CFD – Lab

Preliminary Session

Nikola Tchipev

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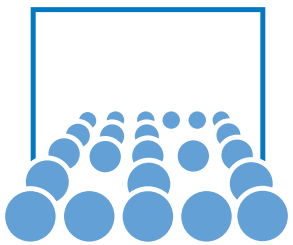


Introduction to Grid-Based CFD

- theoretical background on fluid dynamics
- implementing two distinct approaches (C)
  - solving the Navier–Stokes equations (NSE)
  - Lattice–Boltzmann method (LBM)
- treating arbitrary geometries (maybe VTune)
- MPI parallelization

Project Work (topic chosen by the teams)

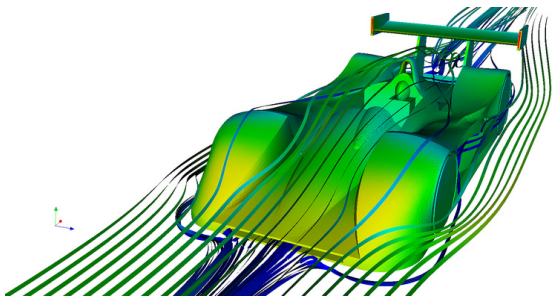
- adding heat transport
- adding turbulence model (RANS/LES)
- OpenMP
- free surfaces
- . . . (or your suggestion)

Prerequisites

- programming skills in C
- basic numerical skills (e.g. Numerical Programming I)
- no preknowledge in fluid dynamics needed
- (some experience with Linux would help)

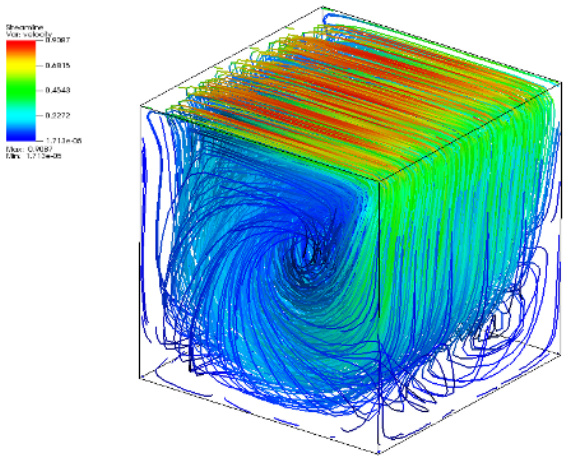
Motivation: Navier–Stokes–Equations

- Describe the motion of fluid substances
- Obey general laws of continuum mechanics
- Widely used in different scientific areas :
  - → Model of weather
  - → Automobile, Airplane industry..
  - → Medical science
  - → Others:Geophysics, Chemistry, Astrophysics..



ParaView - Flow Around Car

NSE: How does it work?

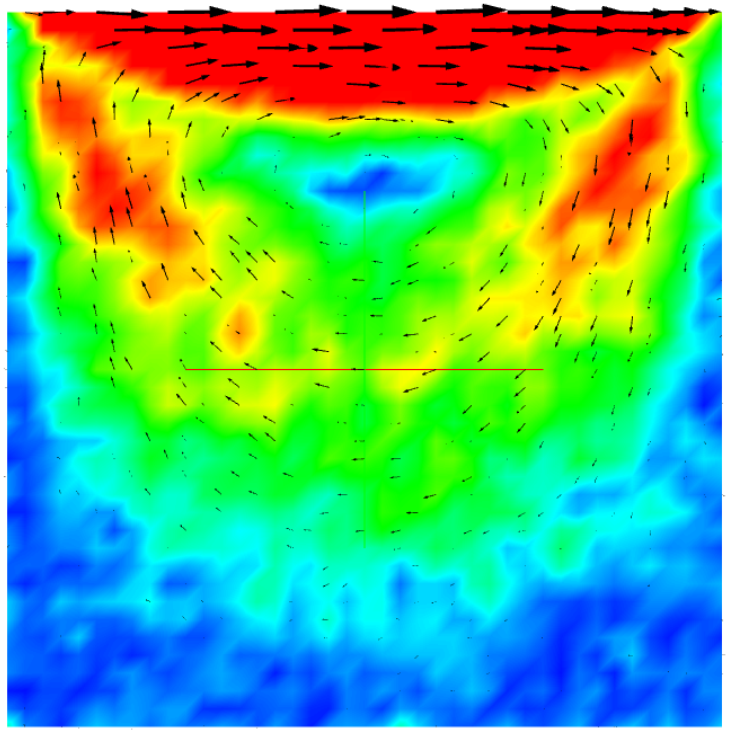


Driven cavity scenario in 3D

- Derived from Newton's second law
- A system of two partial differential equations
  - → Equation of momentum
  - → Continuity equation
  - → Initial-boundary-value Problem

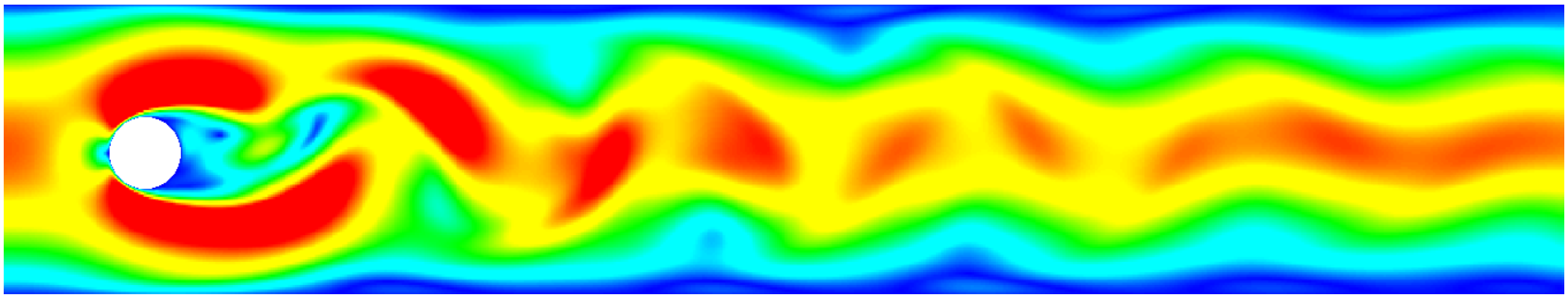
Motivation: Lattice–Boltzmann Method

- **Mesoscopic** approach to fluid dynamics
  - → allows to simulate fluids on smaller scales
  - → widely used for the simulation of micro- and nanoflows
- **Local** scheme
  - → efficient for simulations in complex geometries



Cavity on nanoscale with Brownian motion effects

LBM: How does it work?



Karman vortex street at $Re = 100$ simulated by LBM

- Based on **Statistical mechanics**
- Special finite difference discretisation of the **Boltzmann equation**
  - $\rightarrow$ Compute probability for fluid molecules to have velocity v at position x and time t
  - $\rightarrow$ Leads to an update scheme similar to **cellular automata** (Great for computer scientists :-))
  - $\rightarrow$ Basic scheme (relatively) easy to implement (also in 3D!)
- In continuum (=macroscopic) limit: LBM $\leftrightarrow$ Navier-Stokes

Whole lab is done in group work

- groups of 3
- oral examination for the whole group
- recommended: group members have different background

Course of Action

1. lecture on the theoretical background
2. explanation of the task
3. programming
4. examination
5. `GOTO 1`

Examination compulsory

- one code handed in
- theoretical knowledge is tested
- questions concerning the implementation have to be answered
- **compulsory for each team member**

Registration

- registration with the *matching-system*
- starts today
- `http://docmatching.in.tum.de/`