CS 470 Project Proposal - N-Body Problem Analysis

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1 Goal

The goal of this project is to examine the viability of several different solutions to solve the n-body problem. In physics, the n-bodies problem relates to the forces of many celestial bodies when acted upon by n other celestial bodies of significant mass and gravitational pull. Because this problem is well-known, there are many established methods for solving it. Our goal is to examine several different methods for solving the n-body problem, including a method that was examined previously by research groups in previous years. We will then analyze the performance of these existing implementations to determine where parallelization or expansion would be appropriate. Once we have completed this preliminary analysis we intend to attempt improve n-body computation performance and make informed recommendations on a direction in which to take this project in the future.

2 Relevance

The n-body problem is a classic computationally expensive algorithm to perform. Particle-to-particle methods perform fairly poorly, being in $O(n^2)$, but give the most accurate results. In the past, teams have tried to parallelize this problem to improve its speed, however not much progress was made. In order to parallelize this problem, we must change our perspective and the technologies we use to approach this problem. Algorithms such as the Barnes-Hut simulation work to speed up the n-bodies problem by grouping together bodies and calculating on groups when they are significantly far enough away. Other approaches such as the one taken by our Russian friends in this paper (https://mmp.susu.ru/article/en/495), utilize very new parallel technologies such as OpenMP-CUDA and GPU-Direct to significantly speed up, parallelize, and maintain the accuracy of the particle-to-particle method. We would be applying our knowledge of parallel technologies to analyze which avenue would be better to pursue, the speed of the approximation algorithms or the accu-

racy of existent particle-to-particle algorithms performed on developing parallel technologies.

3 Methods

There are already many pre-existing github repositories with implementations of approximation n-body algorithms such as the Barnes-Hut method. We will contact the writers of the Russian paper and attempt to get the source code for their simulation of the n-body problem. If we are not able to acquire it, we would work on implementing a traditional particle-to-particle algorithm using Open-MP-CUDA and GPU-Direct technologies. A bulk of the project would be in comparing that modified traditional algorithm with multiple approximation algorithms – such as Barnes-Hut and Fast Multipole Methods (FMM) – and even comparing approximation algorithms among themselves.

4 Possible Roadblocks

The code for implementing a N-body method on GPUs in parallel is quite complex and has already been implemented in the past for a research paper. However, the code was not published. We plan to ask the researchers who wrote the paper for their source code, but if we do not get it we will need to decide whether or not to include that paper in our analysis, since we would have to implement their algorithm from scratch. Implementing the algorithm from scratch could take quite a long time and would reduce the level of analysis we could do of n-bodies problems. This means our final project deliverables may end up changing in the middle of our project depending on whether we are able to acquire the source code. We plan to work closely with Dr. Lam and keep him informed of how things progress.

5 Mid-Project Deliverable

Our mid-project deliverable will include all the source code that we will analyze and all of the data sets that we will use to analyze that code. These are the two major deliverables that we will need to finish quickly in order to perform a nuanced analysis of each program. Along with the source code and data sets, we will also include a discussion of the methods we used to determine the contents of the data sets.

6 Showcase

If we are able to get the source code most of our project will be analysis; we should easily be able to present on a poster board and we will likely not have a demo. However, if we are not able to get the source code, our project will

become more implementation-based, and using only a poster board may not be adequate for displaying our implementation and results. If this is the case we may also need to set up a demo video, and we would need a projector or display.

7 Final Deliverable

In addition to the analysis mentioned earlier, our final deliverable will include the source code that we analyzed, as well as the final data sets we used to analyze each program. We will likely summarize and present these results in the form of a research paper.