Tyler Petrochko

CPSC 525 Assignment #4

## Included Files

I've included the following files in my submission

serial.c

parallel.c

serial_data1.txt

serial_data2.txt

serial_data3.txt

serial_data4.txt

parallel_data1.txt

parallel_data2.txt

parallel_data3.txt

parallel_data4.txt

Makefile

run.sh

timing.h

The first two files are the source code for my serial and parallel implementation of the assignment respectively. They are both fully functional in that they correctly calculate generate the centers of mass and average velocities when tested against the test data provided in the data/ directory.

The next eight files include the output generated when the serial and parallel implementations are run against the four "actual" data files. The file serial_data4.txt is intentionally blank; as discussed later, the simulation was unable to complete within a reasonable time frame.

The Makefile provided can be used to generate the serial and parallel binaries with the command

> $ make all

or simply

> $ make

The file run.sh can be used to generate the .txt output files when run according to the specifications from the assignment, i.e. 8 MPI processes, with 2 processes on each of 4 nodes. To do so, I used the following bash command after SSH-ing into the Omega cluster:

> $ qsub -I -l procs=8,tpn=2,mem=34gb,walltime=15:00 -q fas_devel

I included the file timing.h because my Makefile relied on it, although this could easily be changed.


## Performance

The performance for my parallel implementation is as following

| Time Steps | Bodies | Execution Time (s) |
|---|---|---|
| 1024 | 800 | 3.754109 |
| 1024 | 1600 | 15.653886 |
| 1024 | 3200 | 67.525101 |
| 1024 | 6400 | 251.359509 |

While the performance for my serial implementation is as follows

| Time Steps | Bodies | Execution Time (s) |
|---|---|---|
| 1024 | 800 | 14.345081 |
| 1024 | 1600 | 59.697339 |

| 1024 | 3200 | 248.527077 |
|---|---|---|
| 1024 | 6400 | **??** |

The serial program was unable to complete the 6400 body simulation due to time constraints, i.e. it still hadn't completed a single time step after 15 minutes. This suggests that, while the execution time seems roughly linear with a smaller number of bodies, the execution time spikes beyond 3200 bodies. While the parallel implementation performs better in every case, its main advantage is that is still manages to scale execution time linearly at 6400 bodies.

In each parallel_data<x>.txt I've provided a load balance printout at each "checkpoint," but to avoid taking up too much space I'll only include a sample load balance from the 6400 bodies simulation

| Time Step | Q0 | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 |
|---|---|---|---|---|---|---|---|---|
| 0 | 828 | 790 | 814 | 769 | 802 | 808 | 780 | 809 |
| 128 | 834 | 889 | 754 | 802 | 775 | 775 | 808 | 763 |
| 256 | 400 | 1219 | 398 | 1220 | 400 | 1169 | 425 | 1169 |
| 384 | 294 | 1302 | 275 | 1305 | 275 | 1339 | 308 | 1302 |
| 512 | 224 | 1345 | 208 | 1369 | 189 | 1437 | 247 | 1381 |
| 640 | 192 | 1381 | 176 | 1323 | 159 | 1497 | 190 | 1482 |
| 768 | 169 | 1399 | 169 | 1313 | 162 | 1501 | 169 | 1518 |
| 896 | 180 | 1416 | 156 | 1293 | 161 | 1496 | 184 | 1514 |
| 1024 | 196 | 1389 | 179 | 1245 | 169 | 1495 | 201 | 1526 |

As illustrated in this breakdown, the load balance quickly becomes an issue. By the 256th time step, the third quadrant contains only 398 bodies while the first quadrant contains 1219. At this point, the quadrants that "own" more bodies (Q1, Q3, Q5, and Q7) are causing a performance bottleneck by forcing the other quadrants to idle while they finish their calculations. To fix this, at the end of each step, the 3D Cartesian plane could be shifted so that the origin is at the center of mass. This would likely roughly rebalance the bodies between quadrants, allowing the load to stay more even.

**Development Environment**

To develop, I used the following bash commands to load all required modules. The run.sh script specified handles loading all required modules to run the simulations.

$ module load Langs/Intel/15; module load Langs/Intel/15 MPI/OpenMPI/1.8.6-intel15