Parallel Visualization

Visualizing Cosmological N-body Simulations

Greg Dooley 18.337 Final Project December 12, 2012

Simulate The Universe

- Simulate formation of structure in the universe.
- Learn about galaxy formation
- Test cosmological and dark matter theories.



- Dark Matter Only
 - Gas + DM simulations are hard!
 - Dark Matter makes up 84% of matter

Simulation Code

- GADGET 2 Volker Springel
 - Gravitational N-body solver
 - Smoothed Particle Hydrodynamics (SPH)
- Particles smoothed by adaptive smoothing length: h
 - Kernal volume $\frac{4\pi}{3}h_i^3$ contains constant mass.
 - High density region: small h. Low density region: large h

0.0

0.2

0.4

0.6

0.8

1.0

Monaghan Cubic Spline: $W(r,h) = \frac{8}{\pi h^3} \begin{cases} 1 - 6\left(\frac{r}{h}\right)^2 + 6\left(\frac{r}{h}\right)^3, & 0 \le \frac{r}{h} \le \frac{1}{2}, \\ 2\left(1 - \frac{r}{h}\right)^3, & \frac{1}{2} < \frac{r}{h} \le 1, \\ 0, & \frac{r}{h} > 1. \end{cases}$

Density Calculation

$$\rho_i = \sum_{j=1}^N m_j W(|\boldsymbol{r}_{ij}|, h_j)$$



- User Specifies:
 - Volume of interest
 - Pixel dimensions
 - 2D Projection direction
- Periodic Boundary Conditions for full box only
- Impose h_{min} and h_{max}



Data and Parallelization

Data Set 1

- 512³ particles = 134,217,728
- Position data: 3.3 GB
- Smoothing data: 1.1 GB

Data Set 2

- 606,866,170 particles
- Position data: 16 GB
- Smoothing data: 5.3 GB

Density Calculation is Embarrassingly Parallel

- Read position, smoothing data in parallel into distributed arrays on N processors
- Wait to finish
- Compute density in parallel on N processors
- Sum the results

Visualization

- Python script to color density projection
- Chose color scheme and density cutoffs by hand





Performance

• Tested on ¹/₄ data set. 1 Processor: 1540 seconds. 50: 48 seconds



Simulations Data Sets

Aquarius Simulation



- Box size = ~600 Kpc/h
- 6 x 10⁸ particles
- 8.6 x 10⁸ Msun / h particle mass
- 1 month on supercomputer

My Simulations



- Box size = 25 Mpc/h
- 512³ ~ 10⁸ particles
- 8.7 x 10⁶ Msun / h particle mass
- ~1 week at CfA cluster