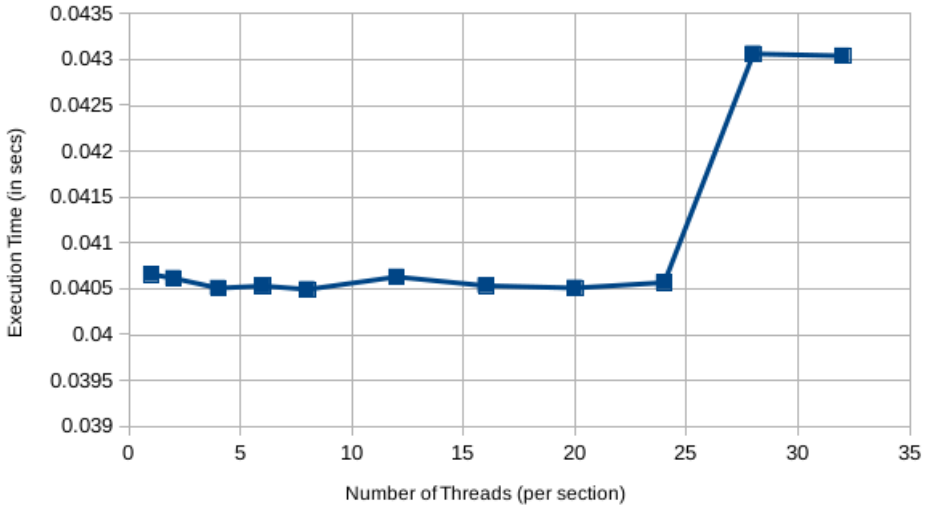
Figure 1: Number of Threads vs Execution Time of Mean Filtering for varying filter size in OpenMP without sections



(a) Performance of Mean Filtering for 3x3 Filter (with sections)



(b) Performance of Mean Filtering for 5x5 Filter (with sections)



(c) Performance of Mean Filtering for 7x7 Filter (with sections)

Figure 2: Number of Threads vs Execution Time of Mean Filtering for varying filter size in OpenMP with sections