A Parallel Architecture for IISPH Fluids

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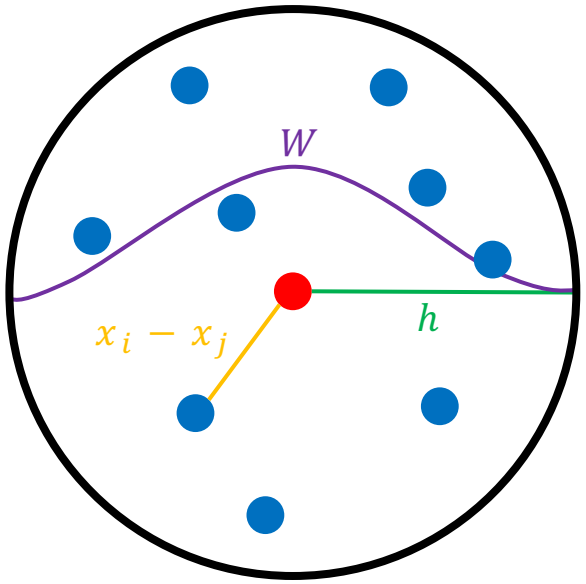
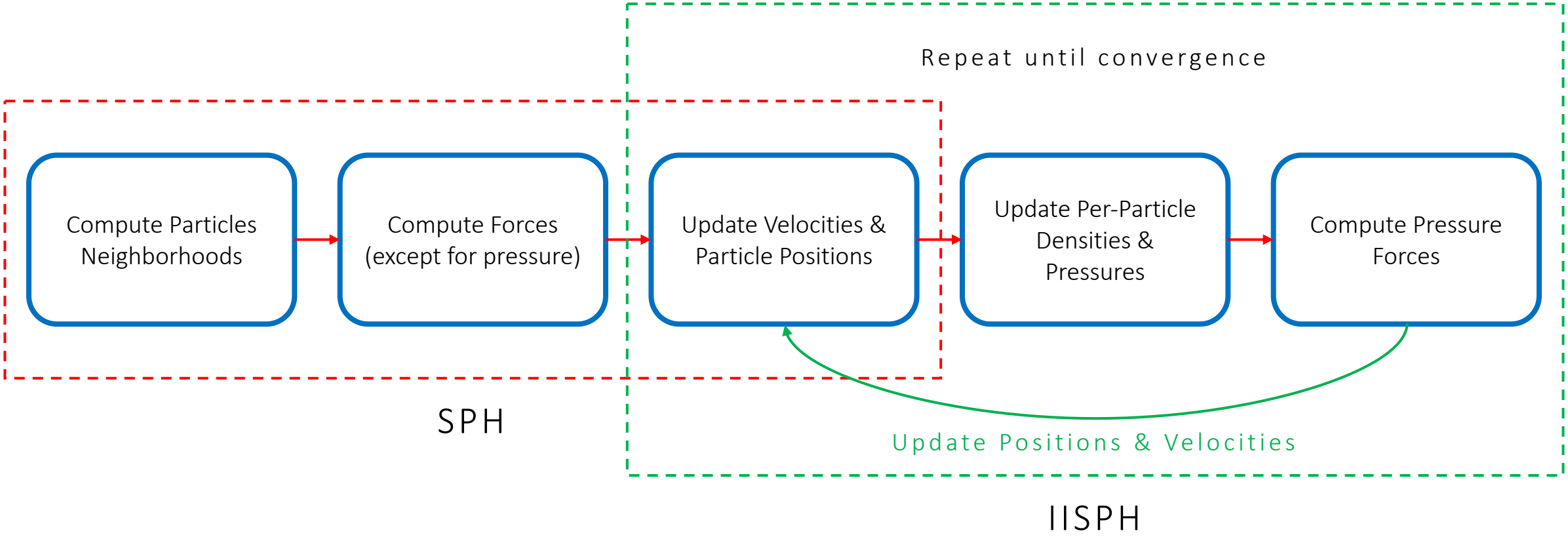
J. Bender, C. Duriez, F. Jaillet, and G. Zachmann (Editors)

SPH : Smoothed Particle Hydrodynamics

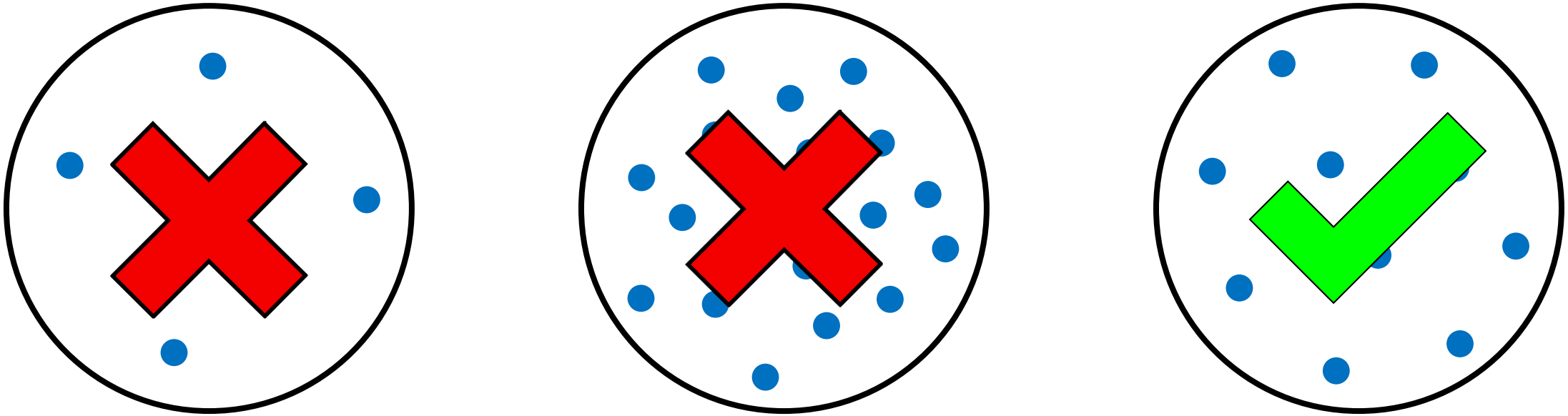


$$A_i = \sum_j \frac{m_j}{\rho_j} A_j W(x_i - x_j, h)$$

IISPH : Implicit Incompressible Smoothed Particle Hydrodynamics



IISPH : Implicit Incompressible Smoothed Particle Hydrodynamics



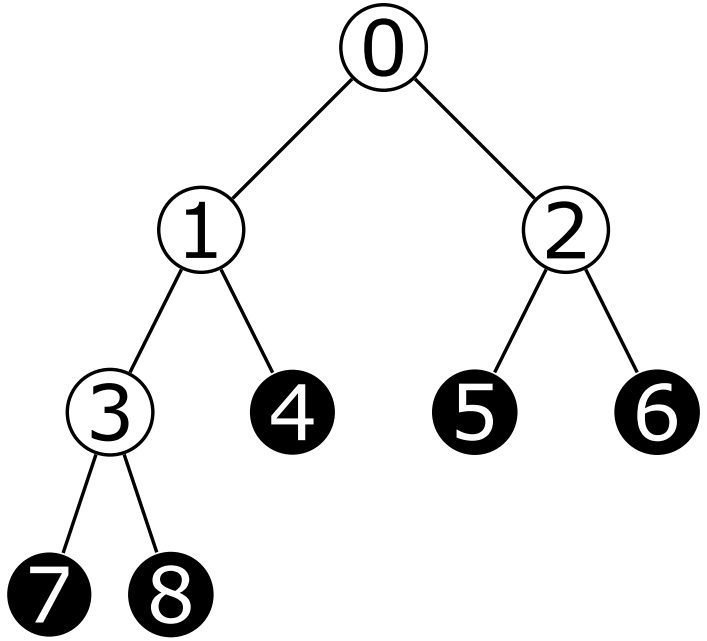
METHOD
Recursive Domain Decomposition

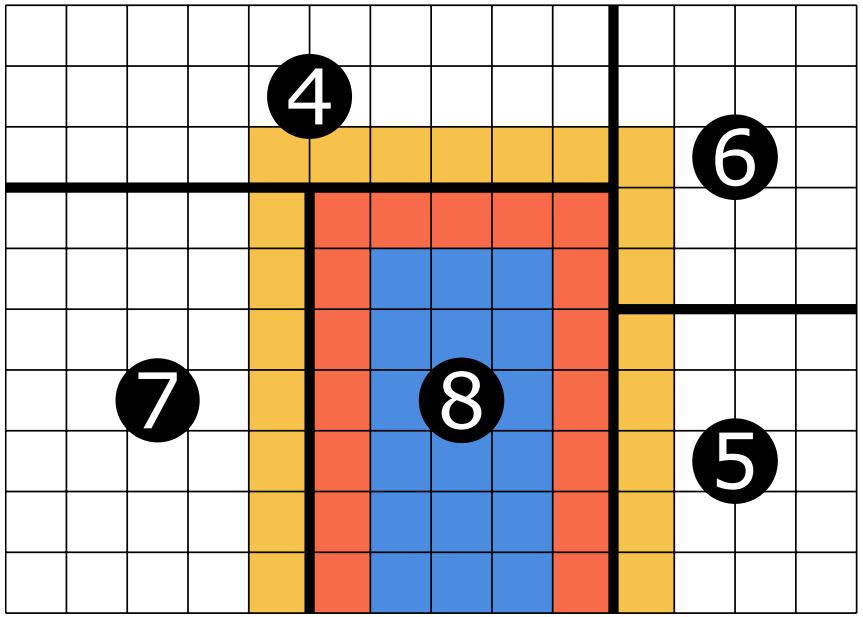
Orthogonal Recursive Bisection (ORB)

- Particles distributed to constant number of nodes
- Simulation is split recursively (each node receives multiple particles)
- Each process manages a box-shaped subdomain with approximately equal load

METHOD

Recursive Domain Decomposition





METHOD
Communication

Only particles inside the blue, red and yellow regions are stored locally on a process

Computation split into 2 parts : loop over inner cells & outer cells

Standard MPI is used for communication between neighbor processes

Load balancing control (redistribution of particles to processes – update ORB)

IMPLEMENTATION

Prediction of Advection

foreach particle i, do # not parallel due to external dependencies
  ↳ compute density

density synchronization

foreach particle i, do # loop for inner and outer cells (parallel)
  ↳ compute velocity and displacement

velocity and displacement synchronization

foreach particle i, do # loop for inner and outer cells (parallel)
  ↳ compute and update density

IMPLEMENTATION
Pressure Solve

while no density convergence, do:

pressure synchronization

foreach particle i, do # loop for inner and outer cells (parallel)
↳ compute movement caused by neighboring pressure value

movement synchronization

foreach particle i, do # loop for inner and outer cells (parallel)
↳ compute and update pressure (and density)

IMPLEMENTATION
Time Integration

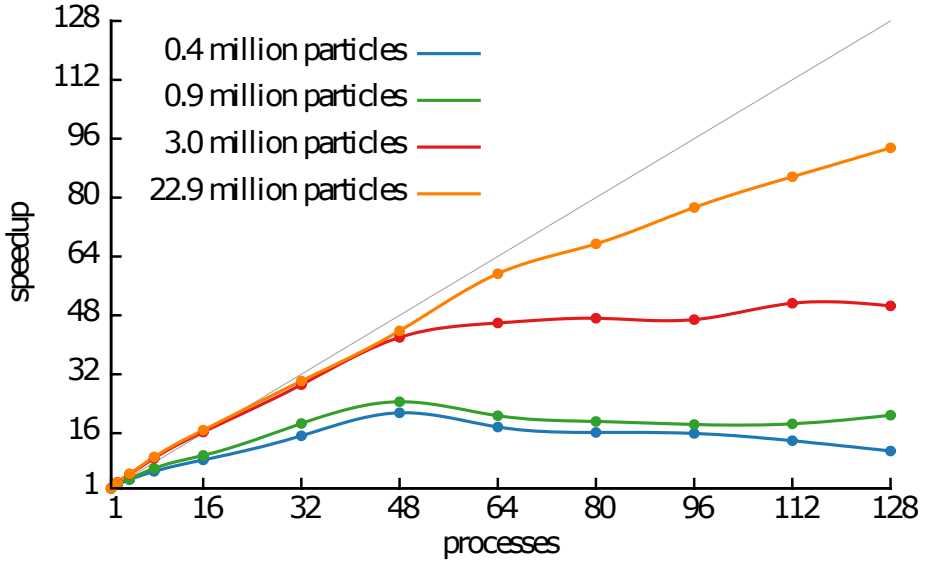
pressure synchronization

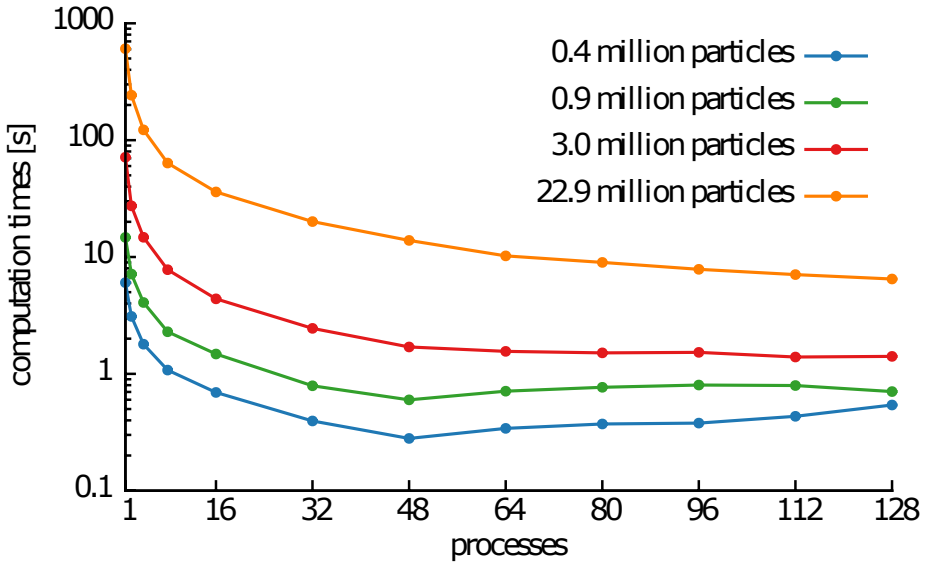
foreach particle i, do # loop for inner and outer cells (parallel)
  ↳ compute pressure forces

foreach particle i, do
  ↳ integrate

RESULTS

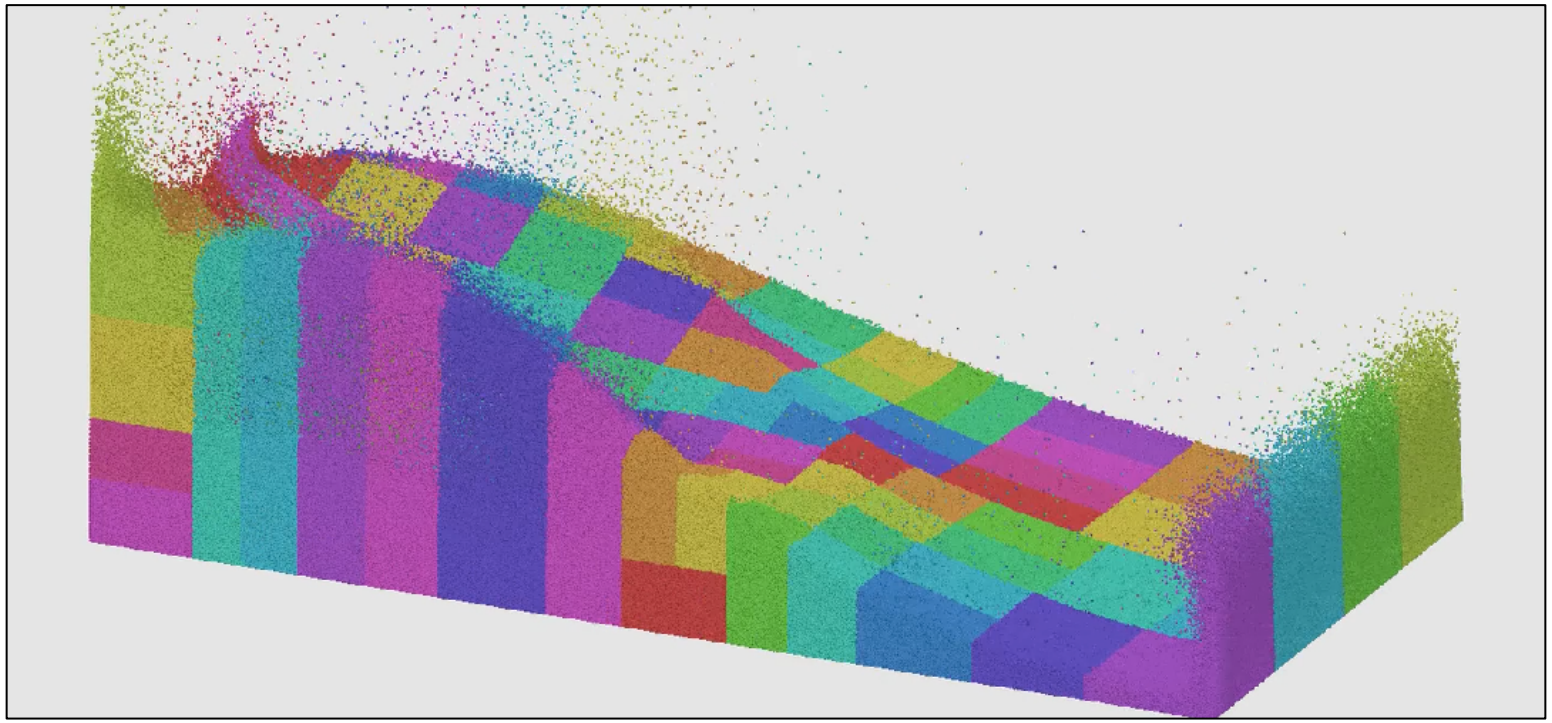
Scaling & Performance





8 cluster nodes, each of them with 4 sockets & 2.5GHz quad core processors (Total = 128 cores)

RESULTS
Load Balancing



THANK YOU