A Journey Through Time and Space

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Galaxies Merge

Galaxy Mergers make Binary Black Holes

3C75 (radio image)
NGC 6240 (X-ray image)
The Gravitational N-Body Problem

\[ \frac{d^2 x_i}{dt^2} = \sum_{j \neq i} \frac{G m_j x_{i,j}}{r_{i,j}^3} \]

- Each particle feels the force from every other particle
- The number of force calculations scales as \( N^2 \)
- For \( N = 10^6 \), the number of force calculations is \( 10^{12} \)

Special-Purpose Hardware

GRAPE = GRavity PipELine

- Custom-designed pipelines for computing gravitational forces
- Very fast (1 TFlops), but limited particle numbers (<1/4 million)
- Manufactured by Hamamatsu Metrix (Tokyo)

The GRAPE Cluster

- 8 dual-Xeon PC nodes
- Infiniband interconnects
- Built by PSSC Labs
- Particle numbers up to one million
- Speed of 1 TFlops
Binary Black Holes make Gravitational Waves

LISA (“Laser Interferometer Space Antenna”) will be able to directly detect gravitational radiation from merging, super massive black holes, even at enormous distances. This will provide the first direct test of Einstein’s equations in the strong-field limit.

Problem Description

What is Required?

- Camera movement in space
  - Unconstrained
  - Be able to look everywhere
- Forwards/Backwards in time
- Visualization plug in
- Distributed
- This is it...
  - Will allow to visualize different systems
  - Liquid
  - Landing of Huygens space probe

Problem Description

- Visualize Colliding Galaxies:
  - File Format
    \[
    \{{\text{id}, x, y, z, a_1, a_2, \ldots}\} \quad 1 \leq i \leq n, \text{id} \in \text{IN} \\
    \{{\text{id}, t, x, y, z, a_1, a_2, \ldots}\} \quad \text{id} \in \text{IN}, t \in \text{Double}
    \]
  - File size: > 10GB
  - Standard hardware
  - Question: What would you like to see?
  - Answer: Not sure, but at least …
One Algorithm

• for $t = 0; t <= \text{maxTime}; t += \Delta t$
  For $\forall$ particles do
  $p_i = \text{calcPosOfParticle}(t)$

Interpolation

• Linear
  – Two data points are needed
• Taylor Series
  – One data points is needed

Demonstration

Captain James D. Kirk: Scotty, let’s go for a ride.
Scotty: We are ready to go.
Spock: Captain, I advise not to use warp speed.

A Movie ....
**Design: The Big Picture**

- MapView ➔ CameraViews ➔ ViewController ➔ Switchboard ➔ Feeder ➔ ParticlesView

**Communication**

- A simple language controls the system
- The language consist of primitives
- More sophisticated tools use this language to solve complicated tasks
- The language can be used to experiment

**Sprache**

- A simple language controls the system
- Designed to be open
- Sprache is German for language - credit to Jonathan Coles
- Example:
  - camera new 1
  - camera 1 moveto 1 3 4
  - camera rotate x y z
  - camera up x y z
  - ...

**From a Slider Wiggle to Camera Moment**
Intended Use of the Language

• GUI produce simple statements
• More sophisticated tools allow to do more sophisticated tasks
  – Moving through the system
  – Focus on specific areas
  – etc

Use of External Tools - Idea

Use of External Tools - How

Use of External Tools - Stmts

load ../../..\\theSimulation.sim14003:color:compact:binary:Z
camera new 1 "ll"
updateview
setDeltaT 0.003
camera 1 moveto 2 -2 2
camera 1 lookat 0 0 0
thisPointInTime 0
updateview
camera 1 moveto 2.0588 -1.93882 2
updateview
camera 1 moveto 2.1152 -1.87533 2
updateview
camera 1 moveto 2.1692 -1.80963 2
updateview
camera 1 moveto 2.2208 -1.74182 2
updateview
....
Use of External Tools - Movie

Summary

- Distributed visualization system
- Multiple cameras
- Language controlled
- Movie making capability, distributed
- Plug and Play technology