Particle Methods – Simplified Project Proposals

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Proposal 1: Simplified 2D MPS Simulation of Sloshing Fluid

Objective:
The goal of this project is to implement a basic two-dimensional simulation using the Moving Particle Semi-implicit (MPS) method. The simulation will capture free-surface sloshing motion in a rectangular tank. To maintain simplicity, the pressure correction step will use an artificial compressibility model instead of solving the Poisson equation, and viscosity will be omitted.

Planned Implementation:

- Particles are initialized in a rectangular block of water inside a tank.
- Density is computed using summation over neighboring particles with a simple kernel.
- Pressure force is calculated using a pseudo-pressure equation of state (e.g., $p = k(\rho - \rho_0)$).
- Acceleration from pressure and gravity is used to update velocity and position via an explicit Euler method.
- Boundary conditions are handled by fixed particles along the tank walls.
- Visualization of particle positions at each time step.

Expected Results:

- Free-surface sloshing behavior with recognizable wave motion.
- Time evolution of kinetic energy showing damping behavior.
- Qualitative agreement with physical intuition and literature figures.

Feasibility:
The simplified MPS removes the pressure Poisson solver and viscous terms. This reduces the computational and implementation complexity significantly. With a particle count of around 100–200, the simulation can be run efficiently on a laptop, and core ideas of particle-based fluid dynamics can still be demonstrated.

Proposal 2: 2D DEM Simulation of Granular Drop with Simple Collisions

Objective:
This project aims to implement a basic 2D Discrete Element Method (DEM) simulation for visualizing how granular particles fall under gravity and settle in a container. The contact model will be restricted to a linear spring without damping or friction to focus on the essentials.

Planned Implementation:

- Generate 50–100 circular particles with random initial positions above a fixed floor.
- Detect collisions using simple circle overlap logic.
- Apply normal contact force using Hooke's law ($F_n = -k_n\delta$), where δ is the overlap.
- Fixed particles form the container walls.
- Motion is integrated using the explicit Euler method.
- Visualize the drop and settling process step by step.

Expected Results:

- Realistic settling of particles under gravity.
- Formation of a granular pile at the bottom.
- Time-series plot of kinetic energy decay.

Feasibility:
The reduced DEM model excludes tangential forces, rotation, and energy dissipation terms, ensuring quick implementation. The small number of particles allows fast simulation and easy debugging while still demonstrating granular dynamics.