Particle-based Viscoelastic Fluid Simulation

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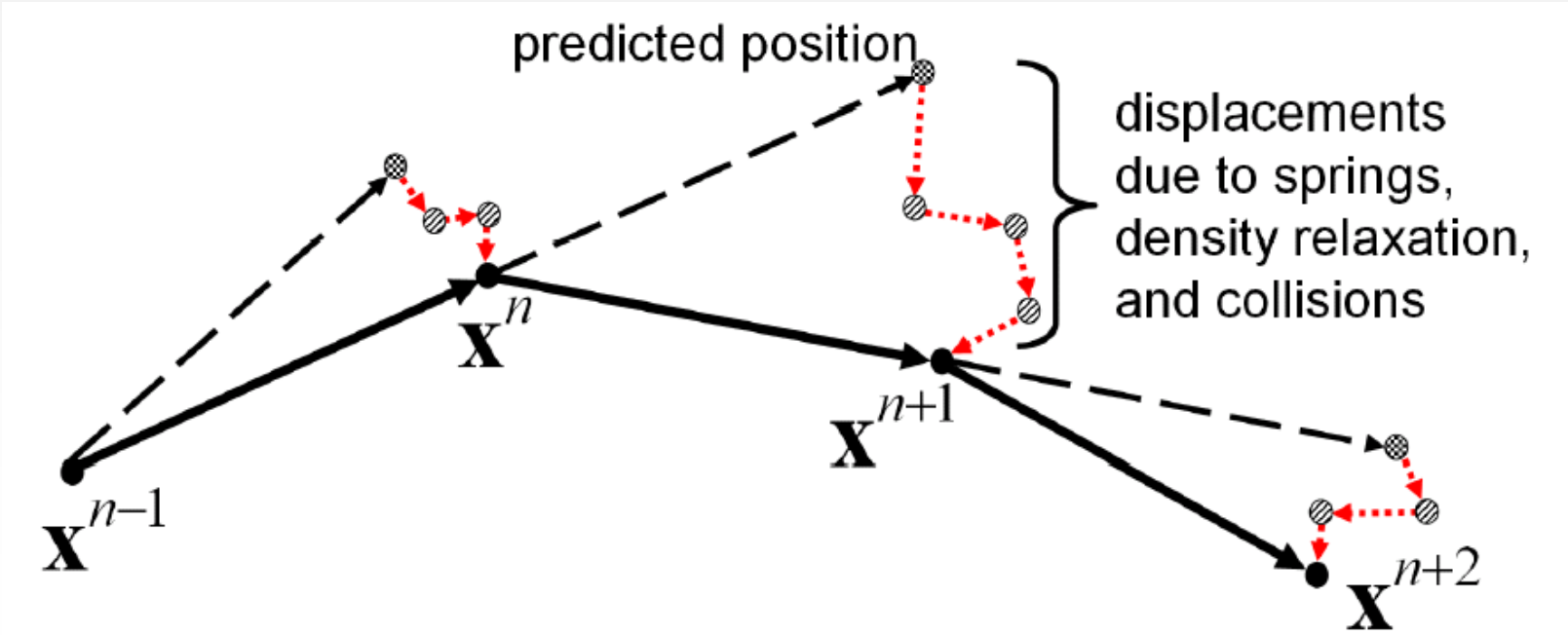
Goals

- Intuitive and versatile framework for particle-based fluid simulation
- Viscoelasticity
  - Viscosity
  - Elasticity
- Plasticity
- Incompressibility
- Stickiness

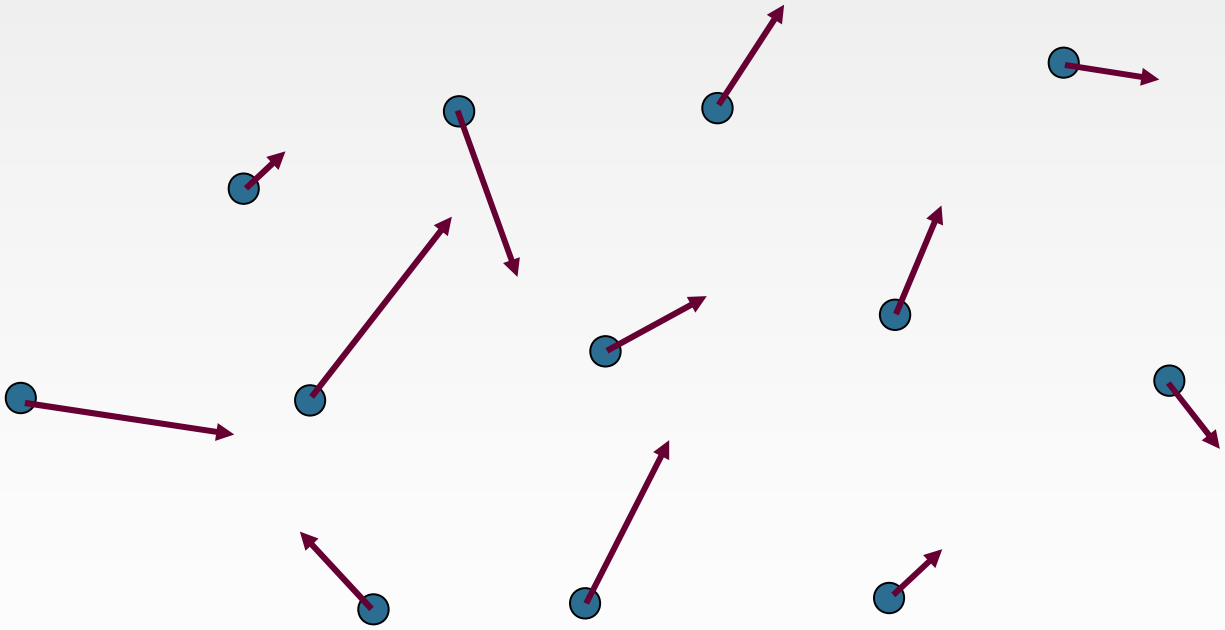
Integration scheme

- Advance particles to predicted positions
- Relax according to positional constraints



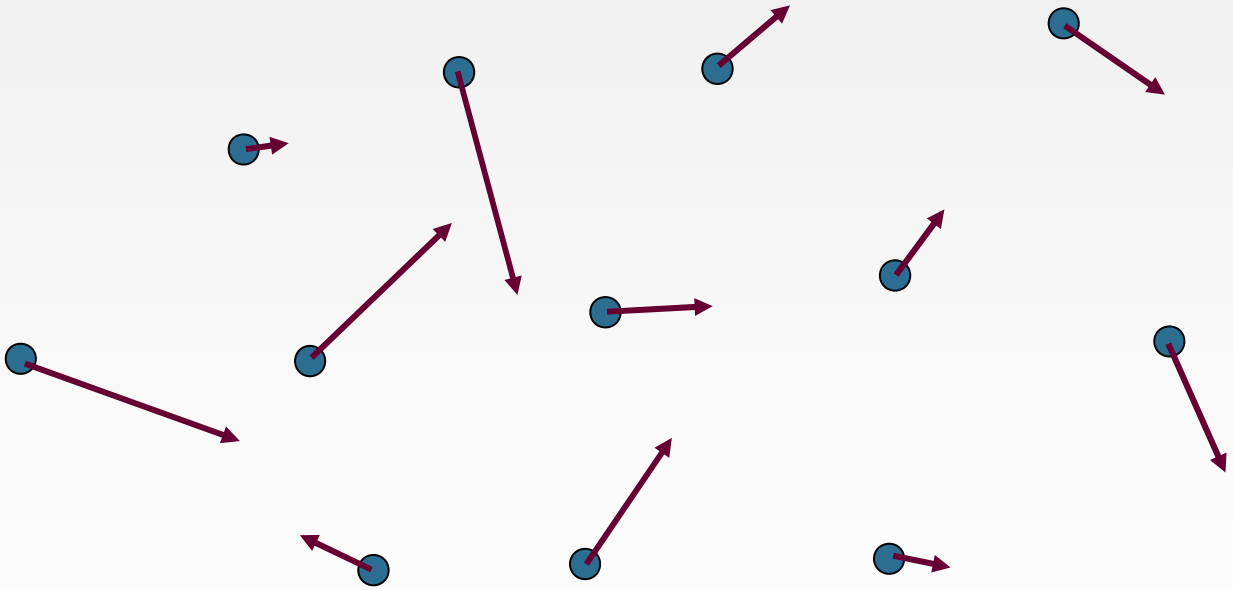
Simulation

- Preserved velocities



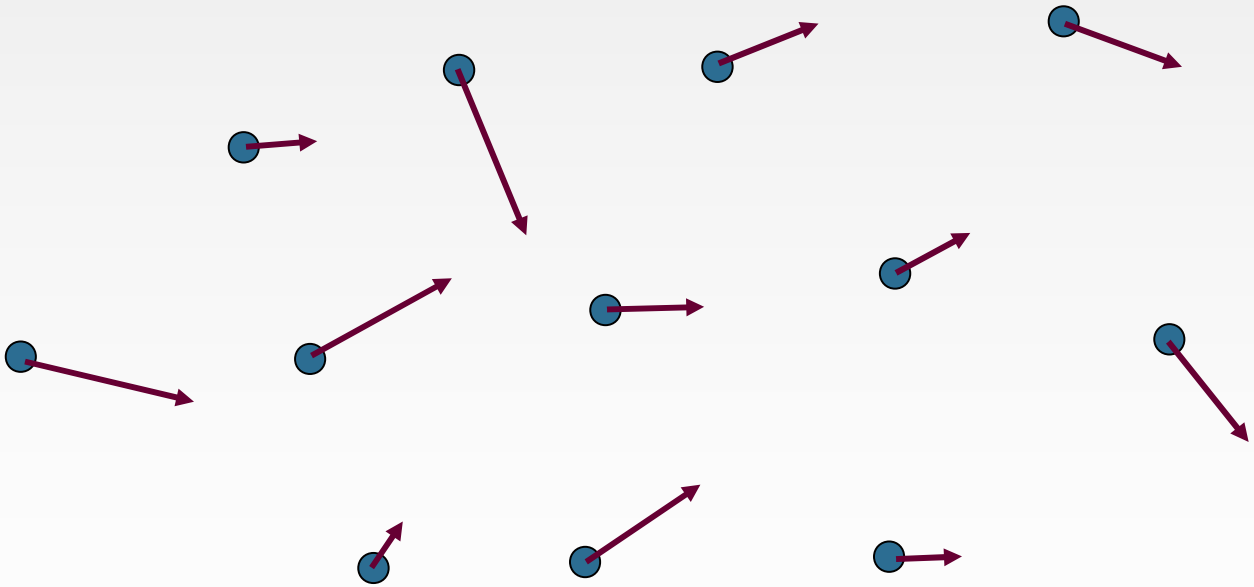
Simulation

- Apply gravity



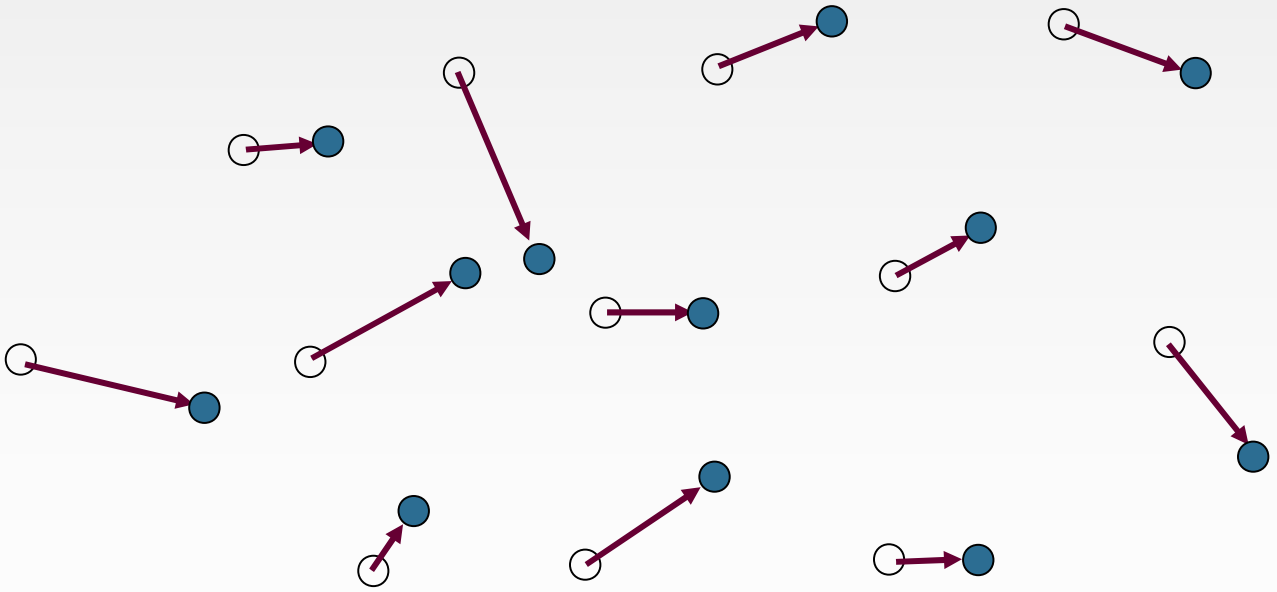
Simulation

- Apply viscosity



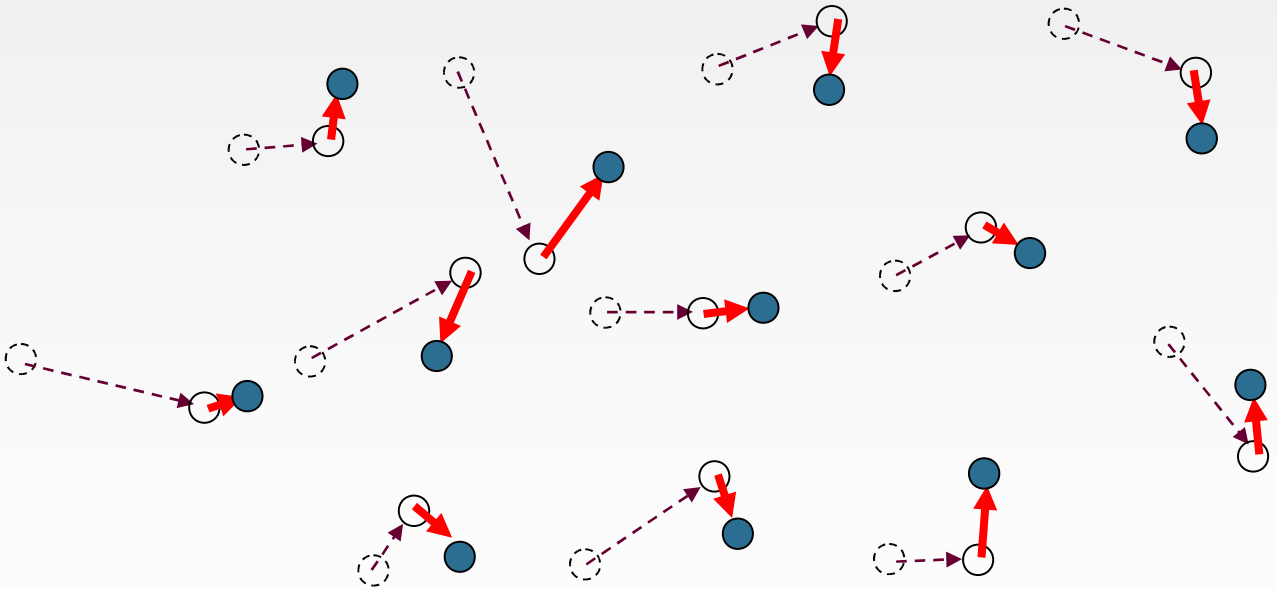
Simulation

- Advance to predicted positions



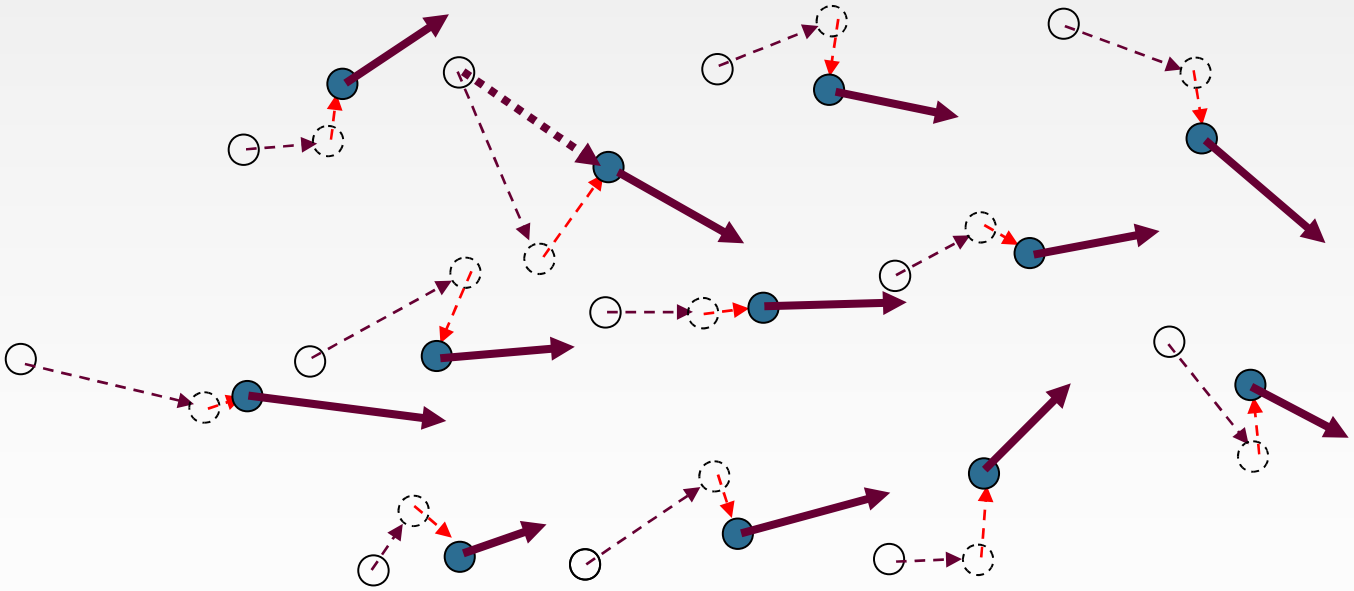
Simulation

- Relax (density and strings)



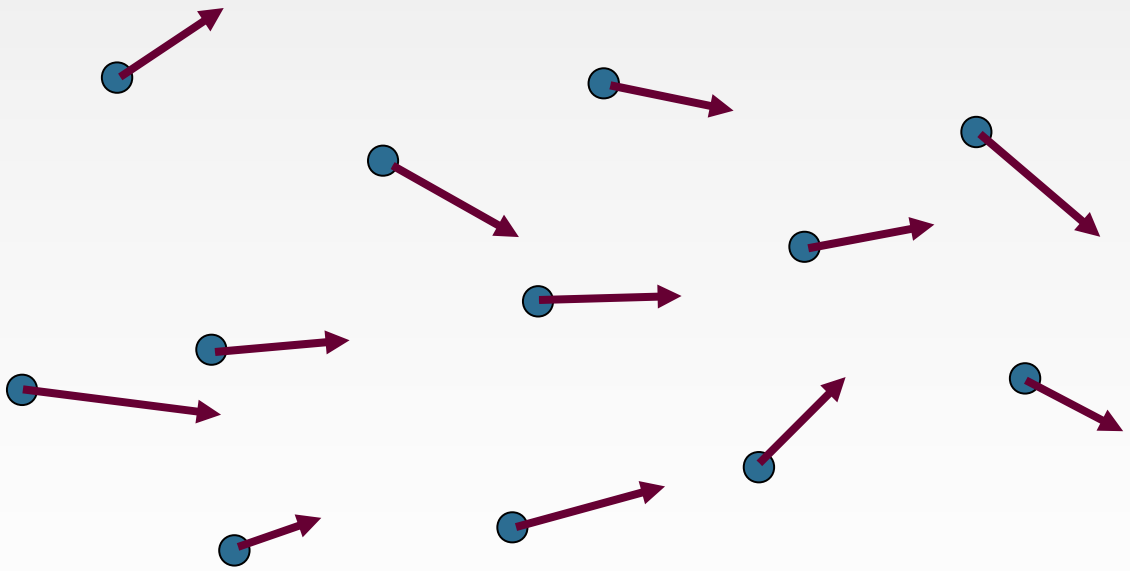
Simulation

- Obtain new velocities



Simulation

- Repeat with new velocities



Density relaxation

- Goal
  - Minimize compressibility
  - Maintain constant density
- Approach
  - For each particle
    - Compute its density
    - Modify particle and its neighbors position to approach rest density

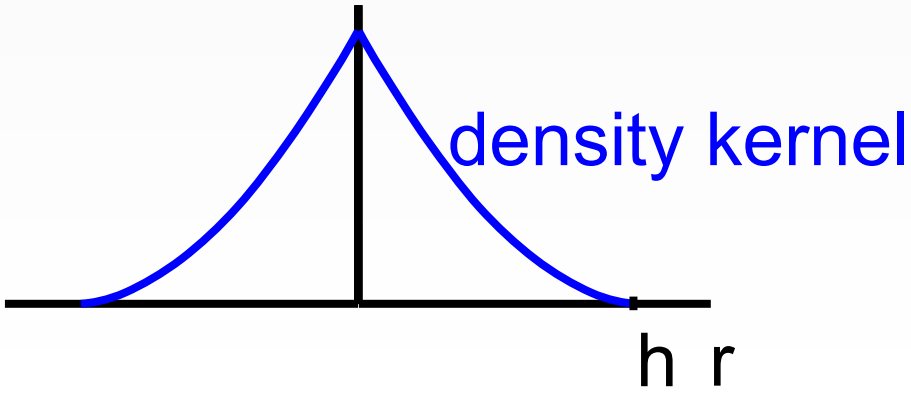
Initialization

- For each particle
  - Compute density

$$\rho_i = \sum_{j \in N(i)} \left(1 - \frac{r_{ij}}{h}\right)^2$$

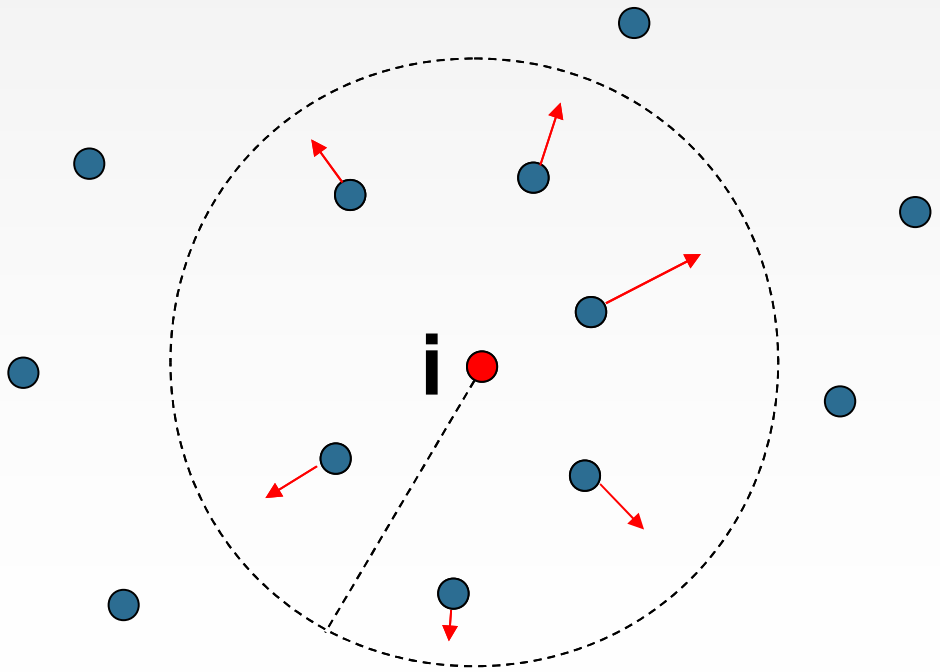
  - Compute proportional pressure

$$P_i \sim \rho_i - \rho_0$$



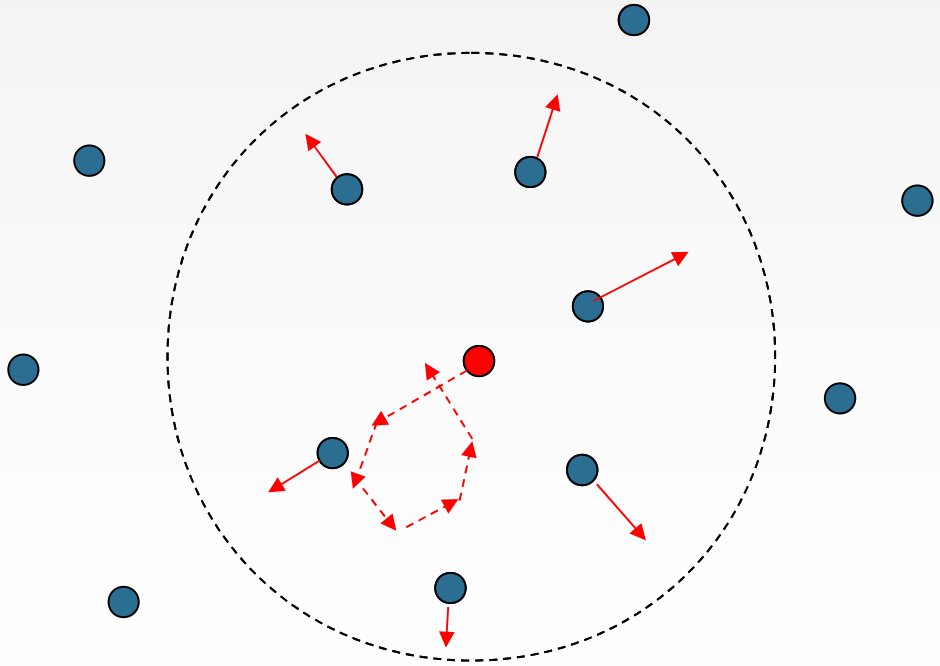
Particles relocation

- Compute displacement for neighbors $D \sim P_i\left(1 - \frac{r_{ij}}{h}\right)$



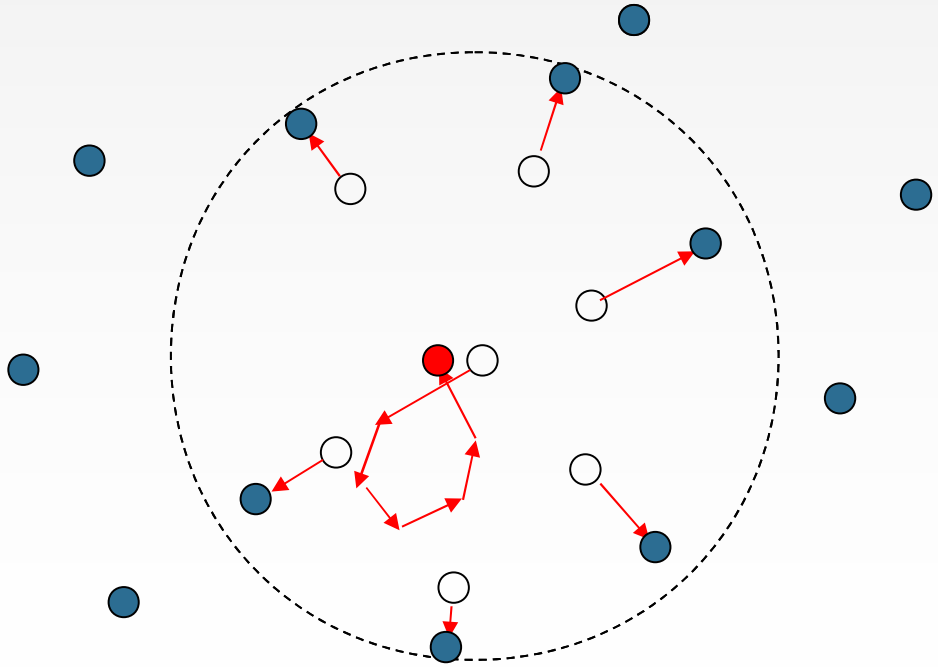
Particles relocation

- Compute displacement for particle



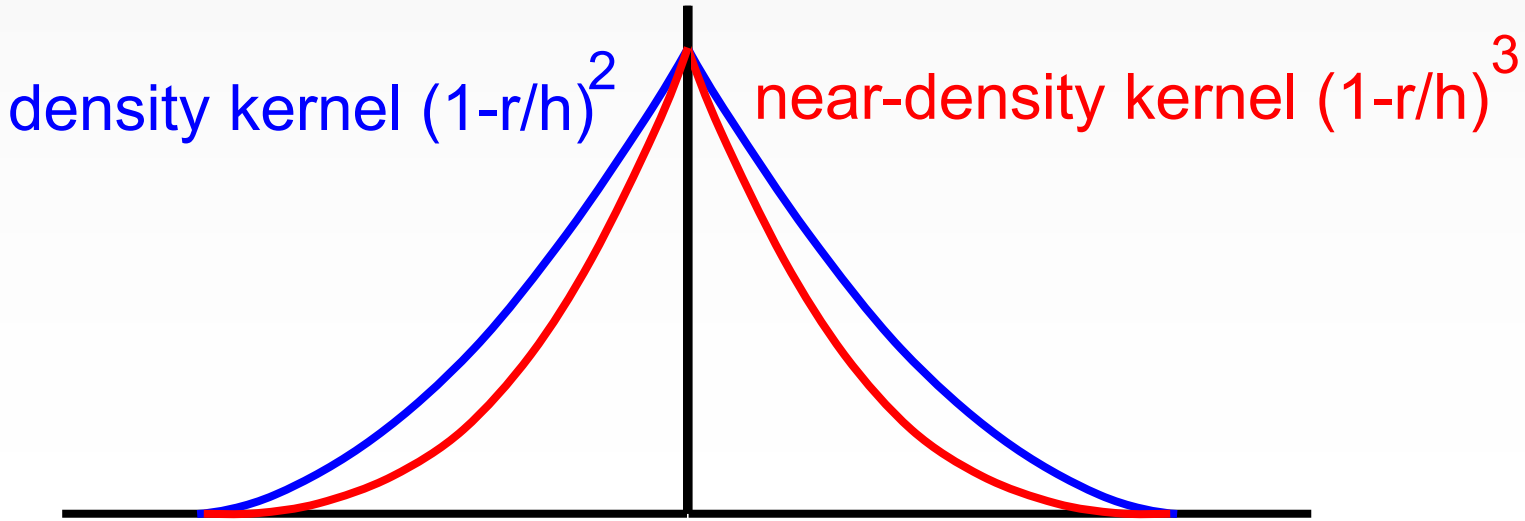
Particles relocation

- Move particles



Near-density

- Motivation
  - Avoid particle clustering
- Solution
  - Add repulsive forces for near neighbors
  - Sharper near-density kernel

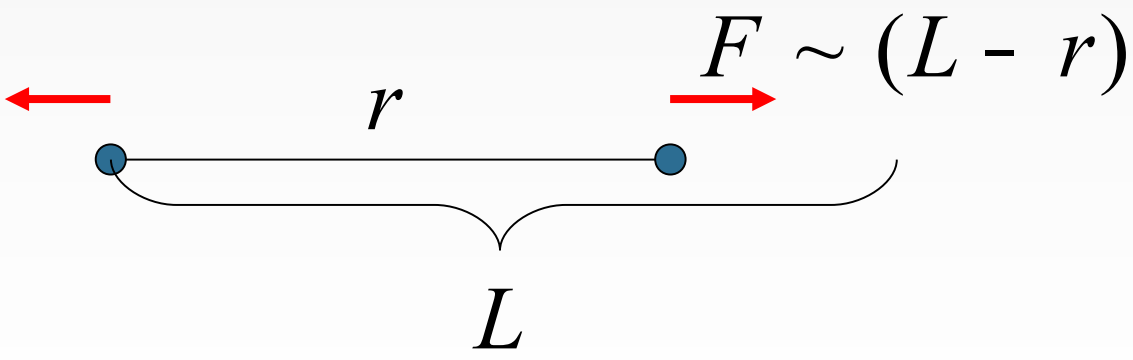


Near-density

- Near-density has zero rest value (only repulsive forces)
  - Density $P_i \sim \rho_i - \rho_0$
  - Near-density $P_i^{NEAR} \sim \rho_i^{NEAR}$
  - Neighbor displacement $D \sim P_i\left(1 - \frac{r_{ij}}{h}\right) + P_i^{NEAR}\left(1 - \frac{r_{ij}}{h}\right)^2$

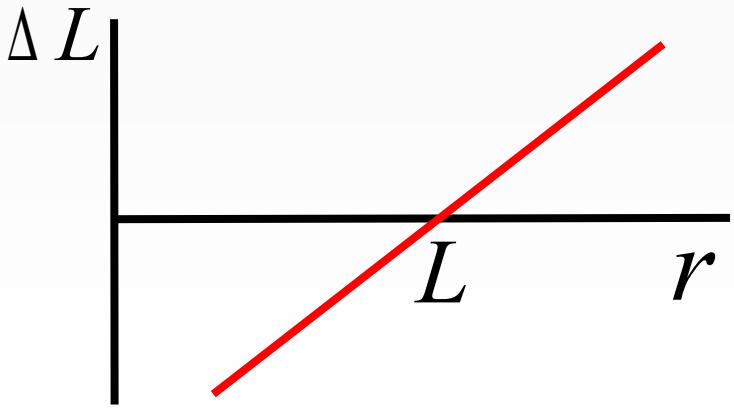
Elasticity

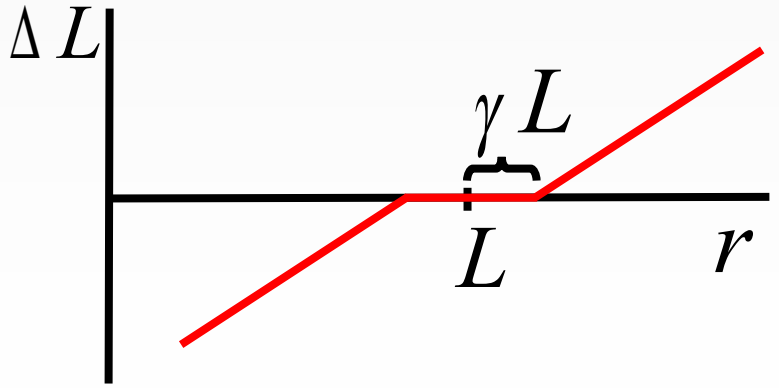
- Springs between neighboring partices
- Move partices to achieve spring rest length



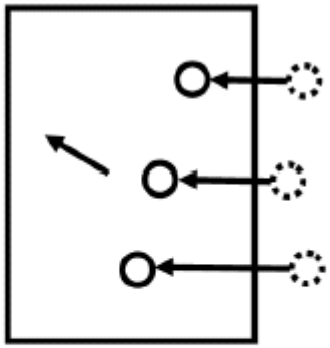
Plasticity

- Add and remove strings
- Change string rest length based on current length
- Linear
  - Plastic flow for every deformation $\Delta L \sim \alpha (r - L)$
- Nonlinear
  - Plastic flow only if deformation is large enough

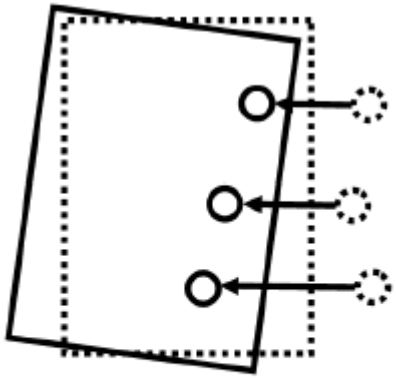




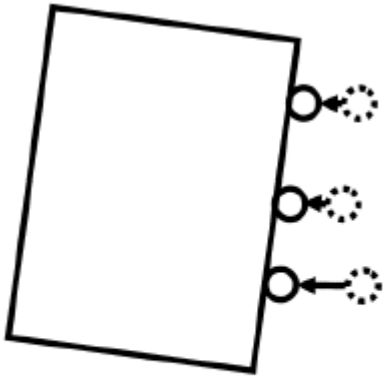
Collisions



1) Accumulate particle impulses on body



2) Update body configuration



3) Update particle positions

Stickiness

- Detach particles to objects
- Apply, if distance small enough
- Attraction impulse to particles

Results

- Video

Zdroje

- Particle-based Viscoelastic Fluid Simulation (Simon Clavet, Philippe Beaudoin, Pierre Poulin)
- http://www.iro.umontreal.ca/labs/infographie/papers/Clavet-2005-PVFS/index.html

Priestor na otázky