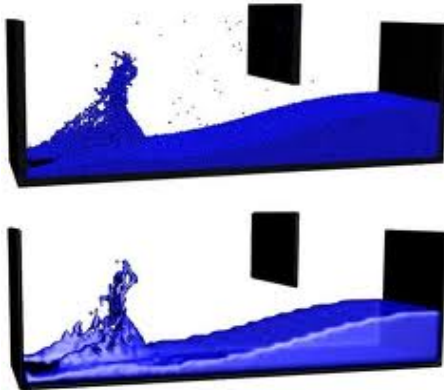




Particle methods in Fluid Mechanics.



What is a "good" numerical method?.

- Method for simulating continuum flow phenomena in different physical systems.
 - Wide range of applications.
 - Adaptive.
 - Computationally efficient.
 - Stable.
 - Accurate.

- Grid-based methods.

- Mesh-free methods.
 - Particle methods.

- Many examples in the CFD community: FEM, FV, FD, spectral...
- Mesh generation is a prerequisite for the simulation.
- Mesh types:
 - Lagrangian grids.
 - Eulerian grids.
- Problems with large deformations.
Re-meshing.(Lagrangian).
- Difficult to deal with moving boundaries or free surfaces.(Eulerian).

Those methods that do not use any connectivity between nodes or particles.

- 1 Smoothed particle hydrodynamics (SPH) Lucy Gingold and Monaghan 1977.
- 2 Finite point method Liszka and Orkisz (1980) and Oñate (1996).
- 3 Diffuse element method Nayroles et al. (1992).
- 4 Element Free Galerkin Belytschko (1994-1998)
- 5 Reproduced kernel particle method (RKPM) Liu (1995)
- 6 HP-cloud Duarte and Oden (1996)
- 7 etc....
- 8 Coupling with conventional numerical schemes (PFEM) Idhelson.

- 1 Interface capturing (ex: vortex sheets).
- 2 The major difficulty of classical methods (FDM, FEM, FV) are inherited from the use of a mesh.
- 3 Costly and time consuming process of regenerating a good quality mesh. Bad mesh quality implies bad accuracy.
- 4 No fixed connectivity between particles.
- 5 Only initial discretization is required.
- 6 The system moves as the particle move.
- 7 Free surface, deformable boundaries, large deformations and moving interfaces.

- 1 Accurate treatment of boundary conditions.
- 2 Severe particle distortion that may introduce spurious scales.
- 3 Clumpings.

- 1 SPH Lucy Gingold and Monaghan 1977.
- 2 Molecular Dynamics Alder 1957 .
- 3 Monte Carlo Metropolis and Ulam. (1949).
- 4 Discrete simulation Monte Carlo Bird (1994)
- 5 dissipative particle dynamics (DPD) Español (1998)
- 6 Lattice Boltzmann Chen (1998)
- 7 Moving Particle Semi-implicit Koshizuka (1998)
- 8 Discrete Element Method (DEM) Cundall (1987).
- 9 Vortex methods. Chorin (1973)

- Method for exploring diverse physical systems as:
 - Planetary dark matter
 - Proteins
 - Unsteady separated flows
 - Plasmas

Discretization concept: particle representation.

Instead of using a mesh, the computational domain is discretized using particles.

- Particles can be viewed as objects carrying a physical property of a system.
- The solution of Ordinary Differential Equations (ODEs) determine the trajectories and the evolution of the properties carried by the particles.

- Earliest mesh free particle method.
- Integral representation.
- Deterministic method based on physical laws.
- Lagrangian method.
- Explicit method. WCSPH-ISPH

- Incompressibility condition.
- Tensile instability.
- Consistency.
- Boundary conditions.
- Particle irregularity and accuracy. Mathematical background.