IB-LBM coding session: brief introduction

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Outline

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IB-LBM coding sessions

part 1: deformable particle (sphere/RBC) in simple shear flow

- tank-treading/tumbling
- lateral migration

part 2: rigid cylinder in Poiseuille flow

- streamline penetration
- Kármán vortex street

Model properties (1)

- D2Q9 BGK lattice Boltzmann model
- Ladd/Guo forcing
- immersed boundary method with bi-linear interpolation
- elastic forcing model

Model properties (2)

deformable cylinder

- elastic springs between neighboring nodes
- elastic 'bending springs' between neighboring links
- freely moving in space

rigid cylinder

- elastic penalty force for each node, $\boldsymbol{F}_i \propto -(\boldsymbol{x}_i - \boldsymbol{x}_i^0)$
- fixed in space $\Longrightarrow$ no translation/rotation

Algorithm structure

simulation initialization

- specify simulation parameters (user)
- allocate memory and initialize variables

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simulation loop

1. compute node forces from deformation via constitutive model
2. spread node forces to fluid lattice
3. perform LBM including external forcing
4. interpolate fluid velocity to nodes
5. update node positions
6. write data to disk if desired
7. go back to first step

Remarks

code and compiler

- single file, parameters hard-coded $\Longrightarrow$ compile after change
- compiler call:
  `g++ -O3 IBLBM_2D_example.cc -o binary`
- execute without parameters: `./binary`

folders and files

- write VTK data into folders
  - `vtk_fluid`
  - `vtk_particle`

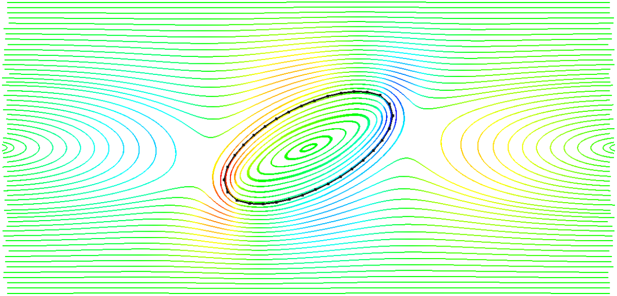
  $\Longrightarrow$ ParaView
- write ASCII data for force, position, velocity into `data.dat`
  $\Longrightarrow$ gnuplot, Tecplot

Outline

Tank-treading in shear flow

aspects to study

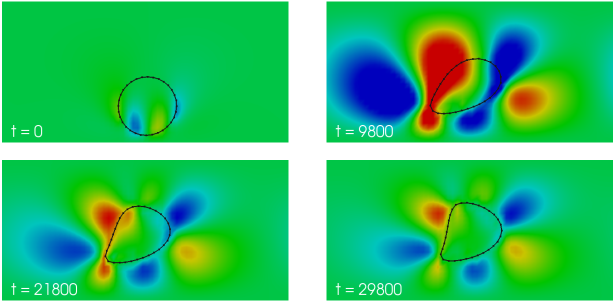
- find valid parameters for tank-treading
- observe tank-treading rotation and streamlines
- visually inspect results with ParaView



Lateral migration in Poiseuille flow

aspects to study

- find valid parameters for lateral migration
- observe migration velocity
- visually inspect results with ParaView



Hints

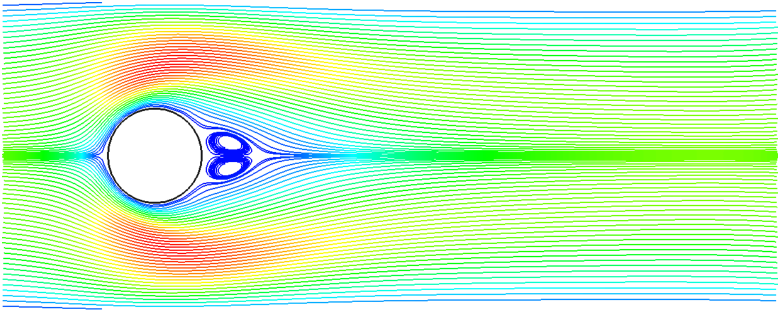
- compile with preprocessor command
  `#define DEFORMABLE_CYLINDER` or
  `#define DEFORMABLE_RBC`
- small system size recommended, e.g., 30×30 (faster)
- use small particle rigidities (deformability important)
- for lateral migration
  - zero wall velocity
  - finite gravity
  - position particle close to one wall
- for tank-treading
  - finite wall velocity
  - zero gravity
  - position particle on centerline

Outline

Steady flow around cylinder

aspects to study

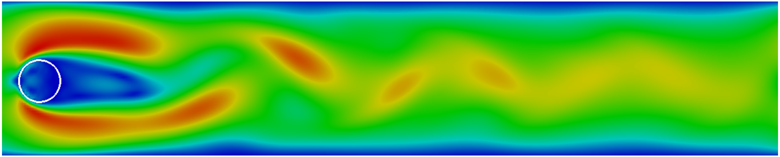
- find valid parameters for stready flow
- visually inspect results with ParaView



Kármán vortex street

aspects to study

- find valid parameters for vortex street
- identify & investigate numerical problems
- obtain lift & drag forces
- visually inspect results with ParaView



Hints

- compile with preprocessor command
  `#define RIGID_CYLINDER`
- large system size recommended, e.g., 300×60 (more stable)
- use higher particle rigidity (rigidity important)
- for vortex street
  - zero wall velocity
  - finite gravity
  - position particle close to but not on centerline
- for steady flow
  - zero wall velocity
  - finite gravity
  - position particle on centerline