Efficient Neighbour Search for Prticle-Based Fluids

(JAMSI 2007)

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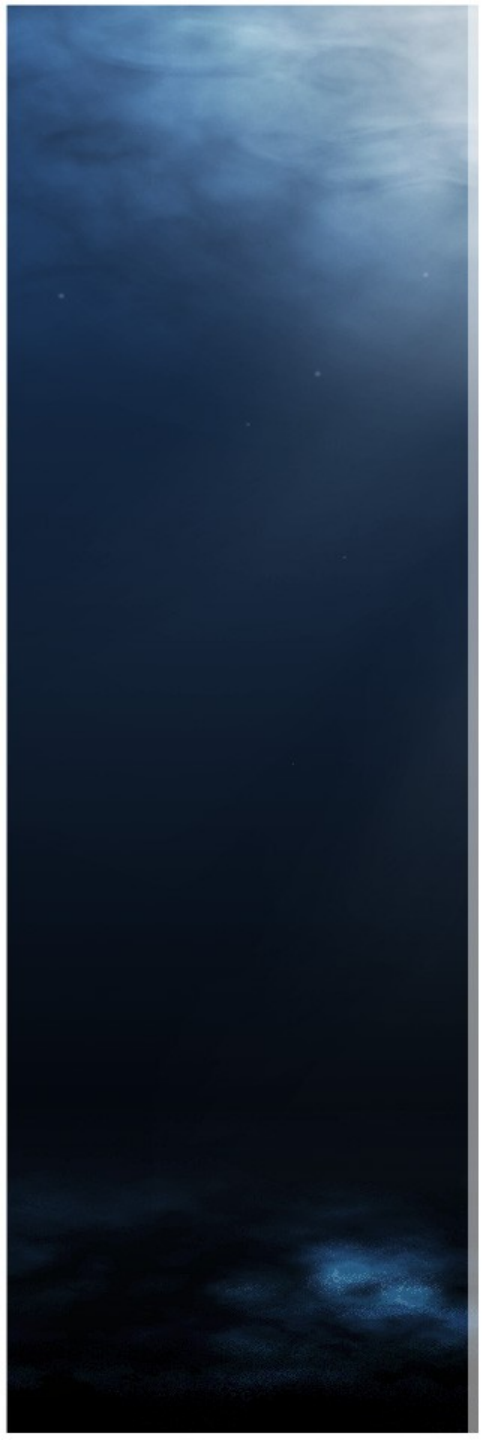
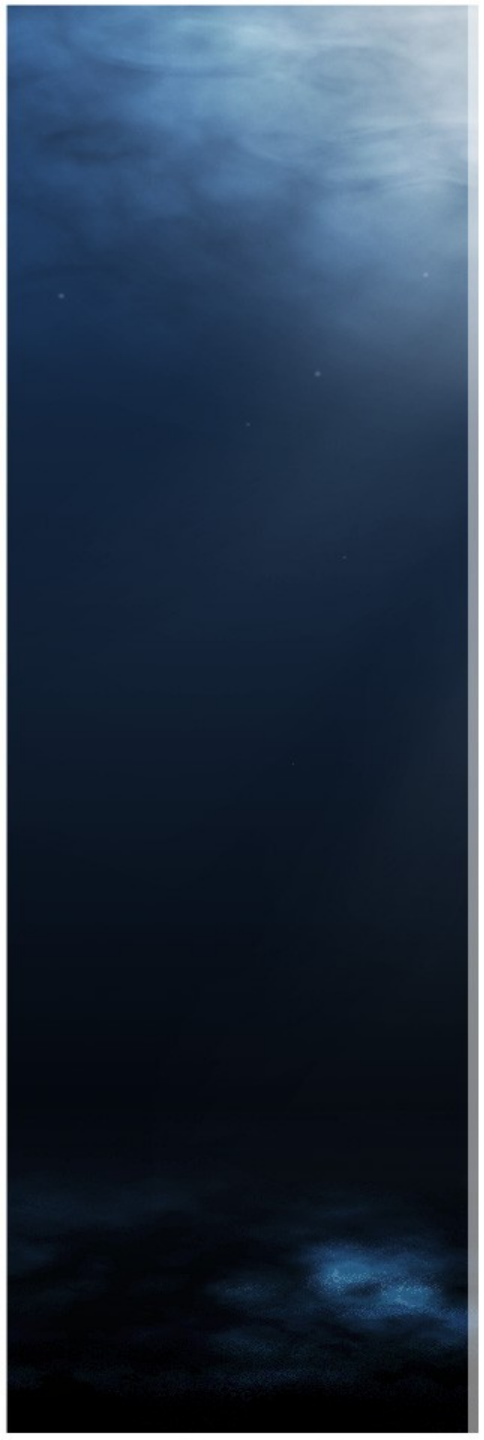


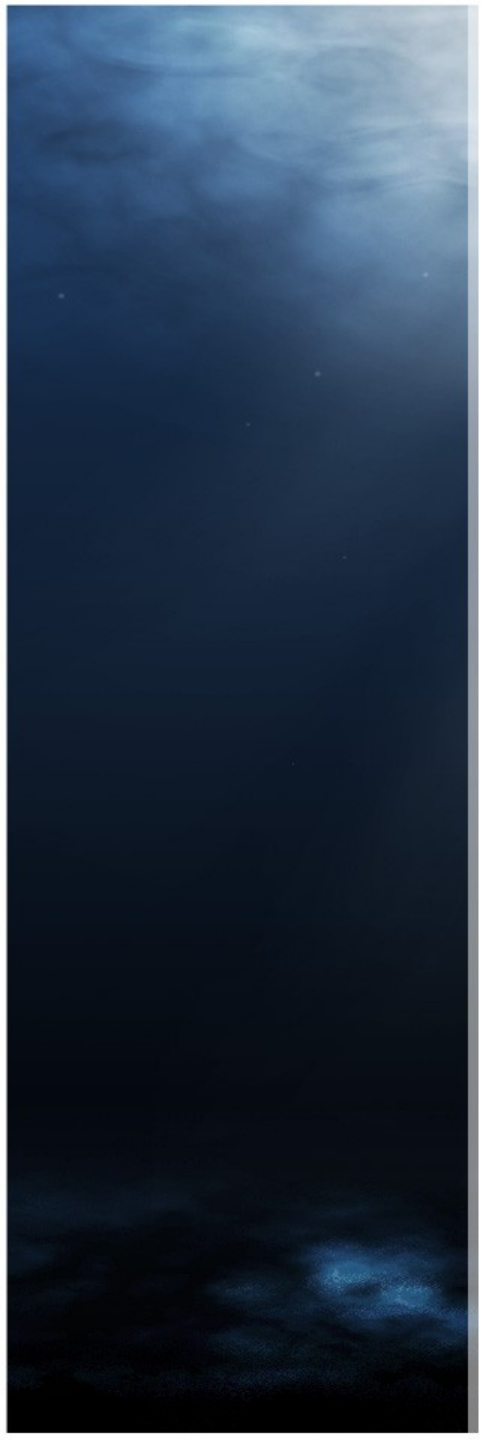
Outline

- Fluids in CG
- Smoothed Particle Hydrodynamics
- Neighbor Search
- Cell indexing
- Results



Fluids in CG

- Eulerian Grid-based methods
  - MAC grid
  - Volume of Fluid
  - Lattice-Boltzman
- Lagrangian Particle-based methods
  - Smoothed Particle Hydrodynamics
  - Moving Particle Semi-Implicit



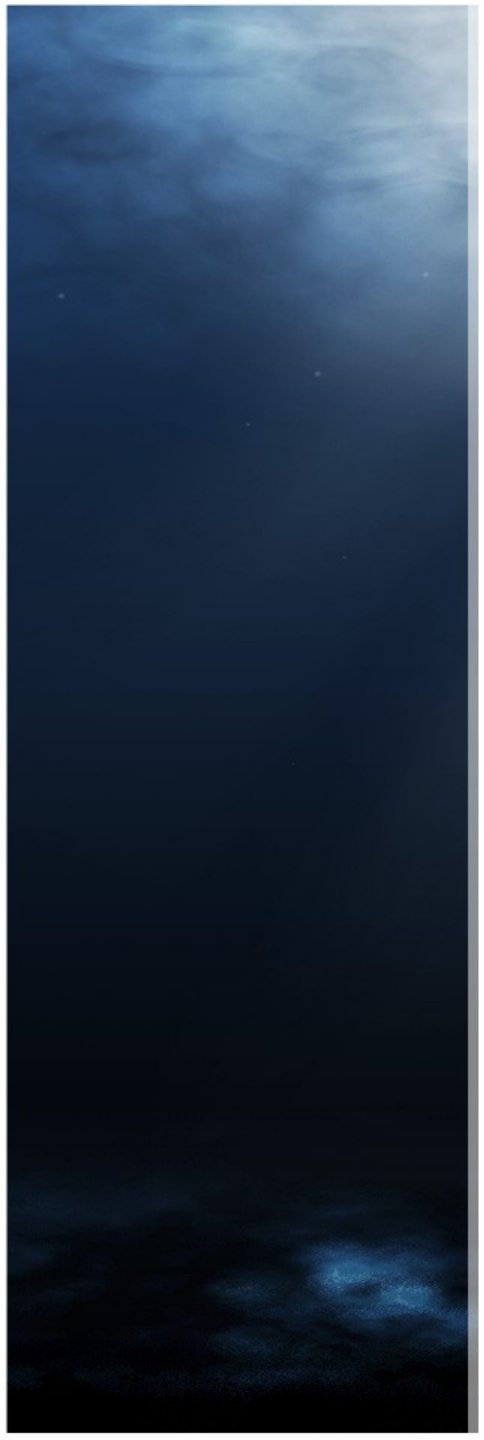
Fluids in CG

- Navier-Stokes Equations

$$\frac{\partial \vec{u}}{\partial t} + (\vec{u} \cdot \nabla)\vec{u} = -\frac{1}{\rho}\nabla p + \nu \nabla^2 \vec{u} + \vec{f}$$

$$\nabla \cdot \vec{u} = 0$$

  - u – velocity
  - p – pressure
  - f – body forces
  - ν – viscosity
  - ρ – density



Fluids in CG

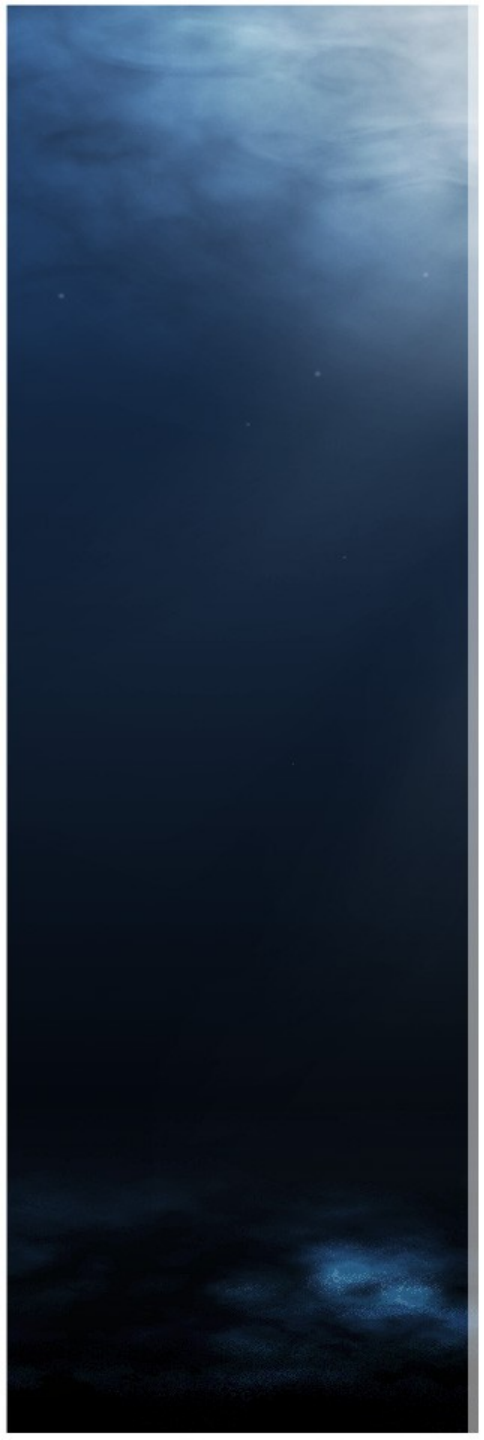
- Continuity equation
  - mass preserving

$$\nabla \cdot \vec{u} = 0$$

Fluids in CG

- Momentum equation
  - velocity field of fluid changes over time

$$\frac{\partial \vec{u}}{\partial t} = -(\vec{u} \cdot \nabla)\vec{u} - \frac{1}{\rho}\nabla p + \nu \nabla^2 \vec{u} + \vec{f}$$



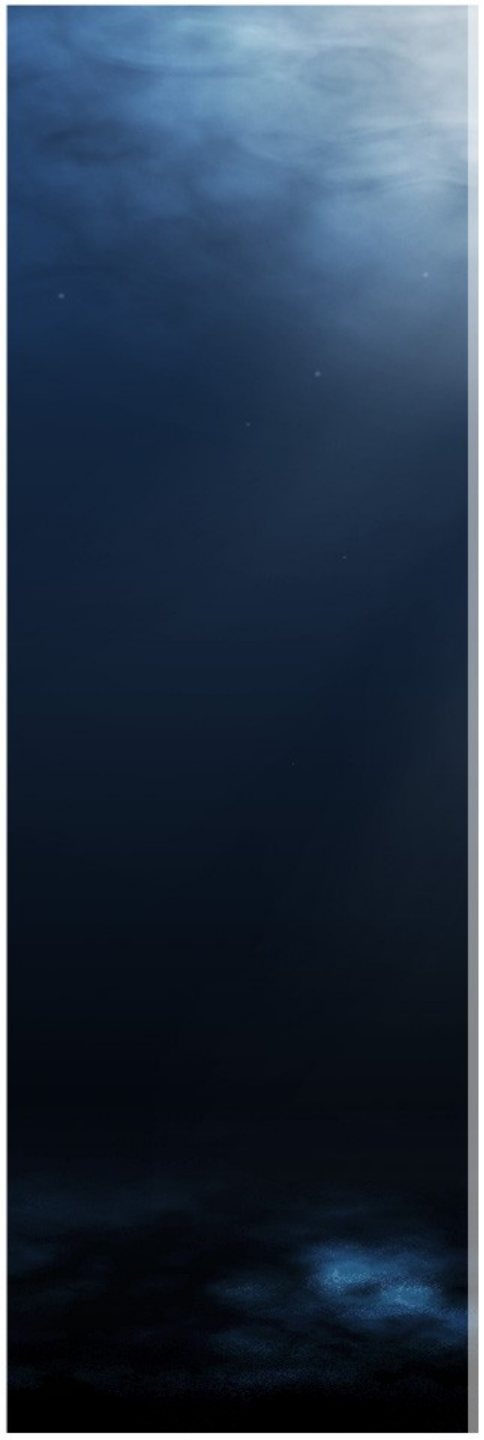
SPH

- Smoothed Particle Hydrodynamics
- Mesh-less Lagrangian technique
- Advantages
  - Inherently mass preserving
  - Spatialy unlimited domain
  - Information carried in particles only
- Drawbacks
  - Time consuming neighbor search
  - Difficult to achieve incompressible fluid

Neighbor Search

$$N_i(h) = \{\ j \quad | \quad |\mathbf{r}_i - \mathbf{r}_j| \leq h\}$$

- All pair test – $O(n^2)$
- Spatial hashing – particle clustering
- Cell indexing – novel extension of spatial hashing



Cell indexing

- Extension of spatial hashing
- Linear approach
- Effective sub-cell precision using H-mask

Cell indexing

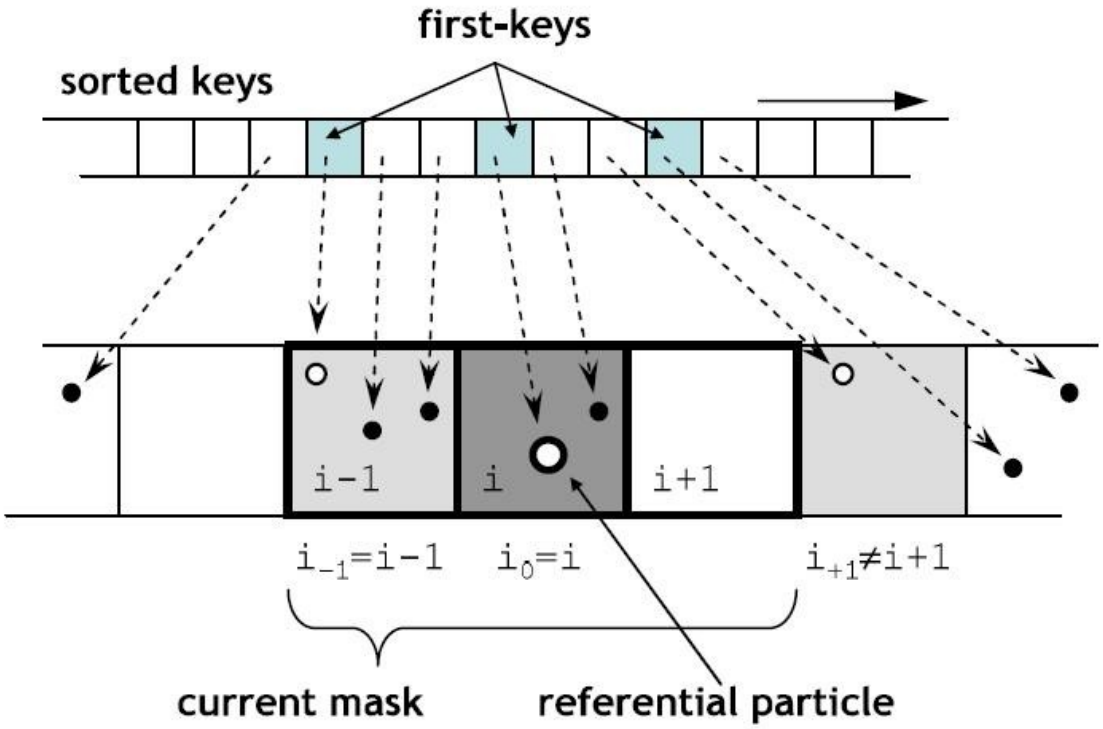
- Spread particles in cells
- Assign each particle a key
- Same cell = same key
- Sort keys – radix sort

$$cell(x,y,z,h) = \left(\left\lfloor \frac{x - x_{min}}{h} \right\rfloor, \left\lfloor \frac{y - y_{min}}{h} \right\rfloor, \left\lfloor \frac{z - z_{min}}{h} \right\rfloor \right)$$

$$key(i,j,k) = i + I \cdot j + I \cdot J \cdot k \quad \text{and} \quad \begin{matrix} I \leq \lfloor B_x/h \rfloor \\ J \leq \lfloor B_y/h \rfloor \end{matrix}$$

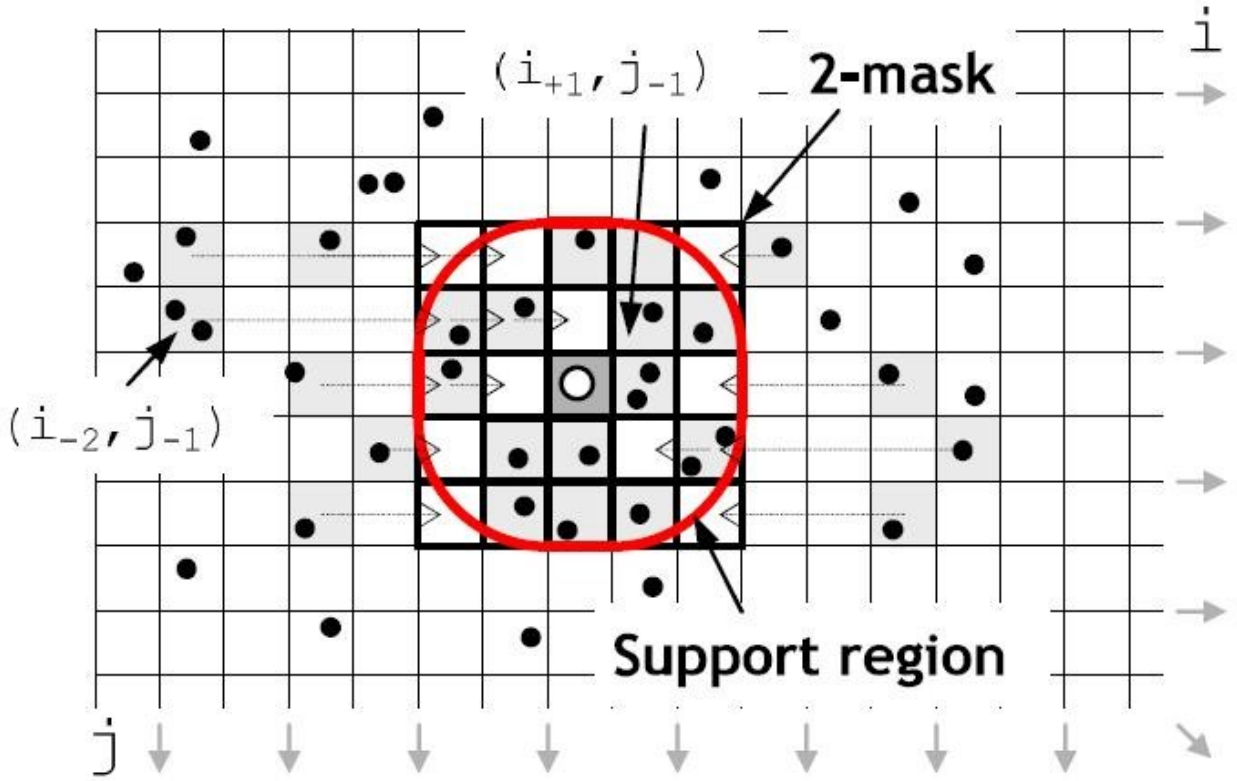
Cell indexing

- 1D example



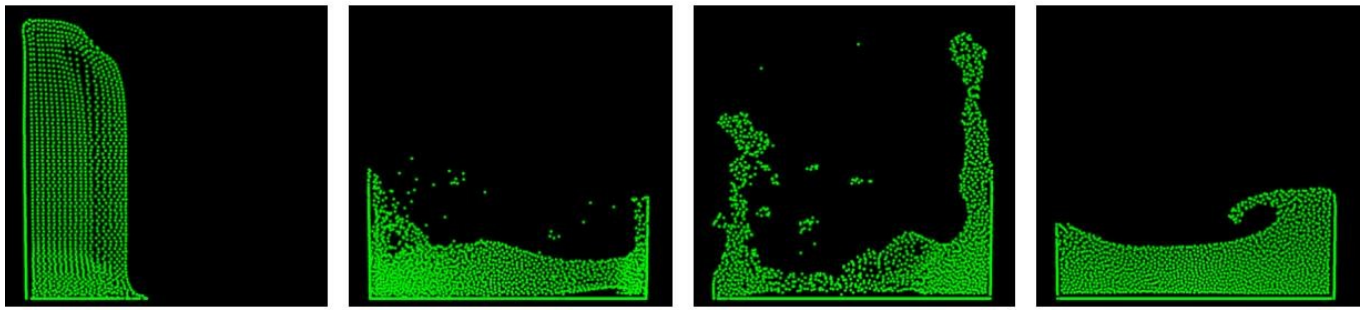
Cell indexing

- 2D example



Results

- Improvement of Spatial hashing
- Linear approach
- Reasonable space requirements
- H-mask – constant factor slowdown



Thank you