Title: Evolution of a Star Cluster using Gravitational N-Body Simulations

Abstract

The evolution of a star cluster can be accurately animated by using N-body simulations with the number N of particles limited from 1 to 5 \* 10^3. I develop an N-body simulation code on my own personal computer by editing the base code provided by our professor, M. Haworth. I execute different N-body simulations randomizing the starting position and mass of each particle to form unique instances of star clusters. The maximum number of particles that can be simulated on my machine is 5 \* 10^3, in which 1 particle corresponds to a star within the star cluster. I find that the randomly generated star clusters end up clumping in the center of the screen where most of the massive particles of the simulation will be.

Introduction

N-body simulations have plenty of use being a theoretical tool for scientific and engineering applications. One of these applications uses the gravitational n-body simulation to simulate the creation and evolution of star systems, star clusters, galaxies and galaxy clusters. The difficulty with these problems is calculating the physical equations which govern how everything in the seeable universe interact with each other in real time. It is possible to do smaller amounts of particles but in order to get an accurate representation we must use as many particles as we can to simulate these systems.

Related Work

For each: Identify work, give context where used project

Cosmological N-Body Simulations   
<https://aip.scitation.org/doi/pdf/10.1063/1.4822978>

- “represent the dynamics of galaxies in a large scale volume” specifically using n-body simulation to show that there is some unknown dark matter effecting galaxies which help us create the formation and clustering of galaxies  
- Used numerical method section to help understand what to do in my own program. Did not use what they did but used what they lerned to help work with large N-body = “The Hierarchical tree code reduces the operations count to O( N log N) by treating distant clumps of particles as single massive psudo particles” (p.166)

Visualizing astrophysical N-body systems

<https://iopscience.iop.org/article/10.1088/1367-2630/10/12/125002/pdf>

- discusses case studies like cosmological simulations, nightfall and MW-Andromeda collision.  
- inspiration as has wonderful images for examples using millions of particles for the nightfall and the collision  
- Gives ideas for future works on the assignment

Particle Number Dependence of the N-body simulations of moon formation

<https://iopscience.iop.org/article/10.3847/1538-4357/aab369/pdf>

- Talks about the N-body simulation being used to recreate the possible formation of the moon  
- Used to figure out the rotation of particles around each other (specifically equation 3)  
- used their conclusion to figure out parameters for my own simulation, with less particles of course

Overview

* Describe project implementation
* Show and explain methods from a resource (related work?)
* Describe algorithms and mathematics
* Understanding of theory and approaches involved

Evaluation

* Show project results (images, tables etc)
* Images: show key aspect of system.(2-4 images per. Showing different results)
* Each image discuss faults, edge cases, issues
* Show multiple instances of the simulation and discuss like above (max 200, 1000, 2000, 5000)

Conclusion

* Show findings from the project (running of n-body helpful, equations to calculate the force)
* Challenges described (actually figuring out how to implement the equations, problems with original particles and finding correct parameters to set[mass and position], limit acc so to not go to infinity)
* Future work: make particles actual size equal to mass/radius; calculate multiple particles; creation of gravitational wells/black holes; implements the octrees; make it look prettier (visualize astrophysics paper for full sky and dome projections)