Applications
Generation Methodologies for Lattice Boltzmann and Multigrid

Fusion of Massively-Parallel Simulation Frameworks and Code
Software Coupling

- **ExaStencils** [1]: Cutting-edge whole program generation
  - **Domain**: Multi-solver frameworks on block-structured grids
  - **Code**: Scala framework generating C++ with CUDA, OMP, MPI
  - **Tools**: Multi-layered DSL called ExaSlang
- **waLBera** [2]: Classical C++ multiphysics framework
  - **Domain**: Lattice Boltzmann on octrees
  - **Code**: Modular C+++17 framework
  - **Tools**: Kernel code generation via lbmpy [3]
  - **In-house rigid particle dynamics module MESA-PD** [4]

- **Research Goals**
  - Develop a combined toolchain for both frameworks
  - Automated combination of code generation and frameworks
  - Automated mapping between different data structures

Fusion of Massively-Parallel Simulation Frameworks and Code
Software Design

**ExaStencils**

- **ExaSlang 2** (Discrete Model)
- **ExaSlang 3** (Solver Algorithm)
- **ExaSlang 4** (Whole Program)

**Domain Knowledge**
**Target Knowledge**
**ExaStencils Compiler**

- Optional but recommended

**LB Method Definition**
**LB Update Rule**
**BCs**
**PDF Setter**
**Pack Info**
**LBM Kernel**
**Imply & pystencils**
**LBM Model.py**
**Target Kernels**

**Main**

- interface

**Target Code**
**Interface class**

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Motivation

**Application (NS – LBM Coupling)**

- **Domain**: Fluid flow simulations via NS and LBM solvers
  - Well established techniques with different traits
  - Only little research is done on their coupling
- **Code**: Combined toolchain
  - Temporal coupling can be used for
  - Mutual validation
  - Performance comparison
  - Use results of the other method as starting solution

- **Research goals**
  - Coupling of the different numerical methods
  - Automated mapping of different discretizations

Fusion of Massively-Parallel Simulation Frameworks and Code
Program Flow

- **Layer 2 & 3 used for conciseness.**
- Specification only on Layer 4 is also possible.

Fusion of Massively-Parallel Simulation Frameworks and Code
Results

- Weak scaling on SuperMUC-NG

- **Main**

  - **Method**
    - Interface

  - **Target Code**
    - Interface class

  - **Main**

  - **Target Code**

Fusion of Massively-Parallel Simulation Frameworks and Code
Future scope

- Use coupling for charged-particle application [5]
  - Fluid simulated with LBM in waLBera
  - Particle interaction handled with MESA-PD
  - Electric potentials computed via MG FVM solver generated with ExaStencils
- Spatial LBM and NS solver coupling

Fusion of Massively-Parallel Simulation Frameworks and Code
References


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https://www.cs10.tf.fau.de/