University of Chicago

Winter 2023

GPU N-Body

Assignment 3 : High Performance Computing

Divya Pattisapu

02-06-2023

1 Question 1:

1.1 Serial version: Performance, Testing, Plotting

1.1.1 Particles start in a galaxy spiral formation

- x and y positions of the particles are cos and sin values of a random angle multiplied by a radius which follows a random distribution between 30 and -30 units.
- The velocities are tangential. vx = radius times sin(theta) and vy = radius times cos(theta), multiplied by a velocity scaling factor velFactor
- Depending on the value of velFactor, the particles either remain in the spiral, collapse into the spiral or escape the spiral.
- The benchmark plots are made using a scaling factor of 1 for which the particles remain in the spiral.
- Particles that are very close to each other have very strong gravitational force between them due to which the particles gain a large momentum and tend to veer off the spiral. This is not repelling, it's due to high momentum.
- Performance: Average time taken per iteration is 40.08 seconds for the case where Nparticles = 100K and Niterations = 1000. This is done on Midway3. On a 12th Gen Intel(R) Core(TM) i7-12700H machine with 20 logical cores, it runs at 20.2 seconds per iteration.
- I believe this is due to better cache optimization on this CPU.
- An animation for this simulation is present on this drive link.

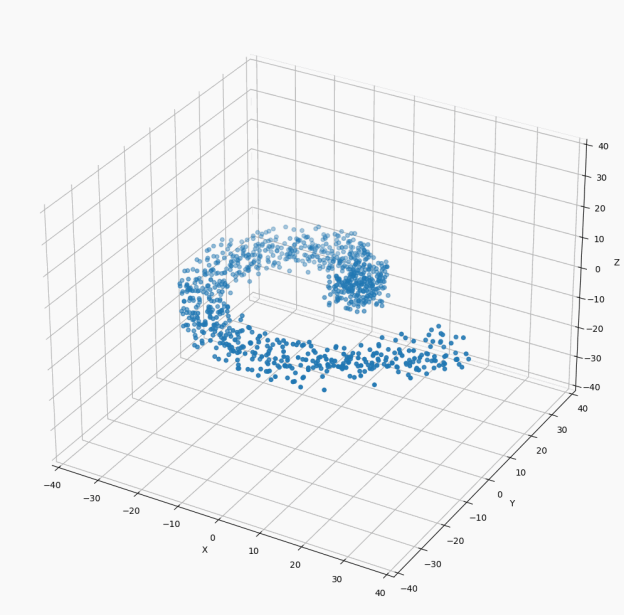

Figure 1: Set of spiral particles

2 Question 2:

2.1 Shared Memory Parallelism

- Performance improves with increase in number of threads and nearly plateaus at 8 threads on a 12th Gen Intel(R) Core(TM) i7-12700H machine as shown in figure
- Comparison of results between different values of velocity of particles is shown in the figure.
- It gives similar results as the serial implementation
- Depending on the value of the velocity, the particles either remain in the spiral (image a), collapse into the spiral (image b over time)

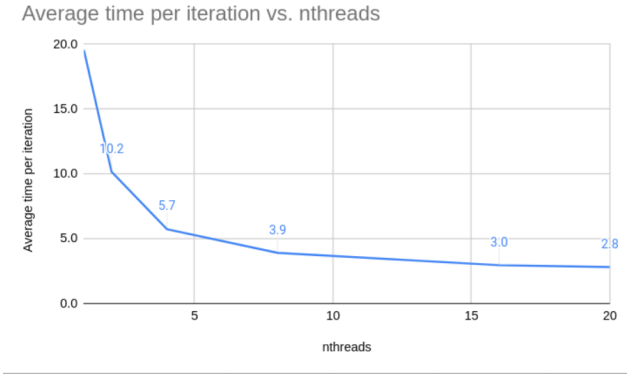

Figure 2: Average time taken per iteration vs number of threads in OpenMP

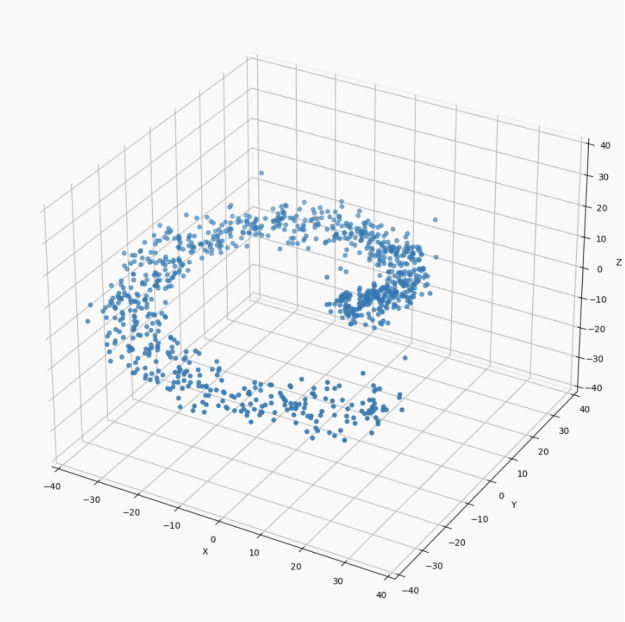

Figure 3: Large velocity of particles

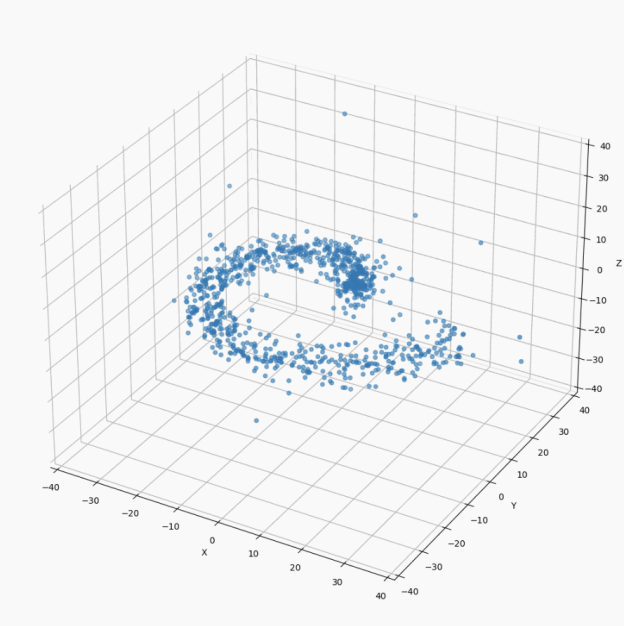

Figure 4: Smaller velocity of particles (decreased by a factor of 10)

3 Question 3:

3.1 GPU Implementation

3.1.1 Results

- As shown in the Table 1, the best time per iteration is observed for threads per block at 256.
- The animations for the 1000 and 100,000 particle simulations are present on this drive link.

3.1.2 Code walk through

- Initialization code : The particles are initialized at increasing radius from the center (constant* i/n)
- The angle is randomly chosen between 0 and 2*pi
- In the z direction, it is randomly initialized to a small value
- In the x, y directions, the particles are intialized at cos and sin theta times radius from the center
- The velocities are tangential (-sin(theta), cos(thetha))

Number of thread per block	Average time per iteration (s)
32	0.000247
64	0.000242
128	0.000220
256	0.000218
512	0.000240
1024	0.000295

Table 1: Optimal configuration of threads per block

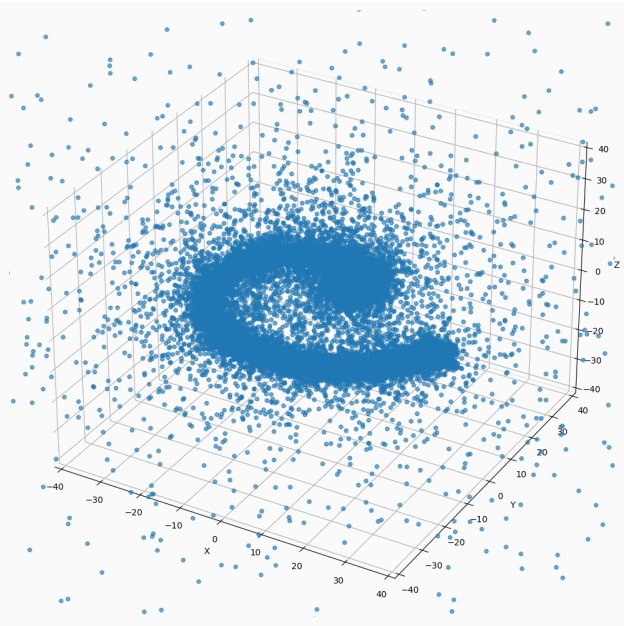

Figure 5: Iteration 20/1000 for dt=0.01 and Nparticles=100,000