**Name: Fan Feng**

**Assignment: 3**

**Course: CPSC 424/524**

**Modules:**

[ff242@omega1 ff242\_ps3\_cpsc424]$ module list

Currently Loaded Modules:

1) StdEnv (S) 2) Langs/Intel/15.0.2 3) MPI/OpenMPI/2.1.1-intel15

Where:

S: Module is Sticky, requires --force to unload or purge

**Environment:**

[ff242@omega1 ff242\_ps3\_cpsc424]$ which icc

/home/apps/fas/Langs/Intel/2015\_update2/composer\_xe\_2015.2.164/bin/intel64/icc

[ff242@omega1 ff242\_ps3\_cpsc424]$ icc --version

icc (ICC) 15.0.2 20150121

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**Output:**

See appendix at the end of this report.

**Task 1 (Serial Program):**

sbatch scripts/build-run.sh

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | 1000 | 2000 | 4000 | 8000 |
| Time (#1) | 0.1826 | 2.8367 | 19.5150 | 154.6797 |
| Time (#2) | 0.1829 | 2.3156 | 19.6447 | 155.7885 |
| Time (#3) | 0.1829 | 2.3171 | 19.6353 | 155.5739 |
| Average Time | 0.1828 | 2.4898 | 19.5983 | 155.3474 |
| F-norm (#1) | 0 | 1 | 5 | 28 |
| F-norm (#2) | 0 | 1 | 5 | 28 |
| F-norm (#3) | 0 | 1 | 5 | 28 |
| Average F-norm | 0 | 1 | 5 | 28 |

Note: F-norm of Error in the table is in .

**Task 2:**

**Part A**

sbatch scripts/mpi-blocking-2a-1.sh

sbatch scripts/mpi-blocking-2a-2.sh

sbatch scripts/mpi-blocking-2a-4.sh

sbatch scripts/mpi-blocking-2a-8.sh

**p = 1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | 1000 | 2000 | 4000 | 8000 |
| Total Time (#1) | 0.1826 | 2.3173 | 19.4314 | 154.8959 |
| Total Time (#2) | 0.1845 | 2.3348 | 19.4398 | 154.4387 |
| Total Time (#3) | 0.1847 | 2.3239 | 19.7273 | 156.2725 |
| Average Total Time | 0.1839 | 2.3253 | 19.5328 | 155.2024 |
| Average F-norm | 0 | 1 | 5 | 28 |

Note that the result is similar to that in task 1.

**p = 2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | 1000 | 2000 | 4000 | 8000 |
| P0 Total Time | 0.1371 | 1.5786 | 15.1353 | 119.6891 |
| P1 Total Time | 0.1360 | 1.5768 | 15.1343 | 119.6874 |
| F-norm | 0 | 1 | 5 | 28 |

**p = 4**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | 1000 | 2000 | 4000 | 8000 |
| P0 Total Time | 0.0963 | 0.7260 | 9.9975 | 80.4681 |
| P1 Total Time | 0.0814 | 0.5944 | 8.1787 | 67.1164 |
| P2 Total Time | 0.0950 | 0.7228 | 9.9849 | 80.4252 |
| P3 Total Time | 0.0959 | 0.7251 | 9.9955 | 80.4660 |
| F-norm | 0 | 1 | 5 | 28 |

**p = 8**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | 1000 | 2000 | 4000 | 8000 |
| P0 Total Time | 0.0548 | 0.4057 | 6.2991 | 53.1475 |
| P1 Total Time | 0.0481 | 0.3514 | 5.4492 | 46.7165 |
| P2 Total Time | 0.0500 | 0.3553 | 5.4609 | 46.7612 |
| P3 Total Time | 0.0520 | 0.3644 | 5.5821 | 47.8310 |
| P4 Total Time | 0.0538 | 0.3838 | 6.0574 | 51.3036 |
| P5 Total Time | 0.0544 | 0.3920 | 6.0650 | 51.5161 |
| P6 Total Time | 0.0547 | 0.4022 | 6.2920 | 53.1248 |
| P7 Total Time | 0.0548 | 0.4043 | 6.2971 | 53.1452 |
| F-norm | 0 | 1 | 5 | 28 |

To assess raw performance, one can compare the total time of process 0. As the number of processes increases, the total time decreases.

In terms of scalability, as p doubles from 1 to 2, 4, 8, performance gets closer and closer to twice as good, although it’s not really possible to achieve linear improvement on performance with respect to the number of processes.

From p = 1 to p = 2, (154 - 119) / 154 = 23%.

From p = 2 to p = 4, (119 - 80) / 119 = 33%.

From p = 4 to p = 8, (80 - 53) / 80 = 34%.

As for load balance, loads are distributed pretty evenly. Although note that processes with higher rank tend to take more time than the ones with lower rank, this is because high rank processes have more non-zero elements in matrix A then lower rank processes, thus computation takes more time.

**Part B**

sbatch scripts/mpi-blocking-2b-p4n1.sh

sbatch scripts/mpi-blocking-2b-p4n2.sh

sbatch scripts/mpi-blocking-2b-p4n4.sh

sbatch scripts/mpi-blocking-2b-p8n1.sh

sbatch scripts/mpi-blocking-2b-p8n2.sh

sbatch scripts/mpi-blocking-2b-p8n4.sh

**#node = 1, p = 4, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 43.9366 23.1260 67.0626

2 53.5871 26.7711 80.3583

3 65.0555 15.3433 80.3988

0 17.3633 63.0367 80.4000

F-norm of Error: 0.0000000028

**#node = 2, p = 4, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 35.2796 22.3059 57.5855

2 49.9221 21.8894 71.8114

3 56.6813 15.1726 71.8539

0 13.6059 58.2479 71.8538

F-norm of Error: 0.0000000028

**#node = 4, p = 4, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 35.4460 22.1138 57.5599

2 49.6578 22.1289 71.7867

3 56.6310 15.1986 71.8296

0 13.5286 58.3010 71.8296

F-norm of Error: 0.0000000028

**#node = 1, p = 8, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 17.4118 29.5162 46.9279

2 21.7068 25.2684 46.9752

3 31.9667 16.0709 48.0376

4 31.4902 20.0279 51.5181

5 38.3784 13.3140 51.6924

6 36.9487 16.3864 53.3351

7 41.8665 11.4885 53.3550

0 5.5352 47.8215 53.3567

F-norm of Error: 0.0000000028

**#node = 2, p = 8, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 11.2412 25.7872 37.0284

2 15.6892 21.3634 37.0526

3 21.2794 17.1515 38.4309

4 27.4727 14.1689 41.6415

5 30.1916 11.4710 41.6626

6 31.8071 11.6271 43.4342

7 32.7451 10.7103 43.4554

0 2.9059 40.5496 43.4555

F-norm of Error: 0.0000000028

**#node = 4, p = 8, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 9.3058 22.7280 32.0338

2 15.3551 16.8338 32.1888

3 19.7139 14.3199 34.0338

4 23.4236 12.4263 35.8499

5 25.9124 10.8562 36.7685

6 27.8797 9.7825 37.6622

7 28.7091 8.9741 37.6833

0 2.4276 35.2558 37.6833

F-norm of Error: 0.0000000028

In terms of raw performance, total time of p = 8 is less than that of p = 4, as seen in part A. For the same number of processes with different number of nodes, performance improves as the number of nodes increases.

In terms of computation time vs. communication time, as rank increases, the computation time increases, due to the fact that matrix A is triangular. With total time being roughly the same, the communication time decreases as rank increases.

As for load balance, similar to part A, loads are distributed pretty evenly, although there are notable differences between processes with lower rank and ones with higher rank.

Possible improvements include:

1. Using collectives, I tried using collectives initially, but had various problems, thus ended up using blocking non-collective send and recv only. Collectives can potentially reduce the overhead of the for loop by scattering and gathering, therefore can perhaps improve performance.
2. Using non-blocking communication. This can improve performance since send and recv operations return immediately so that computations don’t have to wait until communication is finished.
3. To achieve better load balance across processes, one possible approach is to split matrix A and B by the number of elements, instead of by number of rows. This can achieve better load balance since computation time will be closer to each other, although this does make it more complex to implement.

**Task 3:**

**Part A**

sbatch scripts/mpi-non-blocking-3a-1.sh

sbatch scripts/mpi-non-blocking-3a-2.sh

sbatch scripts/mpi-non-blocking-3a-4.sh

sbatch scripts/mpi-non-blocking-3a-8.sh

**p = 1**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | 1000 | 2000 | 4000 | 8000 |
| Total Time (#1) | 0.1766 | 2.2575 | 19.3389 | 153.3338 |
| F-norm | 0 | 1 | 5 | 28 |

**p = 2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | 1000 | 2000 | 4000 | 8000 |
| P0 Total Time | 0.1289 | 1.5393 | 14.8599 | 117.5159 |
| P1 Total Time | 0.1289 | 1.5384 | 14.8592 | 117.5150 |
| F-norm | 0 | 1 | 5 | 28 |

**p = 4**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | 1000 | 2000 | 4000 | 8000 |
| P0 Total Time | 0.0897 | 0.6895 | 8.7717 | 79.7506 |
| P1 Total Time | 0.0763 | 0.5662 | 8.1115 | 66.6237 |
| P2 Total Time | 0.0896 | 0.6793 | 8.7710 | 79.7496 |
| P3 Total Time | 0.0734 | 0.5619 | 8.0905 | 65.3819 |
| F-norm | 0 | 1 | 5 | 28 |

**p = 8**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N | 1000 | 2000 | 4000 | 8000 |
| P0 Total Time | 0.0497 | 0.3544 | 6.1669 | 51.5719 |
| P1 Total Time | 0.0419 | 0.3039 | 4.9550 | 43.7540 |
| P2 Total Time | 0.0432 | 0.3041 | 4.8305 | 43.3229 |
| P3 Total Time | 0.0451 | 0.3058 | 5.2417 | 46.2949 |
| P4 Total Time | 0.0473 | 0.3099 | 5.9386 | 49.7890 |
| P5 Total Time | 0.0484 | 0.3408 | 5.8917 | 50.0115 |
| P6 Total Time | 0.0496 | 0.3544 | 6.1660 | 51.5711 |
| P7 Total Time | 0.0410 | 0.2986 | 4.8499 | 43.3100 |
| F-norm | 0 | 1 | 5 | 28 |

Comparing Task 2 with Task 3, the raw performance in Task 3 is better, although the improvement is not significant (approximately by a few percent).

In terms of scalability, Task 3 has similar behaviors to Task 2.

As for load balance, again loads are distributed pretty evenly, and the distribution is arguably better than that in Task 2.

**Part B**

sbatch scripts/mpi-non-blocking-3b-p4n1.sh

sbatch scripts/mpi-non-blocking-3b-p4n2.sh

sbatch scripts/mpi-non-blocking-3b-p4n4.sh

sbatch scripts/mpi-non-blocking-3b-p8n1.sh

sbatch scripts/mpi-non-blocking-3b-p8n2.sh

sbatch scripts/mpi-non-blocking-3b-p8n4.sh

**#node = 1, p = 4, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

3 65.1012 0.6742 65.7754

1 43.9436 23.1609 67.1045

2 53.7825 26.6072 80.3898

0 17.4252 62.9656 80.3908

F-norm of Error: 0.0000000028

**#node = 2, p = 4, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 35.3305 7.9969 43.3274

3 56.8282 0.2226 57.0508

2 50.0478 11.1964 61.2442

0 13.6601 47.5842 61.2442

F-norm of Error: 0.0000000028

**#node = 4, p = 4, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 35.4480 7.7223 43.1703

3 56.6842 0.1935 56.8776

2 49.5883 11.2227 60.8109

0 13.5497 47.2613 60.8110

F-norm of Error: 0.0000000028

**#node = 1, p = 8, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

7 43.1209 0.3683 43.4891

2 21.6303 21.9607 43.5910

1 17.3946 26.6430 44.0376

3 32.1015 14.5316 46.6330

4 31.5812 18.4714 50.0526

5 39.5601 10.7574 50.3174

6 36.2497 15.6158 51.8655

0 5.6463 46.2202 51.8666

F-norm of Error: 0.0000000028

**#node = 2, p = 8, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

2 15.8147 17.4663 33.2810

1 11.0187 22.2701 33.2889

3 21.1312 12.1620 33.2932

4 27.9032 5.4257 33.3290

7 34.3601 0.2296 34.5897

5 31.6402 6.1593 37.7995

6 32.2975 6.3359 38.6334

0 3.2352 35.3983 38.6335

F-norm of Error: 0.0000000028

**#node = 4, p = 8, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

2 15.3636 12.4946 27.8582

3 19.7776 8.1232 27.9007

1 9.3208 18.7995 28.1203

4 23.4455 4.7024 28.1480

7 28.7278 0.2096 28.9374

5 26.0403 6.5530 32.5933

6 27.8907 5.4294 33.3201

0 2.4828 30.8375 33.3202

F-norm of Error: 0.0000000028

Again, overall performance is better than that in Task 2, although only by a small margin. Similar to Task 2B, performance improves as the number of nodes increases.

For scalability, the same conclusion can be drawn as in Task 3A.

In terms of computation time vs. communication time, the root process has the minimum computation time and the maximum communication time. Unlike Task 2B, the positive relationship between rank and computation time is much less obvious in Task 3B. Also, the difference of computation time or communication time between different processes are less significant than in Task 2B.

As for load balance, a better distribution can be observed in Task 3B than that in Task 2B, although still not perfect. It is more obvious when observing computation and/or communication time, in a sense that different processes now have closer computation and/or communication time than they do in Task 2B.

**Task 4:**

sbatch scripts/mpi-load-balance-4-p4n1.sh

sbatch scripts/mpi-load-balance-4-p4n2.sh

sbatch scripts/mpi-load-balance-4-p4n4.sh

sbatch scripts/mpi-load-balance-4-p8n1.sh

sbatch scripts/mpi-load-balance-4-p8n2.sh

sbatch scripts/mpi-load-balance-4-p8n4.sh

Load balance improves from Task 2 to Task 3, although not achieving perfect distribution.

One possible approach to further improve load balance is to distribute elements in both triangular matrices evenly, rather than distributing rows and columns evenly.

The intuition is that although each process performs exactly p multiplication of blocks, the number of operations between processes is different. Since we only rotate matrix B not A, processes with lower ranks have less computation to do than ones with higher ranks. Distributing elements rather than rows and/or columns will ideally fix this issue and result in better load balance.

**#node = 1, p = 4, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

3 35.7390 31.3485 67.0876

1 45.4326 21.6711 67.1037

2 42.6000 25.3603 67.9604

0 56.8059 11.1555 67.9614

F-norm of Error: 0.0000000028

**#node = 2, p = 4, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

3 31.1711 4.9254 36.0966

2 35.3526 2.8196 38.1722

1 40.7482 0.4001 41.1483

0 49.4325 0.1286 49.5610

F-norm of Error: 0.0000000028

**#node = 4, p = 4, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

3 30.8890 4.9952 35.8842

2 35.0674 2.7993 37.8667

1 40.4260 0.1827 40.6088

0 49.0441 0.1364 49.1805

F-norm of Error: 0.0000000028

**#node = 1, p = 8, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

7 23.6555 22.0014 45.6570

5 26.4975 19.1908 45.6883

3 30.0559 15.6549 45.7108

1 34.1343 11.5990 45.7334

2 33.4359 12.5005 45.9365

6 25.5985 20.8575 46.4560

4 29.9081 16.5929 46.5009

0 40.2060 6.2959 46.5019

F-norm of Error: 0.0000000028

**#node = 2, p = 8, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

2 20.9752 1.0726 22.0479

3 19.4235 2.6567 22.0802

4 18.1091 3.9944 22.1035

5 16.9903 5.1390 22.1293

6 15.9353 6.2204 22.1557

7 15.0224 7.2026 22.2250

1 22.8530 0.5827 23.4357

0 24.3120 0.1514 24.4634

F-norm of Error: 0.0000000028

**#node = 4, p = 8, N = 8000**

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

2 20.9752 1.0726 22.0479

3 19.4235 2.6567 22.0802

4 18.1091 3.9944 22.1035

5 16.9903 5.1390 22.1293

6 15.9353 6.2204 22.1557

7 15.0224 7.2026 22.2250

1 22.8530 0.5827 23.4357

0 24.3120 0.1514 24.4634

F-norm of Error: 0.0000000028

The load balance is much better than in previous tasks, leading to an improvement on raw performance. Note that when p = 4, n = 2 and p = 4, n = 4, the load balance is not perfect, which is probably due to some communication overhead between nodes.

**Task 5:**

TODO: Current program breaks with N = 7644 and p = 7.

**Appendix:**

**Task 1**

[ff242@omega1 PS3]$ cat slurm-1193040.out

/home/fas/cpsc424/ff242/PS3

c30n01

1

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c serial.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul.c

mpicc -o serial -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing serial.o matmul.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

N TIME (secs) F-norm of Error

----- ------------- -----------------

1000 0.1831 0.0000000000

2000 2.3240 0.0000000001

4000 19.8099 0.0000000005

8000 154.5914 0.0000000028

real 3m0.119s

user 2m57.547s

sys 0m0.443s

**Task 2A**

[ff242@omega1 PS3]$ cat slurm-1193042.out

/home/fas/cpsc424/ff242/PS3

c30n01

1

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Total Time

------- ----------

N = 1000

0 0.1862

F-norm of Error: 0.0000000000

N = 2000

0 2.3224

F-norm of Error: 0.0000000001

N = 4000

0 19.6987

F-norm of Error: 0.0000000005

N = 8000

0 156.1402

F-norm of Error: 0.0000000028

real 3m1.427s

user 2m59.857s

sys 0m0.552s

[ff242@omega1 PS3]$ cat slurm-1193050.out

/home/fas/cpsc424/ff242/PS3

c30n01

2

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Total Time

------- ----------

N = 1000

1 0.1342

0 0.1358

F-norm of Error: 0.0000000000

N = 2000

1 1.5803

0 1.5824

F-norm of Error: 0.0000000001

N = 4000

1 15.0862

0 15.0875

F-norm of Error: 0.0000000005

N = 8000

1 119.4221

0 119.4240

F-norm of Error: 0.0000000028

real 2m18.797s

user 4m12.286s

sys 0m24.151s

[ff242@omega1 PS3]$ cat slurm-1193052.out

/home/fas/cpsc424/ff242/PS3

c30n02

4

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Total Time

------- ----------

N = 1000

1 0.0820

2 0.0951

3 0.0963

0 0.0965

F-norm of Error: 0.0000000000

N = 2000

1 0.5899

2 0.7171

3 0.7193

0 0.7215

F-norm of Error: 0.0000000001

N = 4000

1 8.1627

2 9.9895

3 9.9998

0 10.0016

F-norm of Error: 0.0000000005

N = 8000

1 67.1136

2 80.3886

3 80.4289

0 80.4311

F-norm of Error: 0.0000000028

real 1m34.456s

user 5m29.424s

sys 0m31.049s

[ff242@omega1 PS3]$ cat slurm-1193053.out

/home/fas/cpsc424/ff242/PS3

c30n02

8

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Total Time

------- ----------

N = 1000

1 0.0469

2 0.0474

3 0.0487

4 0.0512

5 0.0520

6 0.0537

7 0.0548

0 0.0549

F-norm of Error: 0.0000000000

N = 2000

1 0.3527

2 0.3568

3 0.3655

4 0.3848

5 0.3922

6 0.4041

7 0.4051

0 0.4067

F-norm of Error: 0.0000000001

N = 4000

1 5.4408

2 5.4523

3 5.5706

4 6.0464

5 6.0540

6 6.2810

7 6.2863

0 6.2879

F-norm of Error: 0.0000000005

N = 8000

1 46.8918

2 46.9358

3 48.0180

4 51.4843

5 51.6767

6 53.2971

7 53.3173

0 53.3192

F-norm of Error: 0.0000000028

real 1m5.163s

user 7m36.350s

sys 0m25.344s

**Task 2B**

[ff242@omega1 PS3]$ cat slurm-1193054.out

/home/fas/cpsc424/ff242/PS3

c30n02

4

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 43.9366 23.1260 67.0626

2 53.5871 26.7711 80.3583

3 65.0555 15.3433 80.3988

0 17.3633 63.0367 80.4000

F-norm of Error: 0.0000000028

real 1m22.632s

user 4m44.779s

sys 0m29.976s

[ff242@omega1 PS3]$ cat slurm-1193055.out

/home/fas/cpsc424/ff242/PS3

c30n[01-02]

2

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 35.2796 22.3059 57.5855

2 49.9221 21.8894 71.8114

3 56.6813 15.1726 71.8539

0 13.6059 58.2479 71.8538

F-norm of Error: 0.0000000028

real 1m15.038s

user 2m7.713s

sys 0m7.688s

[ff242@omega1 PS3]$ cat slurm-1193056.out

/home/fas/cpsc424/ff242/PS3

c30n[01-04]

1

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 35.4460 22.1138 57.5599

2 49.6578 22.1289 71.7867

3 56.6310 15.1986 71.8296

0 13.5286 58.3010 71.8296

F-norm of Error: 0.0000000028

real 1m15.652s

user 1m12.125s

sys 0m2.513s

[ff242@omega1 PS3]$ cat slurm-1193058.out

/home/fas/cpsc424/ff242/PS3

c30n01

8

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 17.4118 29.5162 46.9279

2 21.7068 25.2684 46.9752

3 31.9667 16.0709 48.0376

4 31.4902 20.0279 51.5181

5 38.3784 13.3140 51.6924

6 36.9487 16.3864 53.3351

7 41.8665 11.4885 53.3550

0 5.5352 47.8215 53.3567

F-norm of Error: 0.0000000028

real 0m55.415s

user 6m36.211s

sys 0m21.498s

[ff242@omega1 PS3]$ cat slurm-1193059.out

/home/fas/cpsc424/ff242/PS3

c30n[01-02]

4

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 11.2412 25.7872 37.0284

2 15.6892 21.3634 37.0526

3 21.2794 17.1515 38.4309

4 27.4727 14.1689 41.6415

5 30.1916 11.4710 41.6626

6 31.8071 11.6271 43.4342

7 32.7451 10.7103 43.4554

0 2.9059 40.5496 43.4555

F-norm of Error: 0.0000000028

real 0m46.666s

user 2m42.477s

sys 0m4.474s

[ff242@omega1 PS3]$ cat slurm-1193060.out

/home/fas/cpsc424/ff242/PS3

c30n[01-04]

2

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 9.3058 22.7280 32.0338

2 15.3551 16.8338 32.1888

3 19.7139 14.3199 34.0338

4 23.4236 12.4263 35.8499

5 25.9124 10.8562 36.7685

6 27.8797 9.7825 37.6622

7 28.7091 8.9741 37.6833

0 2.4276 35.2558 37.6833

F-norm of Error: 0.0000000028

real 0m41.631s

user 1m12.500s

sys 0m2.780s

**Task 3A**

[ff242@omega1 PS3]$ cat slurm-1193064.out

/home/fas/cpsc424/ff242/PS3

c30n01

1

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-non-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-non-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-non-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Total Time

------- ----------

N = 1000

0 0.1841

F-norm of Error: 0.0000000000

N = 2000

0 2.3218

F-norm of Error: 0.0000000001

N = 4000

0 19.7260

F-norm of Error: 0.0000000005

N = 8000

0 156.2173

F-norm of Error: 0.0000000028

real 3m0.975s

user 2m59.932s

sys 0m0.564s

[ff242@omega1 PS3]$ cat slurm-1193065.out

/home/fas/cpsc424/ff242/PS3

c30n01

2

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-non-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-non-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-non-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Total Time

------- ----------

N = 1000

1 0.1345

0 0.1347

F-norm of Error: 0.0000000000

N = 2000

1 1.5795

0 1.5804

F-norm of Error: 0.0000000001

N = 4000

1 15.0662

0 15.0671

F-norm of Error: 0.0000000005

N = 8000

1 119.3976

0 119.3987

F-norm of Error: 0.0000000028

real 2m18.722s

user 3m54.982s

sys 0m41.348s

[ff242@omega1 PS3]$ cat slurm-1193066.out

/home/fas/cpsc424/ff242/PS3

c30n01

4

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-non-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-non-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-non-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Total Time

------- ----------

N = 1000

3 0.0768

1 0.0797

2 0.0936

0 0.0936

F-norm of Error: 0.0000000000

N = 2000

3 0.5793

1 0.5845

2 0.7118

0 0.7119

F-norm of Error: 0.0000000001

N = 4000

3 8.1229

1 8.1589

2 8.8370

0 8.8380

F-norm of Error: 0.0000000005

N = 8000

3 66.0220

1 66.5430

2 80.6018

0 80.6027

F-norm of Error: 0.0000000028

real 1m32.800s

user 5m16.469s

sys 0m25.167s

[ff242@omega1 PS3]$ cat slurm-1193067.out

/home/fas/cpsc424/ff242/PS3

c30n01

8

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-non-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-non-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-non-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Total Time

------- ----------

N = 1000

7 0.0417

1 0.0428

2 0.0437

3 0.0459

4 0.0477

5 0.0490

6 0.0501

0 0.0501

F-norm of Error: 0.0000000000

N = 2000

7 0.3090

1 0.3138

2 0.3147

3 0.3185

4 0.3192

5 0.3520

6 0.3663

0 0.3663

F-norm of Error: 0.0000000001

N = 4000

7 4.8767

2 5.0345

1 5.1001

3 5.4122

5 5.9741

4 6.0042

6 6.2390

0 6.2397

F-norm of Error: 0.0000000005

N = 8000

7 43.4901

2 43.5769

1 43.9001

3 46.5254

4 50.0358

5 50.2882

6 51.8515

0 51.8525

F-norm of Error: 0.0000000028

real 1m1.118s

user 6m54.846s

sys 0m37.574s

**Task 3B**

[ff242@omega1 PS3]$ cat slurm-1193069.out

/home/fas/cpsc424/ff242/PS3

c30n01

4

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-non-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-non-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-non-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

3 65.1012 0.6742 65.7754

1 43.9436 23.1609 67.1045

2 53.7825 26.6072 80.3898

0 17.4252 62.9656 80.3908

F-norm of Error: 0.0000000028

real 1m22.403s

user 4m38.676s

sys 0m22.224s

[ff242@omega1 PS3]$ cat slurm-1193070.out

/home/fas/cpsc424/ff242/PS3

c30n[01-02]

2

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-non-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-non-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-non-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 35.3305 7.9969 43.3274

3 56.8282 0.2226 57.0508

2 50.0478 11.1964 61.2442

0 13.6601 47.5842 61.2442

F-norm of Error: 0.0000000028

real 1m4.423s

user 1m48.933s

sys 0m2.074s

[ff242@omega1 PS3]$ cat slurm-1193071.out

/home/fas/cpsc424/ff242/PS3

c30n[01-04]

1

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-non-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-non-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-non-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

1 35.4480 7.7223 43.1703

3 56.6842 0.1935 56.8776

2 49.5883 11.2227 60.8109

0 13.5497 47.2613 60.8110

F-norm of Error: 0.0000000028

real 1m3.988s

user 1m2.879s

sys 0m0.850s

[ff242@omega1 PS3]$ cat slurm-1193072.out

/home/fas/cpsc424/ff242/PS3

c30n01

8

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-non-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-non-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-non-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

7 43.1209 0.3683 43.4891

2 21.6303 21.9607 43.5910

1 17.3946 26.6430 44.0376

3 32.1015 14.5316 46.6330

4 31.5812 18.4714 50.0526

5 39.5601 10.7574 50.3174

6 36.2497 15.6158 51.8655

0 5.6463 46.2202 51.8666

F-norm of Error: 0.0000000028

real 0m53.917s

user 6m1.887s

sys 0m33.264s

[ff242@omega1 PS3]$ cat slurm-1193073.out

/home/fas/cpsc424/ff242/PS3

c30n[01-02]

4

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-non-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-non-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-non-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

2 15.8147 17.4663 33.2810

1 11.0187 22.2701 33.2889

3 21.1312 12.1620 33.2932

4 27.9032 5.4257 33.3290

7 34.3601 0.2296 34.5897

5 31.6402 6.1593 37.7995

6 32.2975 6.3359 38.6334

0 3.2352 35.3983 38.6335

F-norm of Error: 0.0000000028

real 0m41.837s

user 2m26.056s

sys 0m4.007s

[ff242@omega1 PS3]$ cat slurm-1193074.out

/home/fas/cpsc424/ff242/PS3

c30n[01-04]

2

rm -f serial mpi-blocking \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-non-blocking.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block.c

mpicc -o mpi-non-blocking -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-non-blocking.o matmul-block.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

2 15.3636 12.4946 27.8582

3 19.7776 8.1232 27.9007

1 9.3208 18.7995 28.1203

4 23.4455 4.7024 28.1480

7 28.7278 0.2096 28.9374

5 26.0403 6.5530 32.5933

6 27.8907 5.4294 33.3201

0 2.4828 30.8375 33.3202

F-norm of Error: 0.0000000028

real 0m36.511s

user 1m5.551s

sys 0m1.588s

**Task 4**

[ff242@omega2 PS3]$ cat slurm-1193372.out

/home/fas/cpsc424/ff242/PS3

c31n01

4

rm -f serial mpi-blocking mpi-load-balance \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-load-balance.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block-load-balance.c

mpicc -o mpi-load-balance -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-load-balance.o matmul-block-load-balance.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

3 35.7390 31.3485 67.0876

1 45.4326 21.6711 67.1037

2 42.6000 25.3603 67.9604

0 56.8059 11.1555 67.9614

F-norm of Error: 0.0000000028

real 1m9.994s

user 4m8.086s

sys 0m27.442s

[ff242@omega2 PS3]$ cat slurm-1193375.out

/home/fas/cpsc424/ff242/PS3

c31n[01-02]

2

rm -f serial mpi-blocking mpi-load-balance \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-load-balance.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block-load-balance.c

mpicc -o mpi-load-balance -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-load-balance.o matmul-block-load-balance.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

3 31.1711 4.9254 36.0966

2 35.3526 2.8196 38.1722

1 40.7482 0.4001 41.1483

0 49.4325 0.1286 49.5610

F-norm of Error: 0.0000000028

real 0m52.725s

user 1m35.367s

sys 0m1.454s

[ff242@omega2 PS3]$ cat slurm-1193376.out

/home/fas/cpsc424/ff242/PS3

c31n[01-04]

1

rm -f serial mpi-blocking mpi-load-balance \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-load-balance.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block-load-balance.c

mpicc -o mpi-load-balance -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-load-balance.o matmul-block-load-balance.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

------- ---------- ---------- ----------

N = 8000

3 30.8890 4.9952 35.8842

2 35.0674 2.7993 37.8667

1 40.4260 0.1827 40.6088

0 49.0441 0.1364 49.1805

F-norm of Error: 0.0000000028

[ff242@omega2 PS3]$ cat slurm-1193379.out

/home/fas/cpsc424/ff242/PS3

c31n01

8

rm -f serial mpi-blocking mpi-load-balance \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-load-balance.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block-load-balance.c

mpicc -o mpi-load-balance -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-load-balance.o matmul-block-load-balance.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

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N = 8000

7 23.6555 22.0014 45.6570

5 26.4975 19.1908 45.6883

3 30.0559 15.6549 45.7108

1 34.1343 11.5990 45.7334

2 33.4359 12.5005 45.9365

6 25.5985 20.8575 46.4560

4 29.9081 16.5929 46.5009

0 40.2060 6.2959 46.5019

F-norm of Error: 0.0000000028

real 0m48.407s

user 5m48.687s

sys 0m29.836s

[ff242@omega2 PS3]$ cat slurm-1193384.out

/home/fas/cpsc424/ff242/PS3

c31n[01-02]

4

rm -f serial mpi-blocking mpi-load-balance \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-load-balance.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block-load-balance.c

mpicc -o mpi-load-balance -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-load-balance.o matmul-block-load-balance.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

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N = 8000

2 26.3034 2.3080 28.6113

3 24.4216 4.1924 28.6140

1 27.9289 0.6973 28.6261

4 21.4499 7.1979 28.6477

5 20.2554 8.5134 28.7688

6 19.1803 9.6132 28.7936

7 18.2902 10.5215 28.8117

0 30.7358 0.1914 30.9272

F-norm of Error: 0.0000000028

real 0m33.983s

user 2m5.370s

sys 0m3.095s

[ff242@omega2 PS3]$ cat slurm-1193385.out

/home/fas/cpsc424/ff242/PS3

c31n[01-04]

2

rm -f serial mpi-blocking mpi-load-balance \*.o

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c mpi-load-balance.c

mpicc -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing -c matmul-block-load-balance.c

mpicc -o mpi-load-balance -g -O3 -xHost -fno-alias -std=c99 -I /home/fas/cpsc424/ahs3/utils/timing mpi-load-balance.o matmul-block-load-balance.o /home/fas/cpsc424/ahs3/utils/timing/timing.o

Matrix multiplication times:

Rank Comp. Time Comm. Time Total Time

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N = 8000

2 20.9752 1.0726 22.0479

3 19.4235 2.6567 22.0802

4 18.1091 3.9944 22.1035

5 16.9903 5.1390 22.1293

6 15.9353 6.2204 22.1557

7 15.0224 7.2026 22.2250

1 22.8530 0.5827 23.4357

0 24.3120 0.1514 24.4634

F-norm of Error: 0.0000000028

real 0m28.492s

user 0m52.390s

sys 0m1.152s