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N-Body visualizations

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Master's Project Proposal

N-Body Visualizations

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Abstract

In the age of technology and information, data calculations and visualizations are key to the communication and understanding of the world in which we live. It is sometimes difficult to display data in a way to make it clear and understanding, or is difficult to calculate the data to be displayed. The N-body problem has elements of both. The N-body problem is a set of N particles representing stars that move in response to the gravitational force generated by the N-1 other particles. There have been many attacks to this problem. The GRAPEcluster Project of RIT has developed software and hardware to display these systems in images and film. The movies provide a wealth of information, but there are properties in the videos that cannot be seen, compared, or studied. The purpose of this project is to be able to show some of these physical properties in a way that can offer insight into the properties and behaviors of particle systems, to allow the comparison of the properties of different systems to be more easily done.

1 Overview

1.1 Background

Much of the groundwork in producing images has been done by members of the GRAPEcluster project. They have set up specialized hardware to process great amounts of calculations to help attack the N-body problem, in which a set of N particles representing stars move in response to the gravitational force generated by the N-1 other particles [GRAPEcluster].

Images have been produced that plots each particle in space. Tools have been built to modify the viewing properties. A couple of examples include being able to add and remove axis, or the wire-frame cube. You can rotate the view, or change the view with respect to time. A set of images can be generated from file representing a stellar system. Different images can be produced to show the system with the passing of time. These images can then be compiled and made into a movie. Movies have been produced to show the behaviors of artificial stellar systems, to test algorithms, and to create visualizations of stellar systems.

1.2 An Improvement

The images and video produce great visualizations. These images can be informative, but it would be nice to use the specialized hardware and visualizations to produce more than the images of the particles. There are properties present that cannot be easily seen or understood from the diagram of the particles in space. Some properties include density, linear and angular momentums, gravity fields, velocity, and velocity dispersion. Some properties play an important role in understanding the behavior and properties of systems. Many astrophysical projects hinge upon assigning importance to over-dense regions in a set of points [Eisenstein and Hut].

2 Project

2.1 The Problem

It is sometimes difficult to display data in a way to make it clear and understanding. A system of particles has been displayed showing their relative position. It would be beneficial to be able to look at the diagram(s) and also see other properties of the system.

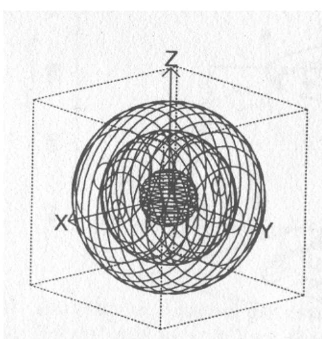
3 <u>Density</u>

The heart of this project will be to find the best way to represent the density regions of a system. The goal is to be able to look at an image that illustrates the positioning of the particles with respect to density. I propose to come up with four different methods to do this:

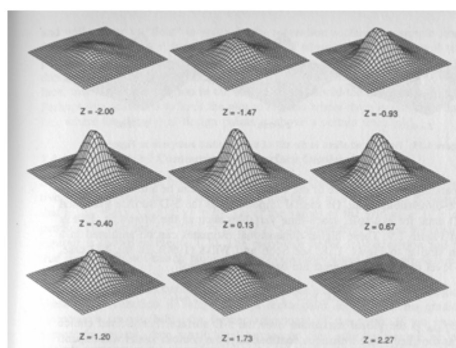
1. Density slices,
2. 3D colored shells
3. Banding
4. Density clouds

3.1 Method I: Density Slices

One way is to divide the space into planes and depict the density as a sequence of slices. For example, if we look at the following diagram on the left that can be pictures as a system of particles with the core of the sphere being the most dense, and the outer parts of the sphere less dense, and create slices we could easily spot the different density regions.



[Scott p. 22]



[Scott p. 23]

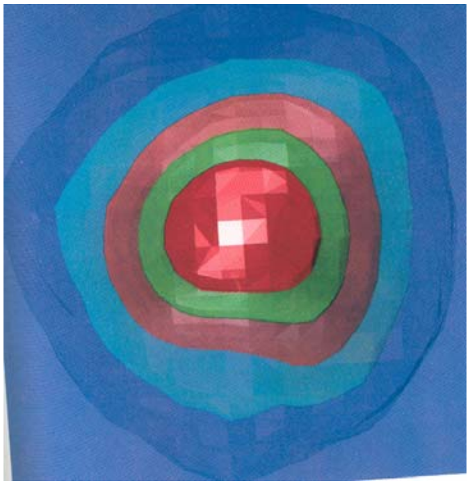
There would be several parameters involved with this density viewing.

a. number of slices
b. scale of the grid
   i. x-scale (lower, more accurate, more computational)
   ii. y-scale
   iii. density scale

Each slice would represent a plane (z = *c*, for constant *c*) with the density values on that plane. The algorithm would calculate the density, $d_{x,y}$,of each location, (x,y) ,on the given plane. Then the slice would be 'drawn' using rectangles with vertices (x,y, $d_{x,y}$), for each (x,y).

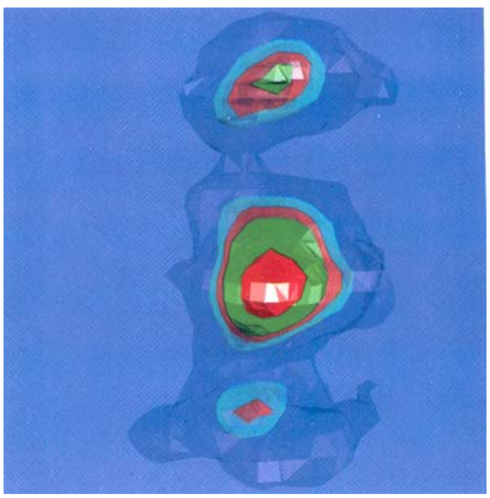
3.2 Method 2 : 3D colored shells

I would also like to be able to create a 3-D Model depicting the same idea, but using colors to represent the densest regions. The previous diagrams could be depicted as the following diagram:



[Scott plate 6]

A more impressive diagram would be as follows, where you could easily find the three dense regions, one center, and two others above and below. (Note: this is a five transparent α-level contours of the average shifted histogram of the Mount St. Helens earthquake epicenter data.)



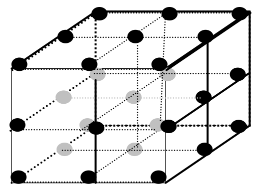
[Scott plate 8]

The algorithm used would be similar to the first method, but would be more computational intensive.

There would be several parameters involved with this density viewing.

a. scale of the space (x,y,z) (lower, more accurate, more computational)
b. the density range for each color

The algorithm would take and divide up space into a three dimensional matrix of points, (x,y,z) equally dispersed. (The following diagram may help clarify this, but in reality, there will be many more points.)



The local-density at each point will then be calculated. All the points within the same density range will then be connected using triangles of a particular color. This will create the color division of the area by density. The difficult part will be to have the ability to view all the different regions, to have a ‘cut’ view.

I anticipate handling this viewing problem by:

a. Finding the outside ‘shell’ of the most dense region,
b. Find the approximate mean plane (like a line-of-best-fit) of that volume,
c. Calculate a plane that cuts the most dense region in half,
d. And not connect any of the points in the ‘viewing space’.

I anticipate variations in the above viewing alteration. It may be better to find multiple most dense regions and create a ‘viewing space’ (no density zone coloring) that falls on multiple planes. Perhaps it would be best if finding the mean of the all the density regions created the ‘viewing space’.

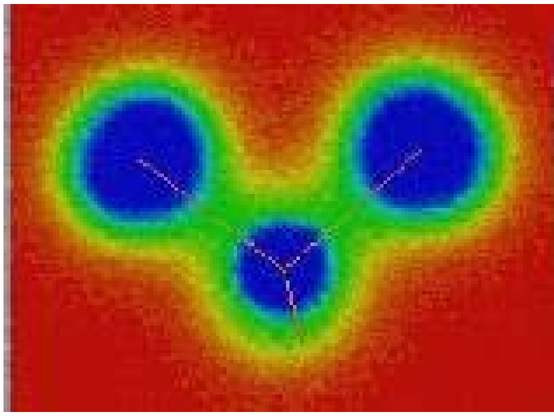
3.3 Method III: Contour (Banding)

This procedure will be very similar to the one above, with the three dimensional matrix, and the calculation of the densities. Instead of making shells with the (almost) equal densities, connect the tri-ordinates with segments. The more dense contour lines would be thicker and darker, while the less dense will be thinner and lighter in color. The one main parameter is the number of different density contours to add to the diagram. The diagram may be more informative with only two or three density levels contoured.

3.4 Method IV: Density Clouds

This procedure will involve a similar procedure as the previous two with the three dimensional matrix and density calculations. This procedure will then place a certain color cloud (fog) depending on the density. I expect this to produce similar results to the density shells (method II), but with the ability to show many of the individual particles.

I found this diagram of a molecule, and suspect similar looking diagrams to be produced with this method.



http://www.canby.com/hemphill/chmvis.htm

4 **Results**

I anticipate producing models with several different N-Body particle systems. I suspect the following strengths and weaknesses for each process:

Method	Pros	Cons
I: Density Slices	See particles. Can represent a wide range of densities more clearly.	Takes two diagrams. More difficult to interpret.
II: Density Shells	Looks impressive, gives quick idea of relative density measurements.	Will not be able to see original particles.
III: Contouring	See particles.	Image is cluttered, difficult to interpret much.
IV: Density Clouds	Quick visual comprehension. See most of the particles.	Density values are vague.

After producing several models, I will meet with astrophysicists for their feedback on the pros and cons of each method, what might be done better, and the overall best informative technique that was used.

5 **Tools**

I will be using an interface that members of GRAPEcluster Project have developed, as well as Java and Java 3D.

6 Schedule

Task Expected Completion

- Proposal approved 7/7/05
- Generate density graphs (method I) 7/12/05
- Generate density graphs (method II) 7/18/05
- Generate density graphs (method III) 7/22/05
- Generate density graphs (method IV) 7/25/05
- Analysis of program results 7/29/05
- Complete write-up 8/10/05
- Project defense 8/22/05

Reference

The GRAPEcluster Project: A dedicated parallel platform for astrophysical dynamics. http://www.cs.rit.edu/~grapecluster/

Eisenstein, Daniel J. and Hut, Piet. HOP: A New Group Finding Algorithm for N-body Simulations. Institute for Advance Stude, Princeton, NJ 08540. 1997

Scott, David W. Multivariate Density Estimation Theory, Practice, and Visualization. John Wiley & Sons, Inc. New York. 1992.

Walnum, Clayton. 3-D Graphics Programming with OpenGL. Que Corporation. USA. 1995