# System Programming

# HW5 Report


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## Objective

This is my final homework for this semester. The idea is to use POSIX threads to parallelize a couple of simple mathematical tasks. Let's see how much we can accelerate via threads.

Example:./hw5 -i filePath1 -j filePath2 -o output -n 4 -m 2

## My Design Decisions

->The threads must wait for each other and not advance to the second part of the calculations before all have finished the first part. This is a synchronization barrier. Because in order to calculate each DFT coefficient, threads need to access all the matrix elements.

->All threads run concurrently.

->Every consecutive 2^n characters that it reads will be considered as one matrix row.

->If any of the two files has insufficient content, this will be considered a fatal error.

->Include a timestamp before each output line.

->Once threads have all finished, the process collect the outputs of each thread and write them to the output file (relative or absolute path), in CSV format (one matrix row per file line).

->In case of SIGINT, the process and the threads terminate gracefully, closing all open files and freeing all allocated resources

->Inside myThread funtion; I find the starting index of the matrix for multiplication and calcualte the matrix C for this particular thread's share. After than I set up the barrier using threads mutex and condition variable, so that all the threads will calculate the first task and then advance to the second part. Later threads will calculate the second task and return gracefully.

## How i solved this problem

->I solved all synchronization problems only with mutexes and condition variables.

->Threads calculated C=AxB in a parallel fashion. This means that each thread will be responsible for calculating (2^n)/m columns of C. For example if m=2, then the first thread will calculate the left half of C, and the second thread will calculate the right half of C.

I achieved all requirements.

**Running And Result**

Inputfile 1

```
1 asdfdsgasgsdgsadgsadgsdagasdgsdgasdgasdg324ipo5432ijh5t234io5fc1
```

Inputfile 2

```
1 sadgsgsaGsadGsdgsdGa'!^4!'^5%'^5!'352saDGsdag2ttewrrtcwetwb545ba
```

Terminal outputs

For M=8 , N=3

```
atar@ubuntu:~/Desktop/hw5$ ./hw5 -i inputfile -j inputfile2 -o output.csv -n 3 -m 8
2022-05-22 16:03:03,Two matrices of size 8x8 have been read. The number of threads is 8
2022-05-22 16:03:03,Thread 1 has reached the rendezvous point in 0.000249 seconds.
2022-05-22 16:03:03,Thread 2 has reached the rendezvous point in 0.000508 seconds.
2022-05-22 16:03:03,Thread 3 has reached the rendezvous point in 0.000605 seconds.
2022-05-22 16:03:03,Thread 6 has reached the rendezvous point in 0.001128 seconds.
2022-05-22 16:03:03,Thread 7 has reached the rendezvous point in 0.001199 seconds.
2022-05-22 16:03:03,Thread 4 has reached the rendezvous point in 0.001278 seconds.
2022-05-22 16:03:03,Thread 5 has reached the rendezvous point in 0.001321 seconds.
2022-05-22 16:03:03,Thread 8 has reached the rendezvous point in 0.001362 seconds.
2022-05-22 16:03:03,Thread 8 is advancing to the second part.
2022-05-22 16:03:03,Thread 2 is advancing to the second part.
2022-05-22 16:03:03,Thread 3 is advancing to the second part.
2022-05-22 16:03:03,Thread 7 is advancing to the second part.
2022-05-22 16:03:03,Thread 2 has has finished the second part in 0.001652 seconds.
2022-05-22 16:03:03,Thread 1 is advancing to the second part.
2022-05-22 16:03:03,Thread 4 is advancing to the second part.
2022-05-22 16:03:03,Thread 1 has has finished the second part in 0.001929 seconds.
2022-05-22 16:03:03,Thread 6 is advancing to the second part.
2022-05-22 16:03:03,Thread 4 has has finished the second part in 0.002018 seconds.
2022-05-22 16:03:03,Thread 7 has has finished the second part in 0.002102 seconds.
2022-05-22 16:03:03,Thread 8 has has finished the second part in 0.002131 seconds.
2022-05-22 16:03:03,Thread 3 has has finished the second part in 0.002184 seconds.
2022-05-22 16:03:03,Thread 5 is advancing to the second part.
2022-05-22 16:03:03,Thread 6 has has finished the second part in 0.002270 seconds.
2022-05-22 16:03:03,Thread 5 has has finished the second part in 0.002320 seconds.
2022-05-22 16:03:03,The process has written the output file. The total time spent is 0.002871 seconds.
atar@ubuntu:~/Desktop/hw5$
```

Output File(CSV Format)

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | 4105035.000i+(0.000)j | 125758.219i+(16662.205)j | -250793.703i+(15127.039)j | -32333.023i+(-149746.172)j | 71323.000i+(-0.820)j | -32333.805i+(149743.812)j | -250791.703i+(-15130.930)j | 125765.117i+(-16663.494)j |
| 2 | 33484.441i+(-402189.750)j | 3693.531i+(-26856.219)j | -1894.167i+(13964.823)j | -10609.043i+(-717.919)j | 3241.179i+(1331.265)j | 13322.474i+(9583.863)j | 5009.256i+(10694.416)j | 3755.168i+(-13716.403)j |
| 3 | 149770.094i+(27777.438)j | 20003.373i+(6061.663)j | -8557.309i+(2541.991)j | 952.542i+(-2711.704)j | -1270.043i+(5561.949)j | -13581.329i+(5490.076)j | -3573.688i+(1813.838)j | -874.613i+(9400.137)j |
| 4 | -34267.289i+(-98422.602)j | -5848.770i+(2166.054)j | -4867.462i+(-509.388)j | -6463.121i+(-2644.090)j | -4056.308i+(-2708.740)j | 4171.180i+(-13199.579)j | 1923.964i+(2777.010)j | -5828.639i+(-12452.047)j |
| 5 | 175707.000i+(-0.760)j | 3528.460i+(2486.187)j | -6849.934i+(-6815.988)j | 3952.362i+(-1897.818)j | -6293.000i+(-0.306)j | 3952.618i+(1897.861)j | -6849.775i+(6815.824)j | 3528.691i+(-2486.229)j |
| 6 | -34267.344i+(98420.062)j | -5828.696i+(12451.844)j | 1924.085i+(-2776.620)j | 4171.105i+(13199.832)j | -4056.195i+(2708.584)j | -6462.333i+(2643.988)j | -4866.903i+(509.501)j | -5848.465i+(-2166.022)j |
| 7 | 149772.312i+(-27779.312)j | -874.656i+(-9399.830)j | -3574.031i+(-1813.982)j | -13581.559i+(-5490.298)j | -1269.811i+(-5562.207)j | 952.894i+(2711.513)j | -8557.688i+(-2542.264)j | 20003.127i+(-6061.051)j |
| 8 | 33488.996i+(402187.688)j | 3755.277i+(13715.463)j | 5008.944i+(-10694.100)j | 13322.657i+(-9584.121)j | 3241.433i+(-1331.182)j | -10608.887i+(718.045)j | -1894.748i+(-13964.158)j | 3692.626i+(26857.352)j |

For M=4, N=3

```
atar@ubuntu:~/Desktop/hw5$ ./hw5 -i inputfile -j inputfile2 -o output.csv -n 3 -m 4
2022-05-22 18:08:33,Two matrices of size 8x8 have been read. The number of threads is 4
2022-05-22 18:08:33,Thread 1 has reached the rendezvous point in 0.000512 seconds.
2022-05-22 18:08:33,Thread 4 has reached the rendezvous point in 0.000610 seconds.
2022-05-22 18:08:33,Thread 3 has reached the rendezvous point in 0.000785 seconds.
2022-05-22 18:08:33,Thread 2 has reached the rendezvous point in 0.000811 seconds.
2022-05-22 18:08:33,Thread 2 is advancing to the second part.
2022-05-22 18:08:33,Thread 3 is advancing to the second part.
2022-05-22 18:08:33,Thread 4 is advancing to the second part.
2022-05-22 18:08:33,Thread 1 is advancing to the second part.
2022-05-22 18:08:33,Thread 3 has has finished the second part in 0.001139 seconds.
2022-05-22 18:08:33,Thread 2 has has finished the second part in 0.001276 seconds.
2022-05-22 18:08:33,Thread 4 has has finished the second part in 0.001306 seconds.
2022-05-22 18:08:33,Thread 1 has has finished the second part in 0.001448 seconds.
2022-05-22 18:08:33,The process has written the output file. The total time spent is 0.001859 seconds.
atar@ubuntu:~/Desktop/hw5$
```

Output File(CSV Format)

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | 4105035.000i+(0.000)j | 125758.219i+(16662.205)j | -250793.703i+(15127.039)j | -32333.023i+(-149746.172)j | 71323.000i+(-0.820)j | -32333.805i+(149743.812)j | -250791.703i+(-15130.930)j | 125765.117i+(-16663.494)j |
| 2 | 33484.441i+(-402189.750)j | 3693.531i+(-26856.219)j | -1894.167i+(13964.823)j | -10609.043i+(-717.919)j | 3241.179i+(1331.265)j | 13322.474i+(9583.863)j | 5009.256i+(10694.416)j | 3755.168i+(-13716.403)j |
| 3 | 149770.094i+(27777.438)j | 20003.373i+(6061.663)j | -8557.309i+(2541.991)j | 952.542i+(-2711.704)j | -1270.043i+(5561.949)j | -13581.329i+(5490.076)j | -3573.688i+(1813.838)j | -874.613i+(9400.137)j |
| 4 | -34267.289i+(-98422.602)j | -5848.770i+(2166.054)j | -4867.462i+(-509.388)j | -6463.121i+(-2644.090)j | -4056.308i+(-2708.740)j | 4171.180i+(-13199.579)j | 1923.964i+(2777.010)j | -5828.639i+(-12452.047)j |
| 5 | 175707.000i+(-0.760)j | 3528.460i+(2486.187)j | -6849.934i+(-6815.988)j | 3952.362i+(-1897.818)j | -6293.000i+(-0.306)j | 3952.618i+(1897.861)j | -6849.775i+(6815.824)j | 3528.691i+(-2486.229)j |
| 6 | -34267.344i+(98420.062)j | -5828.696i+(12451.844)j | 1924.085i+(-2776.620)j | 4171.105i+(13199.832)j | -4056.195i+(2708.584)j | -6462.333i+(2643.988)j | -4866.903i+(509.501)j | -5848.465i+(-2166.022)j |
| 7 | 149772.312i+(-27779.312)j | -874.656i+(-9399.830)j | -3574.031i+(-1813.982)j | -13581.559i+(-5490.298)j | -1269.811i+(-5562.207)j | 952.894i+(2711.513)j | -8557.688i+(-2542.264)j | 20003.127i+(-6061.051)j |
| 8 | 33488.996i+(402187.688)j | 3755.277i+(13715.463)j | 5008.944i+(-10694.100)j | 13322.657i+(-9584.121)j | 3241.433i+(-1331.182)j | -10608.887i+(718.045)j | -1894.748i+(-13964.158)j | 3692.626i+(26857.352)j |

Conclusion;

According to the tests, when the dimensions of the matrices are increased, they have increased spend time. When the number of threads is increased, the amount of spend time has increased again. In this above part, theoretically, when the number of threads increases, it is expected that the spend time will decrease, but this theory could not be observed depending on the number of cores in my computer. However, in the example below, it has been observed that when the number of threads increases in the example made in a larger file, the spend time decreases. As a result the advantage of threads is understood with this assignment.

```
atar@ubuntu:~/Desktop/hw5$ ./hw5 -i inputfile -j inputfile2 -o output.csv -n 7 -m 4
2022-05-22 18:26:06,Two matrices of size 128x128 have been read. The number of threads is 4
2022-05-22 18:26:06,Thread 1 has reached the rendezvous point in 0.002559 seconds.
2022-05-22 18:26:06,Thread 2 has reached the rendezvous point in 0.006389 seconds.
2022-05-22 18:26:06,Thread 4 has reached the rendezvous point in 0.008392 seconds.
2022-05-22 18:26:06,Thread 3 has reached the rendezvous point in 0.008604 seconds.
2022-05-22 18:26:06,Thread 3 is advancing to the second part.
2022-05-22 18:26:06,Thread 1 is advancing to the second part.
2022-05-22 18:26:06,Thread 4 is advancing to the second part.
2022-05-22 18:26:06,Thread 2 is advancing to the second part.
2022-05-22 18:26:06,Thread 3 has has finished the second part in 12.807891 seconds.
2022-05-22 18:26:06,Thread 1 has has finished the second part in 12.893166 seconds.
2022-05-22 18:26:06,Thread 2 has has finished the second part in 12.985047 seconds.
2022-05-22 18:26:06,Thread 4 has has finished the second part in 13.038005 seconds.
2022-05-22 18:26:09,The process has written the output file. The total time spent is 13.081710 seconds.
atar@ubuntu:~/Desktop/hw5$ ./hw5 -i inputfile -j inputfile2 -o output.csv -n 7 -m 8
2022-05-22 18:26:28,Two matrices of size 128x128 have been read. The number of threads is 8
2022-05-22 18:26:28,Thread 3 has reached the rendezvous point in 0.001150 seconds.
2022-05-22 18:26:28,Thread 2 has reached the rendezvous point in 0.001797 seconds.
2022-05-22 18:26:28,Thread 8 has reached the rendezvous point in 0.003622 seconds.
2022-05-22 18:26:28,Thread 1 has reached the rendezvous point in 0.003921 seconds.
2022-05-22 18:26:28,Thread 5 has reached the rendezvous point in 0.004715 seconds.
2022-05-22 18:26:28,Thread 6 has reached the rendezvous point in 0.005204 seconds.
2022-05-22 18:26:28,Thread 7 has reached the rendezvous point in 0.005949 seconds.
2022-05-22 18:26:28,Thread 4 has reached the rendezvous point in 0.006684 seconds.
2022-05-22 18:26:28,Thread 1 is advancing to the second part.
2022-05-22 18:26:28,Thread 3 is advancing to the second part.
2022-05-22 18:26:28,Thread 2 is advancing to the second part.
2022-05-22 18:26:28,Thread 8 is advancing to the second part.
2022-05-22 18:26:28,Thread 6 is advancing to the second part.
2022-05-22 18:26:28,Thread 5 is advancing to the second part.
2022-05-22 18:26:28,Thread 4 is advancing to the second part.
2022-05-22 18:26:28,Thread 7 is advancing to the second part.
2022-05-22 18:26:28,Thread 4 has has finished the second part in 12.824573 seconds.
2022-05-22 18:26:28,Thread 2 has has finished the second part in 12.854909 seconds.
2022-05-22 18:26:28,Thread 3 has has finished the second part in 12.856206 seconds.
2022-05-22 18:26:28,Thread 6 has has finished the second part in 12.857018 seconds.
2022-05-22 18:26:28,Thread 7 has has finished the second part in 12.917280 seconds.
2022-05-22 18:26:28,Thread 5 has has finished the second part in 12.924768 seconds.
2022-05-22 18:26:28,Thread 8 has has finished the second part in 12.945101 seconds.
2022-05-22 18:26:28,Thread 1 has has finished the second part in 12.951608 seconds.
2022-05-22 18:26:32,The process has written the output file. The total time spent is 12.988241 seconds.
```