N-Body Simulation

in Rust with Bevy

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I. Project Topic Area

The N-Body problem, a classic problem in physics and computational science, involves predicting the individual motions of a group of bodies interacting with each other gravitationally. This project is in the area of computational physics and real-time scientific visualization. The goal of this project will be to create a simulation that models the gravitational interactions between multiple bodies (particles) in a two-dimensional space. The simulation will calculate the gravitational forces between each pair of particles and update their positions and velocities over time. To that end, the project will involve implementing algorithms to efficiently compute these interactions, as the simulation will ideally be able to handle many bodies simultaneously. After some research, I've decided to utilize the Barnes-Hut algorithm, a well known approximation algorithm for performing an N-body simulation. The design is subject to change, but the aforementioned seems doable within the given time frame.

II. Specific Project Vision

The goal is to build an interactive 2D N-body gravitational simulator that:

1. Models gravitational interactions between bodies.
2. Can scale to a large number of bodies
3. Provides a user-friendly visual interface.
4. Is modular.

To implement the N-body simulation, the following will be required:

1. Game-engine-based visualization using the Bevy engine in Rust.

2. Algorithmic optimization for large-scale particle interactions, including spatial partitioning with a quadtree and (optionally) Barnes–Hut–style approximations.

3. Numerical simulation of gravitational N-body system
    - An extremely high mass body will be at the center (a “black hole” of sorts)
    - Some number of generated bodies. These bodies will have the following parameters randomly set:
        - Starting position (relative to the center)
        - Mass
        - Velocity (Magnitude & Direction)

III. Issues of Concern

Some of the technical issues that may arise during the project:

- N-body simulations scale poorly with the number of bodies
- Gravitational simulations are sensitive to time step size
- Implementing a quadtree that updates every frame can be error-prone.