

Fish: Simulating Forces

CS267 Discussion 2/29/08

Administrivia

- HW1 Status
- HW2 Groups
 - Anybody not have 3?

Fish Code: Many Versions

- **Sharks and Fish 1.** Fish alone move continuously subject to an external current and Newton's laws.
- **Sharks and Fish 2.** Fish alone move continuously subject to gravitational attraction and Newton's laws.
 - **Sharks and Fish 2.5.** Fish alone move continuously subject to Van Der Waal's forces
- **Sharks and Fish 3.** Fish alone play the "Game of Life" on a square grid.
- **Sharks and Fish 4.** Fish alone move randomly on a square grid, with at most one fish per grid point.
- **Sharks and Fish 5.** Sharks and Fish both move randomly on a square grid, with at most one fish or shark per grid point, including rules for fish attracting sharks, eating, breeding and dying.
- **Sharks and Fish 6.** Like Sharks and Fish 5, but continuous, subject to Newton's laws.

Fish Code 1

- At each timestep, each fish has a force applied due to the current. The current is in a constant direction.
- Serial pseudocode:

```
for timestep=1 to end
```

```
  foreach fish
```

```
    fish.pos = fish.v * dt
```

```
    accel = current_at(pos) / fishmass
```

```
    fish.v = fish.v + accel * dt
```

Parallelizing Fish Code 1

- Spatial decomposition?
- Or decompose by fish?
- For each:
 - What are the costs as P increases?
 - What are costs as number of fish increase?

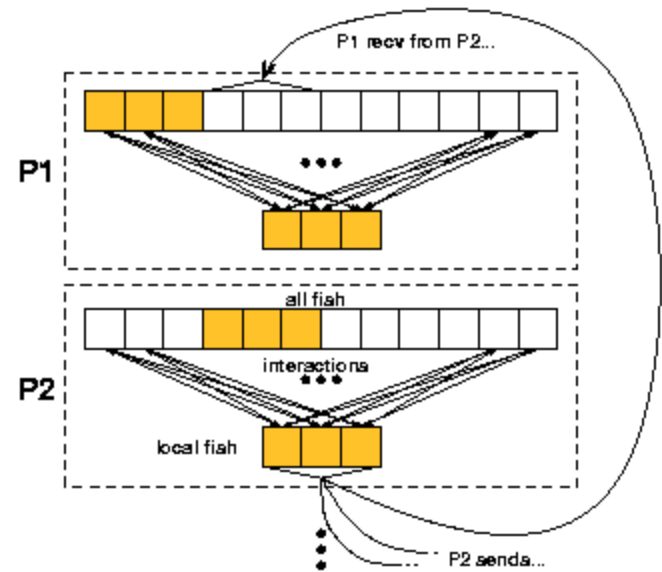
Fish Code 2

- Each fish is subject to a gravitational force from every other fish.
- Gravitational force: $F=(Gm_1m_2)/r^2$
- Pseudocode:

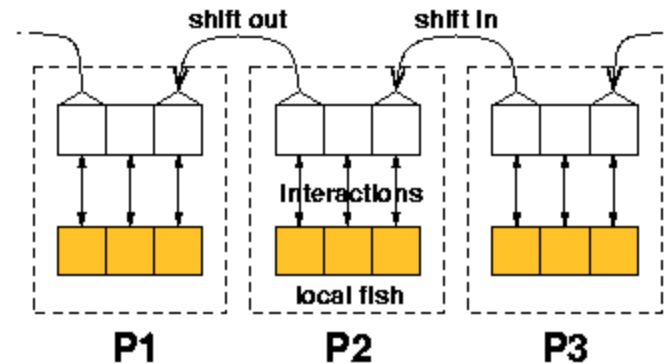
```
For timestep=1 to end
  foreach fish
    force = 0
    foreach fish != this_fish
      force += grav(fish, this_fish)
    this_fish.pos = this_fish.v * dt
    this_fish.v = (force / fish_mass) * dt
```

Parallel Fish Code 2

- In provided implementation, every processor keeps track of every fish
- Which decomposition
 - Spatial?
 - Well known, fast algorithms
 - Fish?
 - Can lower memory requirements

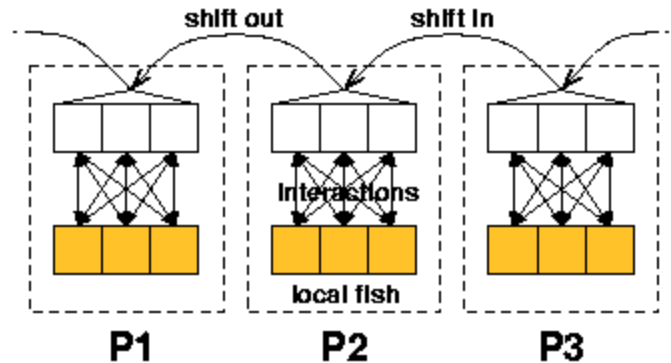


Parallel Fish Code 2: Fish Decomp



- Each processor has subset of fish it is responsible for updating
- At each step, shift fish left by 1
- What is memory cost of this? Communication cost?
- Lots of small messages...

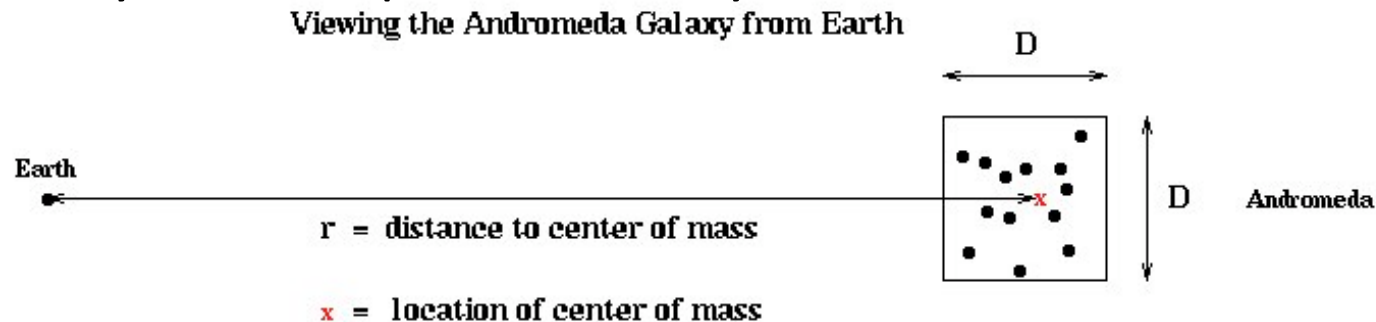
Parallel Fish Code 2: Fish Decomp



- Rotate a block at a time
- Larger messages
- Can do overlap of communication and computation

Parallel Fish Code 2: Spatial Decomp

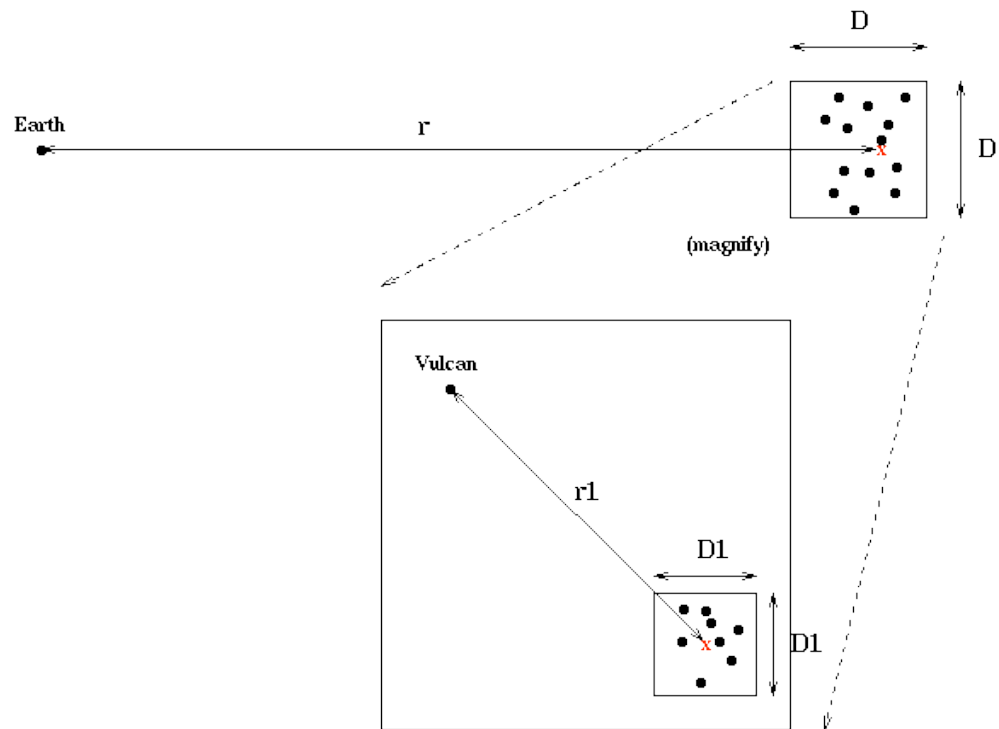
- Consider computing gravitational force on earth from all celestial bodies
 - # of terms \geq visible bodies
 - If you look up, one “star” you see is Andromeda: a galaxy!



- Approximate Andromeda as a single point at its center of mass
- Works if D/r is tiny
- Called N-Body Problem

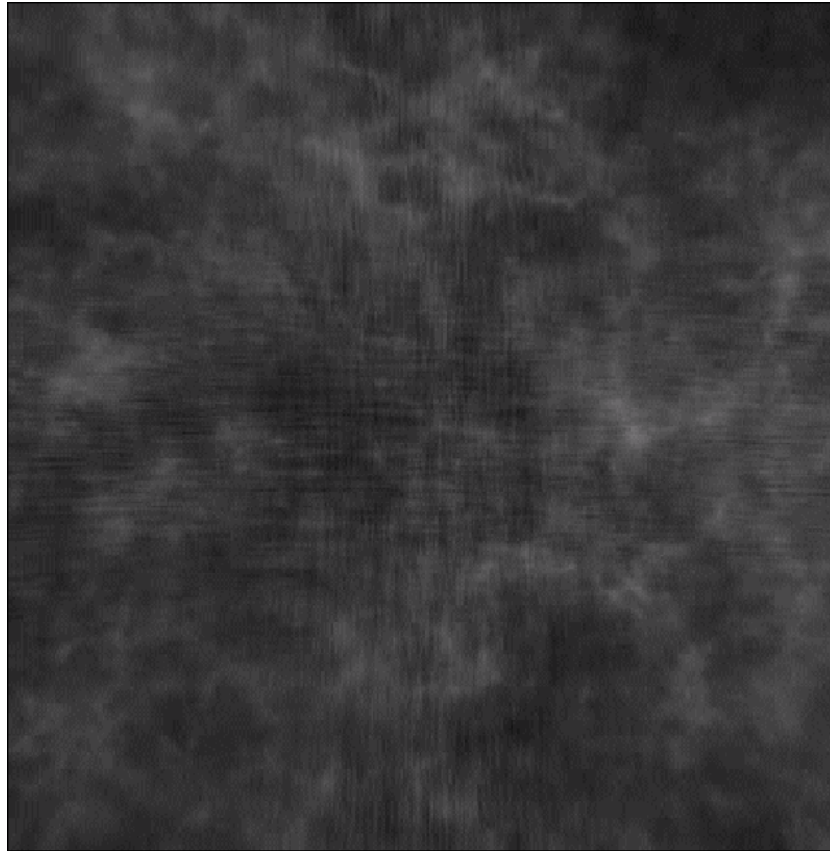
Parallel Fish Code 2: Spatial Decomp

Replacing Clusters by their Centers of Mass Recursively



Parallel Fish Code 2: Spatial Decomp

- Use specialized tree structures to hold the points
 - Parents are approximations of the children
- Then, traverse the tree in the proper order
- Results in $O(n \log n)$ time algorithms, with $\sim 1\%$ inaccuracy
 - Barnes-Hutt and Fast Multipole Method
- Widely used in astrophysics
- Will be covered in lecture in a few weeks



traversal-256

Parallel Fish Code 2.5

- Use a Van Der Waals force, with a distance cutoff

$$F = \begin{cases} C \left(\frac{1}{r} - \frac{1}{40r^2} \right) & \text{for } r \leq \frac{1}{40} \\ 0 & \text{for } r > \frac{1}{40} \end{cases}$$

- Which decomposition?
 - Spatial
 - Fish
- Overlap communication and computation?
- Shared memory vs message passing

A Hint

- If you use spatial decomposition, how many neighbors do you have to communicate with?

A Hint

- If you use spatial decomposition, how many neighbors do you have to communicate with?
- Under what restrictions?
- Can you further limit the communication?

Tools

- IPM
 - Does “profiling” of communication
 - Simple mode is easy to use, full mode is very hard to use
 - Simple mode does give some useful data (e.g. total memory usage)
- TAU
 - Traces MPI codes
 - See tutorial from LBNL
- What about your own timing?
 - Forget `gettimeofday()`
 - Use `MPI_Wtime()` instead