Simulation of dense particle flows with IBOFlow
Immersed Boundary Octree Flow Solver

- **State-of-the-art solver for multi-phase flows**
  - Unique immersed boundary techniques
  - *Greatly simplified pre-processing – ”no bodyfitted meshing”*
  - *Moving geometries handled very efficiently*
  - Very fast implementation – GPU computing
  - Volume of Fluids module
  - Particle and sprays module
  - Multiple cavities

- **Multi-physics applications**
  - Electrostatic module
  - Heat transfer module
  - Structural dynamics module
  - DEM module

- Efficient pre- and post-processing and user-friendly GUI tailored for customer needs
- Physic engine for IPS applications
- Used by Chalmers in some research projects
The Hybrid Immersed Boundary Method

- The objects are connected to the background grid
- Models the presence of the objects in the fluid by interior boundary conditions
  - Transport equations:
    - Implicit Immersed Boundary Condition
    - Mirroring the velocity field over the IB
  - Continuity equation:
    - Physical condition
    - Zero mass flux over IB is ensured by replacing the fictitious velocity field inside the IB with the local velocity of the IB
    - Minimal pressure oscillations
- Other active research groups employ our IB method

Grid generation in IBOFlow

- Read in CAD or an analytical object
- Base grid
  - Uniform octree base grid
  - Anisotropic grid size (dx,dy,dz)
  - Number of cells (nx, ny, nz)
- Adaptive refinement control
  - Geometric
    - Refine around objects
    - Refine around exterior boundaries
  - Regions e.g. box, sphere and plane
  - Liquid surface
Automatic solid cyclic boundary conditions

- 4 objects
- All cyclic boundaries
- Stable velocity field
Automatic solid cyclic boundary conditions

- 1 stationary sphere
- 1 moving sphere
- 2 moving boxes
- All cyclic boundaries
- Automatic
  - Connectivity
  - Refinement
- One new option
Contact modelling

- Particles represented by general unstructured volume meshes
- User input contact time, coefficient of restitution and friction coefficient
- Algorithm
  - Vertex triangle overlaps are found and generates a force
  - Linear-spring-damping (normal) model is used
  - From the particle masses and contact time a contact stiffness is calculated
  - Column friction
  - Single vertex in contact approximation
Cyclic pipe flow with mixed particles

- Rigid body motion handled with LaStFEM
- Automatic cyclic solid and fluid boundary conditions
- Flow controlled inlet pressure boundary condition
- 68 spheres
- 68 cubes
- High solid volume fraction
- 4 way coupling
- Implicit object-object collision including damping and friction
Pipe Flow and Conjugate Heat Transfer

- Fluid temperature transported by the local velocity field
  - Ultimate QUICKEST convective scheme preferable
- Solid temperature solved with an unstructured FEM heat solver
  - First order tetrahedrons with higher order Gaussian quadrature on faces for flux calculation
  - Implemented lumped diagonal mass matrix to handle high Prandtl numbers
- Thermal coupling/boundary conditions
  - DNS – Immersed boundary
  - Wall functions – Immersed boundary based
  - HTC – Local and global heat transfer coefficient flux based