

MULTI-CORE PROGRAMMING

ASSIGNMENT 2

Ali Gholami

Department of Computer Engineering & Information Technology
Amirkabir University of Technology

<https://aligholamee.github.io>
aligholami7596@gmail.com

Abstract

OpenMP is an implementation of multithreading, a method of parallelizing whereby a master thread (a series of instructions executed consecutively) forks a specified number of slave threads and the system divides a task among them. The threads then run concurrently, with the run-time environment allocating threads to different processors. In this assignment, we are going to implement the parallelization of the matrix multiplication.

Keywords. *Heterogeneous Programming, OpenMP, C Programming, C++ Programming, Parallelization, Multi-thread Programming.*

1 Matrix Multiplication

1.1 What's the goal?

In this assignment, we'll be parallelizing the matrix multiplication using *OpenMP*. The goal is to speed up the matrix multiplication by implementing the parallelization in two axis (*1D* & *2D*). Below the serial code for the matrix multiplication. Sources for this assignment is available in the repository merged with this report.

```
void multiply(DataSet dataSet){
    int i, j, k, sum;
    for(i = 0; i < dataSet.n; i++){
        for(j = 0; j < dataSet.p; j++){
            sum = 0;
            for(k = 0; k < dataSet.m; k++){
                sum += dataSet.A[i * dataSet.m + k] * dataSet.B[k * dataSet.p + j];
            }
            dataSet.C[i * dataSet.p + j] = sum;
        }
    }
}
```

1.2 1D Parallelization

The following figures are provided from the problem description by *Dr. Ahmad Siavashi*. Each of the highlighted areas show a job for a thread. Figure 1.1 shows how the multiplication is done by each thread.

Assuming each *integer* as 4 bytes, we'll be filling the table 1.1 using the average time computed after 6 times of running the program. Note that in the dimensions of these matrices is assumed to be same

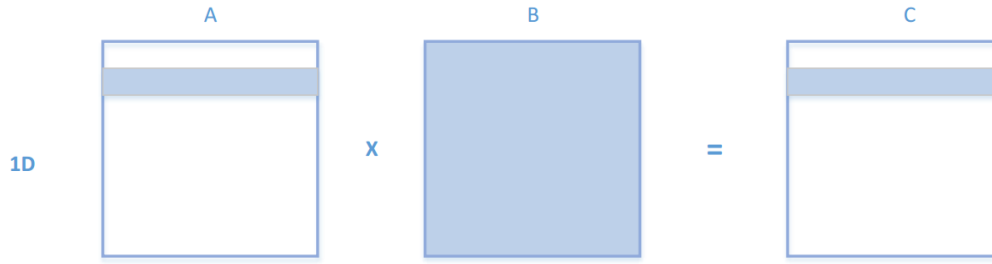


Figure 1.1: Matrix Multiplication Parallelization on Horizontal Axis.

in different axes and we are dealing with squared matrices. According to this assumption, each dimension can be computed as below:

- **100 KB:** $d = \sqrt{\frac{10^5}{4}} = 158$
- **400 KB:** $d = \sqrt{\frac{4 \times 10^5}{4}} = 316$
- **800 KB:** $d = \sqrt{\frac{8 \times 10^5}{4}} = 447$
- **1 MB:** $d = \sqrt{\frac{10^6}{4}} = 500$

1.2.1 Serial Time

The average serial time for this multiplication is 0.239668 seconds.

1.2.2 Parallelized For Loop

In order to make things a bit faster, we'll use *pragma* like so:

```
void multiply(DataSet dataSet){
    int i, j, k, sum;

    #pragma omp parallel for private(i)
    for(i = 0; i < dataSet.n; i++){
        for(j = 0; j < dataSet.p; j++){
            sum = 0;
            for(k = 0; k < dataSet.m; k++){
                sum += dataSet.A[i * dataSet.m + k] * dataSet.B[k * dataSet.p + j];
            }
            dataSet.C[i * dataSet.p + j] = sum;
        }
    }
}
```

Total Size of Each Matrix					
Num of Threads	100 KB	400 KB	800 KB	1 MB	Average Speedup
1	0.024875	0.264729	0.831792	1.115039	-
2	0.025861	0.164219	0.461315	0.653042	1.52
4	0.030058	0.185644	0.402523	0.562593	0.97
8	0.038876	0.273006	0.687464	0.800365	0.8

Table 1.1: Results of 1-Dimensional Parallelization.

1.3 2D Parallelization

The results for the 2D parallelization is given in the table 1.2.

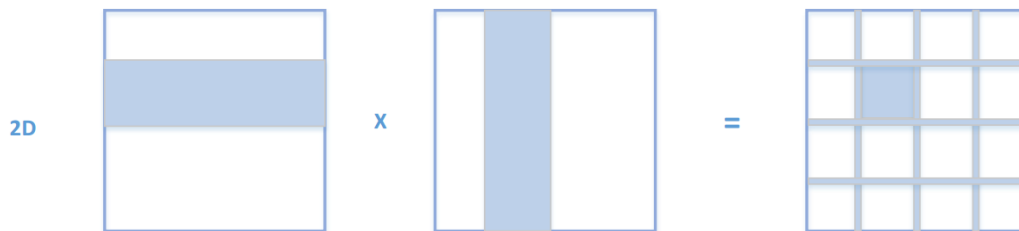


Figure 1.2: Matrix Multiplication Parallelization on Horizontal and Vertical Axis.

1.4 2D Parallelized For Loop

Each of the threads does the job in the highlighted area. In order to make things a bit faster, we'll use *pragma* like so:

```

void multiply(DataSet dataSet){
    int i, j, k, sum;

    #pragma omp parallel for private(i)
    for(i = 0; i < dataSet.n; i++){
        #pragma omp parallel for private(j)
        for(j = 0; j < dataSet.p; j++){
            sum = 0;
            for(k = 0; k < dataSet.m; k++){
                sum += dataSet.A[i * dataSet.m + k] * dataSet.B[k * dataSet.p + j];
            }
            dataSet.C[i * dataSet.p + j] = sum;
        }
    }
}

```

Total Size of Each Matrix					
Num of Threads	100 KB	400 KB	800 KB	1 MB	Speedup
1	0.335665	3.202322	30.957708	295.218567	-
2	0.279533	2.812544	30.707558	300.334747	1.2
4	0.268334	2.400637	30.366821	302.839111	1.04
8	0.294931	2.543862	30.529339	304.471771	0.95

Table 1.2: Results of 2-Dimensional Parallelization.