CSE344
System Programming

Assignment #5
Thread Synchronization
Report

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Step-by-Step Algorithm

1) **Process** gets all necessary arguments, checks if they are valid, stores file paths locally and stores n&m globally.

2) **Process** reads input files and stores them in matrices A and B globally.

3) **Process** starts the timer and creates m **thread**s.

4) **Process** joins and waits for **thread**s to return

5) Each **thread** calculates the $2^n/m$ columns of C (e.g. If there are 4 **thread**s and matrices are 16x16, **Thread**0 calculates columns 0,5,9,13)

6) Each **thread** arrives at rendezvous point and waits for others to arrive too.

7) Each **thread** calculates Fourier transform values of the cells of their columns.

8) Each **thread** returns their columns in an array which has the size $2^n/m$ x $2^{n.}$

9) **Process** collects the outputs and places them in Fourier matrix according to the returned **thread**s number.

10) **Process** writes the resulting matrix to output file in CSV format.

11) **Process** stops the timer, clears after itself and returns.

Test Cases & Results

Test Group 1 (n = 3)

Result

	A	B	C	D	E	F	G	H
1	5607316.000+0.000i	-45884.272+9825.218i	-67242.000-7628.000i	-58207.728+65637.218i	5864.000-0.000i	-58207.728-65637.218i	-67242.000+7628.000i	-45884.272-9825.218i
2	-6548.441+16170.502i	2084.525+282.551i	996.029+390.449i	1253.958-603.761i	508.304+1237.274i	389.141-1092.630i	1098.130+1165.927i	957.206+360.212i
3	-5511.000+14375.000i	588.018+217.793i	-249.000+745.000i	-302.777-544.531i	15.000+629.000i	-928.018-1173.793i	-567.000+707.000i	50.777+476.531i
4	28542.441+24902.502i	-667.958+472.239i	-818.130+311.927i	527.475+1916.551i	-726.304+1185.274i	-775.206+20.212i	-940.029+196.449i	22.859-246.630i
5	-37026.000-0.000i	622.167-592.864i	818.000+74.000i	429.833-812.864i	1062.000+0.000i	429.833+812.864i	818.000-74.000i	622.167+592.864i
6	28542.441-24902.502i	22.859+246.630i	-940.029-196.449i	-775.206-20.212i	-726.304-1185.274i	527.475-1916.551i	-818.130-311.927i	-667.958-472.239i
7	-5511.000-14375.000i	50.777-476.531i	-567.000-707.000i	-928.018+1173.793i	15.000-629.000i	-302.777+544.531i	-249.000-745.000i	588.018-217.793i
8	-6548.441-16170.502i	957.206-360.212i	1098.130-1165.927i	389.141+1092.630i	508.304-1237.274i	1253.958+603.761i	996.029-390.449i	2084.525-282.551i

Test 1.1

m = 2

```
gokbey@gokbey-ABRA-A5-V15-3:~/Desktop/sysprog_hw5$ ./hw5 -i filePath1 -j filePath2 -o output.csv -n 3 -m 2
2022-05-18 14:50:39:491|Two matrices of size 8x8 have been read. The number of threads is 2
2022-05-18 14:50:39:492|Thread 0 has reached the rendezvous point in 0.0001 seconds.
2022-05-18 14:50:39:492|Thread 1 has reached the rendezvous point in 0.0001 seconds.
2022-05-18 14:50:39:492|Thread 1 is advancing to the second part.
2022-05-18 14:50:39:492|Thread 0 is advancing to the second part.
2022-05-18 14:50:39:493|Thread 0 has finished the second part in 0.0009 seconds.
2022-05-18 14:50:39:493|Thread 1 has finished the second part in 0.0010 seconds.
2022-05-18 14:50:39:496|The process has written the output file. The total time spent is 0.0042 seconds.
```

Test 1.2

m = 4

```
gokbey@gokbey-ABRA-A5-V15-3:~/Desktop/sysprog_hw5$ ./hw5 -i filePath1 -j filePath2 -o output.csv -n 3 -m 4
2022-05-18 15:03:01:719|Two matrices of size 8x8 have been read. The number of threads is 4
2022-05-18 15:03:01:719|Thread 1 has reached the rendezvous point in 0.0001 seconds.
2022-05-18 15:03:01:719|Thread 2 has reached the rendezvous point in 0.0001 seconds.
2022-05-18 15:03:01:719|Thread 3 has reached the rendezvous point in 0.0000 seconds.
2022-05-18 15:03:01:719|Thread 0 has reached the rendezvous point in 0.0002 seconds.
2022-05-18 15:03:01:720|Thread 0 is advancing to the second part.
2022-05-18 15:03:01:720|Thread 1 is advancing to the second part.
2022-05-18 15:03:01:720|Thread 3 is advancing to the second part.
2022-05-18 15:03:01:720|Thread 2 is advancing to the second part.
2022-05-18 15:03:01:720|Thread 0 has finished the second part in 0.0004 seconds.
2022-05-18 15:03:01:720|Thread 1 has finished the second part in 0.0004 seconds.
2022-05-18 15:03:01:720|Thread 2 has finished the second part in 0.0004 seconds.
2022-05-18 15:03:01:720|Thread 3 has finished the second part in 0.0005 seconds.
2022-05-18 15:03:01:722|The process has written the output file. The total time spent is 0.0027 seconds.
```

Test 1.3

m=8

```
gokbey@gokbey-ABRA-A5-V15-3:~/Desktop/sysprog_hw5$ ./hw5 -i filePath1 -j filePath2 -o output.csv -n 3 -m 8
2022-05-18 14:59:28:446|Two matrices of size 8x8 have been read. The number of threads is 8
2022-05-18 14:59:28:446|Thread 0 has reached the rendezvous point in 0.0001 seconds.
2022-05-18 14:59:28:446|Thread 1 has reached the rendezvous point in 0.0001 seconds.
2022-05-18 14:59:28:446|Thread 2 has reached the rendezvous point in 0.0001 seconds.
2022-05-18 14:59:28:446|Thread 3 has reached the rendezvous point in 0.0001 seconds.
2022-05-18 14:59:28:446|Thread 4 has reached the rendezvous point in 0.0001 seconds.
2022-05-18 14:59:28:446|Thread 5 has reached the rendezvous point in 0.0000 seconds.
2022-05-18 14:59:28:446|Thread 6 has reached the rendezvous point in 0.0001 seconds.
2022-05-18 14:59:28:447|Thread 7 has reached the rendezvous point in 0.0000 seconds.
2022-05-18 14:59:28:447|Thread 7 is advancing to the second part.
2022-05-18 14:59:28:447|Thread 1 is advancing to the second part.
2022-05-18 14:59:28:447|Thread 5 is advancing to the second part.
2022-05-18 14:59:28:447|Thread 4 is advancing to the second part.
2022-05-18 14:59:28:447|Thread 3 is advancing to the second part.
2022-05-18 14:59:28:447|Thread 0 is advancing to the second part.
2022-05-18 14:59:28:447|Thread 2 is advancing to the second part.
2022-05-18 14:59:28:447|Thread 6 is advancing to the second part.
2022-05-18 14:59:28:447|Thread 1 has finished the second part in 0.0004 seconds.
2022-05-18 14:59:28:447|Thread 3 has finished the second part in 0.0004 seconds.
2022-05-18 14:59:28:447|Thread 0 has finished the second part in 0.0003 seconds.
2022-05-18 14:59:28:447|Thread 4 has finished the second part in 0.0003 seconds.
2022-05-18 14:59:28:447|Thread 2 has finished the second part in 0.0004 seconds.
2022-05-18 14:59:28:447|Thread 7 has finished the second part in 0.0005 seconds.
2022-05-18 14:59:28:447|Thread 5 has finished the second part in 0.0007 seconds.
2022-05-18 14:59:28:447|Thread 6 has finished the second part in 0.0003 seconds.
2022-05-18 14:59:28:449|The process has written the output file. The total time spent is 0.0033 seconds.
```

Acceleration Comparison of Test Group 1

My CPU has 4 cores. So, up until 4 threads, the performance should improve.

The time first part takes is too small to use it as a comparison data. So I used second part data for below comparisons.

When m is doubled (2→4), elapsed times in second parts are improved 2 times as expected (~10 → ~5).

When m is doubled again (4→8) while some of the times are improving, there wasn't a clear effect (Thread 4 took 3 unit time but Thread 5 took 7). This was also expected since my CPU has 4 cores and can't run more than 4 threads in truly parallel.

Test Group 2 (n=6)

Resulting Matrix is too big to fit in a page.

Test 2.1

m=2

```
gokbey@gokbey-ABRA-A5-V15-3:~/Desktop/sysprog_hw5$ ./hw5 -i filePath1 -j filePath2 -o output.csv -n 6 -m 2
2022-05-18 15:11:13:968|Two matrices of size 64x64 have been read. The number of threads is 2
2022-05-18 15:11:13:969|Thread 1 has reached the rendezvous point in 0.0005 seconds.
2022-05-18 15:11:13:969|Thread 0 has reached the rendezvous point in 0.0008 seconds.
2022-05-18 15:11:13:969|Thread 0 is advancing to the second part.
2022-05-18 15:11:13:969|Thread 1 is advancing to the second part.
2022-05-18 15:11:14:926|Thread 1 has finished the second part in 0.9572 seconds.
2022-05-18 15:11:15:207|Thread 0 has finished the second part in 1.2379 seconds.
2022-05-18 15:11:15:229|The process has written the output file. The total time spent is 1.2607 seconds.
```

Test 2.2

m=4

```
gokbey@gokbey-ABRA-A5-V15-3:~/Desktop/sysprog_hw5$ ./hw5 -i filePath1 -j filePath2 -o output.csv -n 6 -m 4
2022-05-18 15:13:40:214|Two matrices of size 64x64 have been read. The number of threads is 4
2022-05-18 15:13:40:216|Thread 0 has reached the rendezvous point in 0.0013 seconds.
2022-05-18 15:13:40:216|Thread 1 has reached the rendezvous point in 0.0015 seconds.
2022-05-18 15:13:40:216|Thread 2 has reached the rendezvous point in 0.0014 seconds.
2022-05-18 15:13:40:216|Thread 3 has reached the rendezvous point in 0.0012 seconds.
2022-05-18 15:13:40:216|Thread 3 is advancing to the second part.
2022-05-18 15:13:40:216|Thread 1 is advancing to the second part.
2022-05-18 15:13:40:216|Thread 2 is advancing to the second part.
2022-05-18 15:13:40:216|Thread 0 is advancing to the second part.
2022-05-18 15:13:40:701|Thread 3 has finished the second part in 0.4849 seconds.
2022-05-18 15:13:40:702|Thread 1 has finished the second part in 0.4864 seconds.
2022-05-18 15:13:40:705|Thread 2 has finished the second part in 0.4887 seconds.
2022-05-18 15:13:40:801|Thread 0 has finished the second part in 0.5854 seconds.
2022-05-18 15:13:40:825|The process has written the output file. The total time spent is 0.6111 seconds.
```

Test 2.3

m=8

```
gokbey@gokbey-ABRA-A5-V15-3:~/Desktop/sysprog_hw5$ ./hw5 -i filePath1 -j filePath2 -o output.csv -n 6 -m 8
2022-05-18 15:14:38:497|Two matrices of size 64x64 have been read. The number of threads is 8
2022-05-18 15:14:38:497|Thread 0 has reached the rendezvous point in 0.0006 seconds.
2022-05-18 15:14:38:497|Thread 1 has reached the rendezvous point in 0.0006 seconds.
2022-05-18 15:14:38:498|Thread 2 has reached the rendezvous point in 0.0007 seconds.
2022-05-18 15:14:38:498|Thread 3 has reached the rendezvous point in 0.0008 seconds.
2022-05-18 15:14:38:498|Thread 4 has reached the rendezvous point in 0.0007 seconds.
2022-05-18 15:14:38:498|Thread 7 has reached the rendezvous point in 0.0006 seconds.
2022-05-18 15:14:38:498|Thread 5 has reached the rendezvous point in 0.0006 seconds.
2022-05-18 15:14:38:498|Thread 6 has reached the rendezvous point in 0.0004 seconds.
2022-05-18 15:14:38:498|Thread 7 is advancing to the second part.
2022-05-18 15:14:38:498|Thread 1 is advancing to the second part.
2022-05-18 15:14:38:498|Thread 6 is advancing to the second part.
2022-05-18 15:14:38:498|Thread 0 is advancing to the second part.
2022-05-18 15:14:38:498|Thread 4 is advancing to the second part.
2022-05-18 15:14:38:498|Thread 2 is advancing to the second part.
2022-05-18 15:14:38:498|Thread 3 is advancing to the second part.
2022-05-18 15:14:38:498|Thread 5 is advancing to the second part.
2022-05-18 15:14:38:899|Thread 2 has finished the second part in 0.4012 seconds.
2022-05-18 15:14:38:900|Thread 6 has finished the second part in 0.4017 seconds.
2022-05-18 15:14:38:905|Thread 3 has finished the second part in 0.4069 seconds.
2022-05-18 15:14:38:905|Thread 4 has finished the second part in 0.4073 seconds.
2022-05-18 15:14:38:906|Thread 5 has finished the second part in 0.4076 seconds.
2022-05-18 15:14:38:906|Thread 0 has finished the second part in 0.4080 seconds.
2022-05-18 15:14:38:938|Thread 1 has finished the second part in 0.4404 seconds.
2022-05-18 15:14:38:977|Thread 7 has finished the second part in 0.4787 seconds.
2022-05-18 15:14:39:7|The process has written the output file. The total time spent is 0.5100 seconds.
```

Test 2.4

m=16

```
gokbey@gokbey-ABRA-A5-V15-3:~/Desktop/sysprog_hw5$ ./hw5 -i filePath1 -j filePath2 -o output.csv -n 6 -m 16
2022-05-18 15:15:54:726|Two matrices of size 64x64 have been read. The number of threads is 16
2022-05-18 15:15:54:727|Thread 0 has reached the rendezvous point in 0.0002 seconds.
2022-05-18 15:15:54:727|Thread 1 has reached the rendezvous point in 0.0002 seconds.
2022-05-18 15:15:54:727|Thread 2 has reached the rendezvous point in 0.0003 seconds.
2022-05-18 15:15:54:728|Thread 4 has reached the rendezvous point in 0.0003 seconds.
2022-05-18 15:15:54:728|Thread 3 has reached the rendezvous point in 0.0004 seconds.
2022-05-18 15:15:54:728|Thread 5 has reached the rendezvous point in 0.0003 seconds.
2022-05-18 15:15:54:728|Thread 6 has reached the rendezvous point in 0.0003 seconds.
2022-05-18 15:15:54:728|Thread 8 has reached the rendezvous point in 0.0003 seconds.
2022-05-18 15:15:54:728|Thread 7 has reached the rendezvous point in 0.0005 seconds.
2022-05-18 15:15:54:728|Thread 11 has reached the rendezvous point in 0.0002 seconds.
2022-05-18 15:15:54:728|Thread 12 has reached the rendezvous point in 0.0002 seconds.
2022-05-18 15:15:54:728|Thread 9 has reached the rendezvous point in 0.0005 seconds.
2022-05-18 15:15:54:728|Thread 10 has reached the rendezvous point in 0.0005 seconds.
2022-05-18 15:15:54:728|Thread 13 has reached the rendezvous point in 0.0004 seconds.
2022-05-18 15:15:54:729|Thread 14 has reached the rendezvous point in 0.0007 seconds.
2022-05-18 15:15:54:729|Thread 15 has reached the rendezvous point in 0.0002 seconds.
2022-05-18 15:15:54:729|Thread 15 is advancing to the second part.
2022-05-18 15:15:54:729|Thread 13 is advancing to the second part.
2022-05-18 15:15:54:729|Thread 5 is advancing to the second part.
2022-05-18 15:15:54:729|Thread 0 is advancing to the second part.
2022-05-18 15:15:54:729|Thread 8 is advancing to the second part.
2022-05-18 15:15:54:729|Thread 4 is advancing to the second part.
2022-05-18 15:15:54:729|Thread 6 is advancing to the second part.
2022-05-18 15:15:54:729|Thread 1 is advancing to the second part.
2022-05-18 15:15:54:729|Thread 12 is advancing to the second part.
2022-05-18 15:15:54:729|Thread 7 is advancing to the second part.
2022-05-18 15:15:54:729|Thread 2 is advancing to the second part.
2022-05-18 15:15:54:729|Thread 3 is advancing to the second part.
2022-05-18 15:15:54:729|Thread 14 is advancing to the second part.
2022-05-18 15:15:54:738|Thread 11 is advancing to the second part.
2022-05-18 15:15:54:754|Thread 10 is advancing to the second part.
2022-05-18 15:15:54:757|Thread 9 is advancing to the second part.
2022-05-18 15:15:54:980|Thread 4 has finished the second part in 0.2508 seconds.
2022-05-18 15:15:54:989|Thread 15 has finished the second part in 0.2595 seconds.
2022-05-18 15:15:54:996|Thread 5 has finished the second part in 0.2664 seconds.
2022-05-18 15:15:55:16|Thread 7 has finished the second part in 0.2857 seconds.
2022-05-18 15:15:55:72|Thread 1 has finished the second part in 0.3423 seconds.
2022-05-18 15:15:55:77|Thread 3 has finished the second part in 0.3465 seconds.
2022-05-18 15:15:55:90|Thread 11 has finished the second part in 0.3520 seconds.
2022-05-18 15:15:55:115|Thread 0 has finished the second part in 0.3855 seconds.
2022-05-18 15:15:55:119|Thread 10 has finished the second part in 0.3653 seconds.
2022-05-18 15:15:55:129|Thread 9 has finished the second part in 0.3710 seconds.
2022-05-18 15:15:55:129|Thread 14 has finished the second part in 0.3940 seconds.
2022-05-18 15:15:55:131|Thread 13 has finished the second part in 0.3569 seconds.
2022-05-18 15:15:55:149|Thread 8 has finished the second part in 0.4197 seconds.
2022-05-18 15:15:55:165|Thread 12 has finished the second part in 0.4347 seconds.
2022-05-18 15:15:55:168|Thread 2 has finished the second part in 0.4376 seconds.
2022-05-18 15:15:55:194|Thread 6 has finished the second part in 0.4652 seconds.
2022-05-18 15:15:55:216|The process has written the output file. The total time spent is 0.4901 seconds.
```

Acceleration Comparison of Test Group 2

As in the Test Group 1, there is no meaningful acceleration after 4 threads since my CPU has 4 cores.