Technische Universität Braunschweig

Institute for computational modeling in civil engineering

iRMB

A Lattice Boltzmann 3D-GPU-Implementation on Non-Uniform Grids

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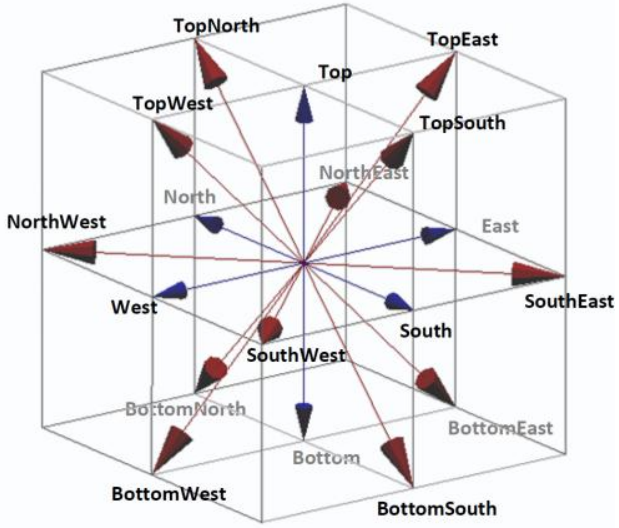
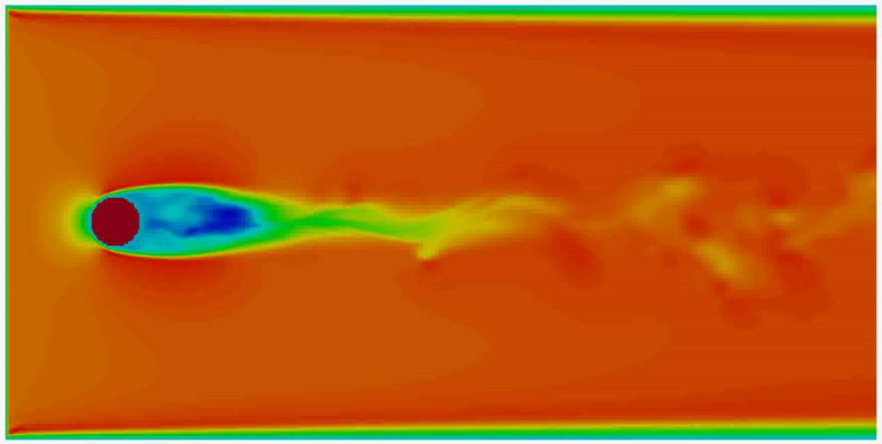
Outline

- Lattice Boltzmann
- General Purpose Graphics Processing Unit (GPGPU)
- Multiscale Method
- Results
- Performance

Lattice Boltzmann

- Cartesian grids
- Suitable for implementation on GPGPUs
- D3Q19 model
- MRT kernel





General Purpose Graphics Processing Unit (GPGPU)

- 30 multiprocessors with 8 processors each = 240 Processors
- Cores running at 1,3 GHz
- 4 GB device memory
- Memory bandwidth = 102 GB/sec
- 933 GFlops of theoretical single precision floating point performance (NVIDIA)
- CUDA –SDK

Multiscale Lattice Boltzmann Method

Motivation:

Cartesian grid for the lattice Boltzmann method

Resolution everywhere the same

Regions with low dynamics as expensive as regions with strong dynamics

Preferable to have variable grid resolution

Solution:

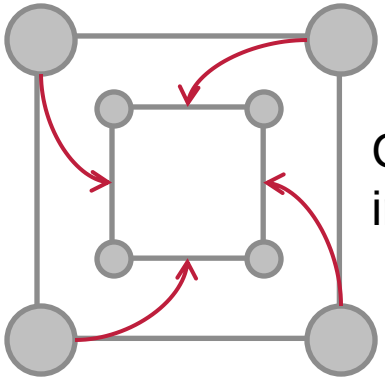
Coupling of Cartesian domains with different resolution

Multiscale Lattice Boltzmann Method

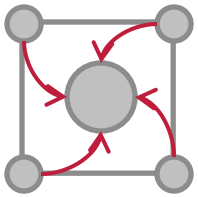
Compact second order interpolation:

Shear rate known at nodes=> extra information on gradients of momentum

No time interpolation required



Coarse to fine interpolation

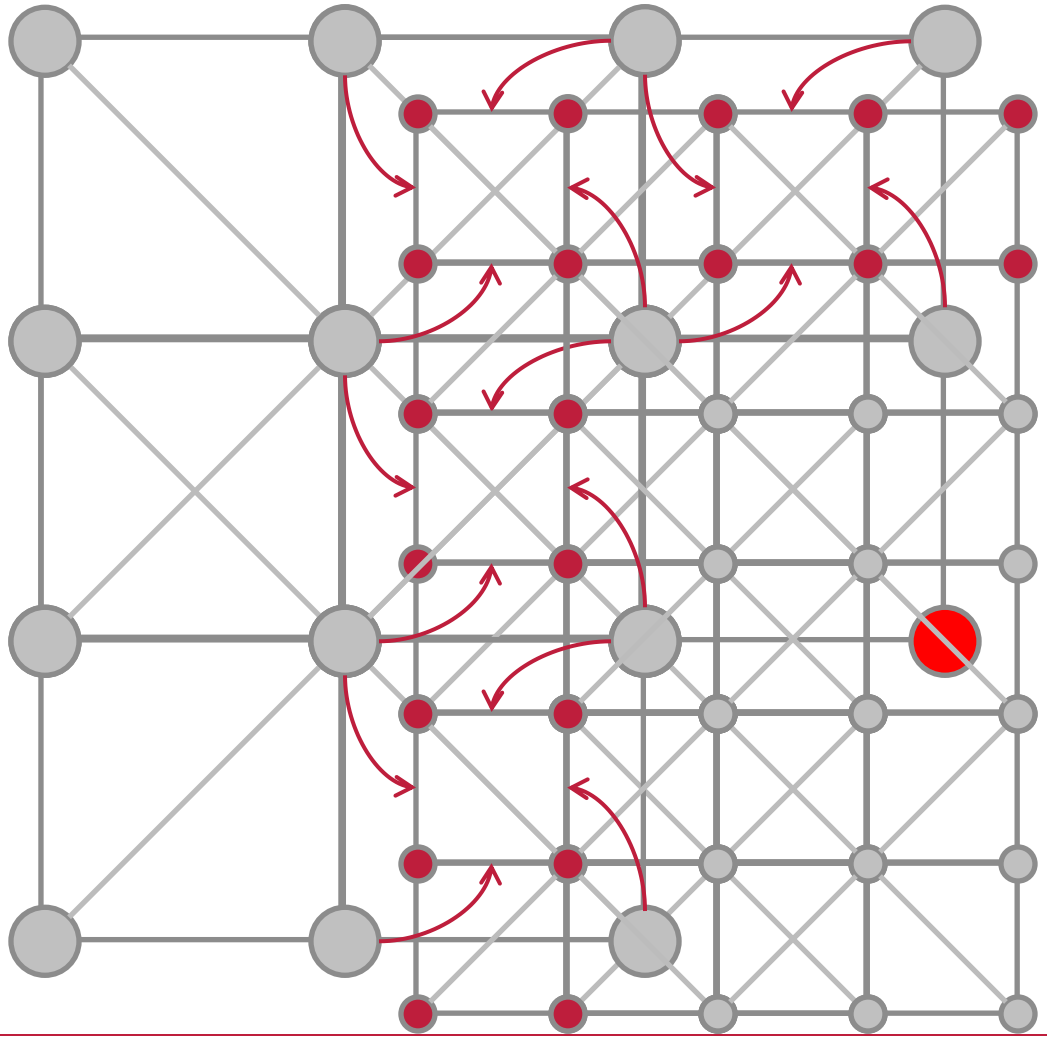


Fine to coarse intepolation

Multiscale Lattice Boltzmann Method

Interface condition:

Step 1: synchronization coarse to fine



Standard node

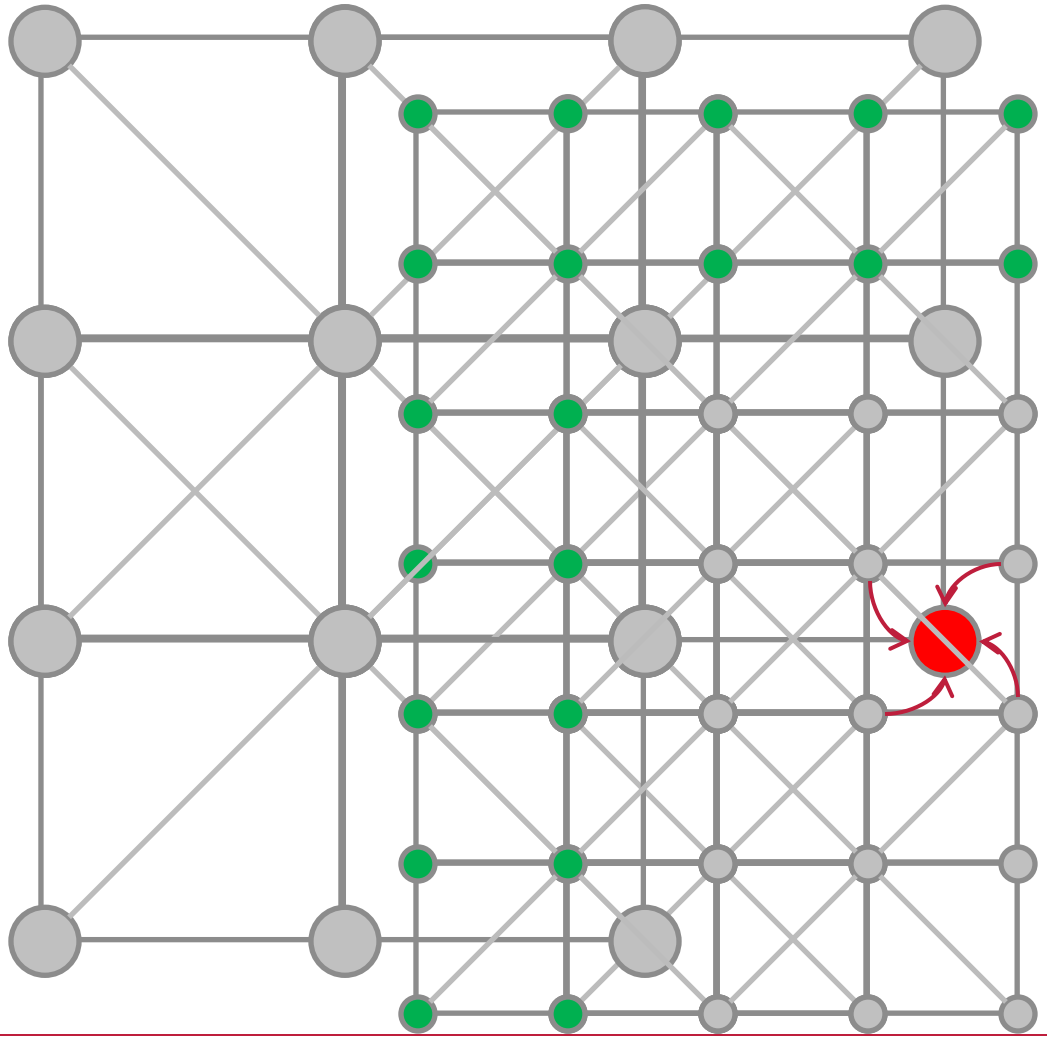
Interface node invalid

Interface node valid

Multiscale Lattice Boltzmann Method

Interface condition:

Step 2: synchronization fine to coarse



Standard node

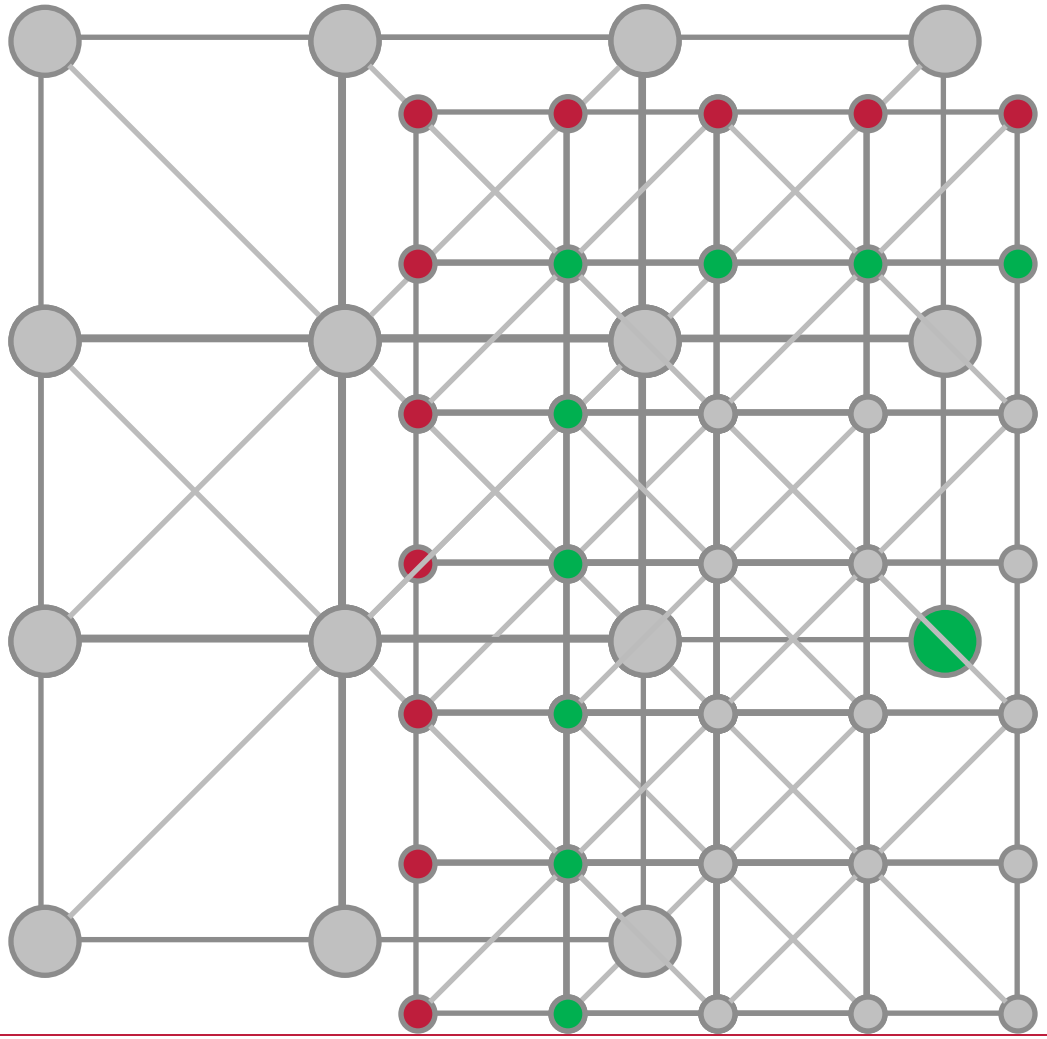
Interface node invalid

Interface node valid

Multiscale Lattice Boltzmann Method

Interface condition:

Step 3: asynchronous time step on fine grid
Boundary nodes become invalid



Standard node

Interface node invalid

Interface node valid

Multiscale Lattice Boltzmann Method

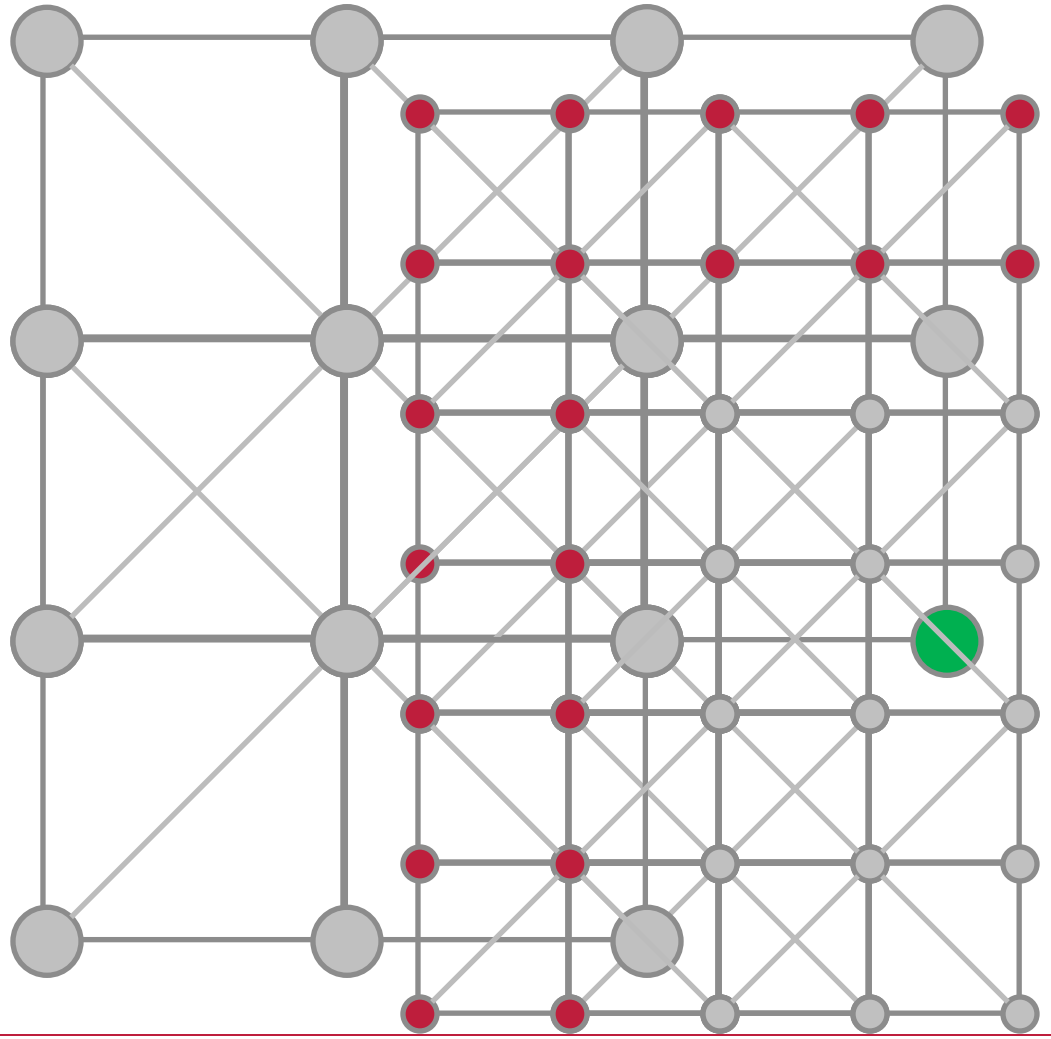
Interface condition:

Step 4: synchronous time step on fine grid
Next layer of nodes become invalid

Standard node

Interface node invalid

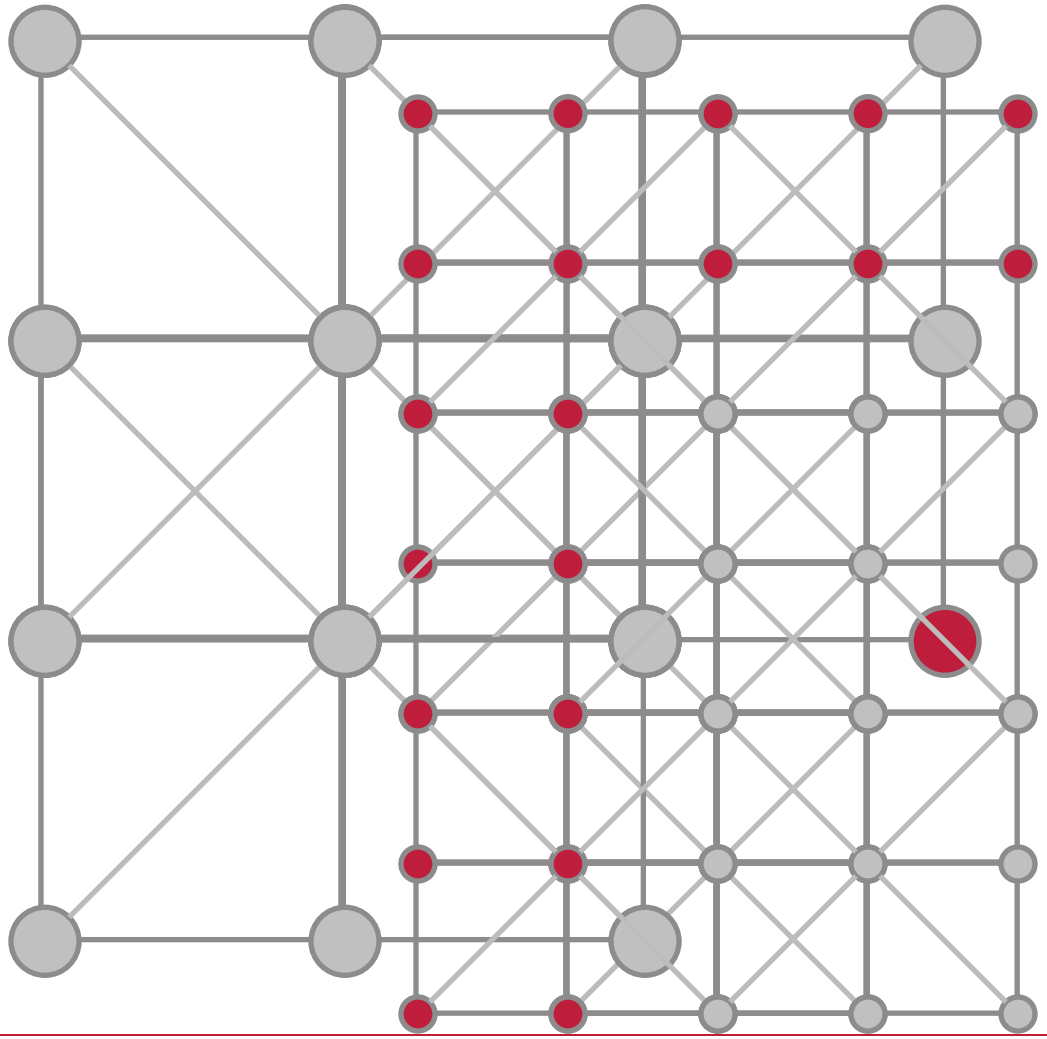
Interface node valid



Multiscale Lattice Boltzmann Method

Interface condition:

Step 5: synchronous time step on coarse grid
Coarse boundary nodes become invalid



Standard node

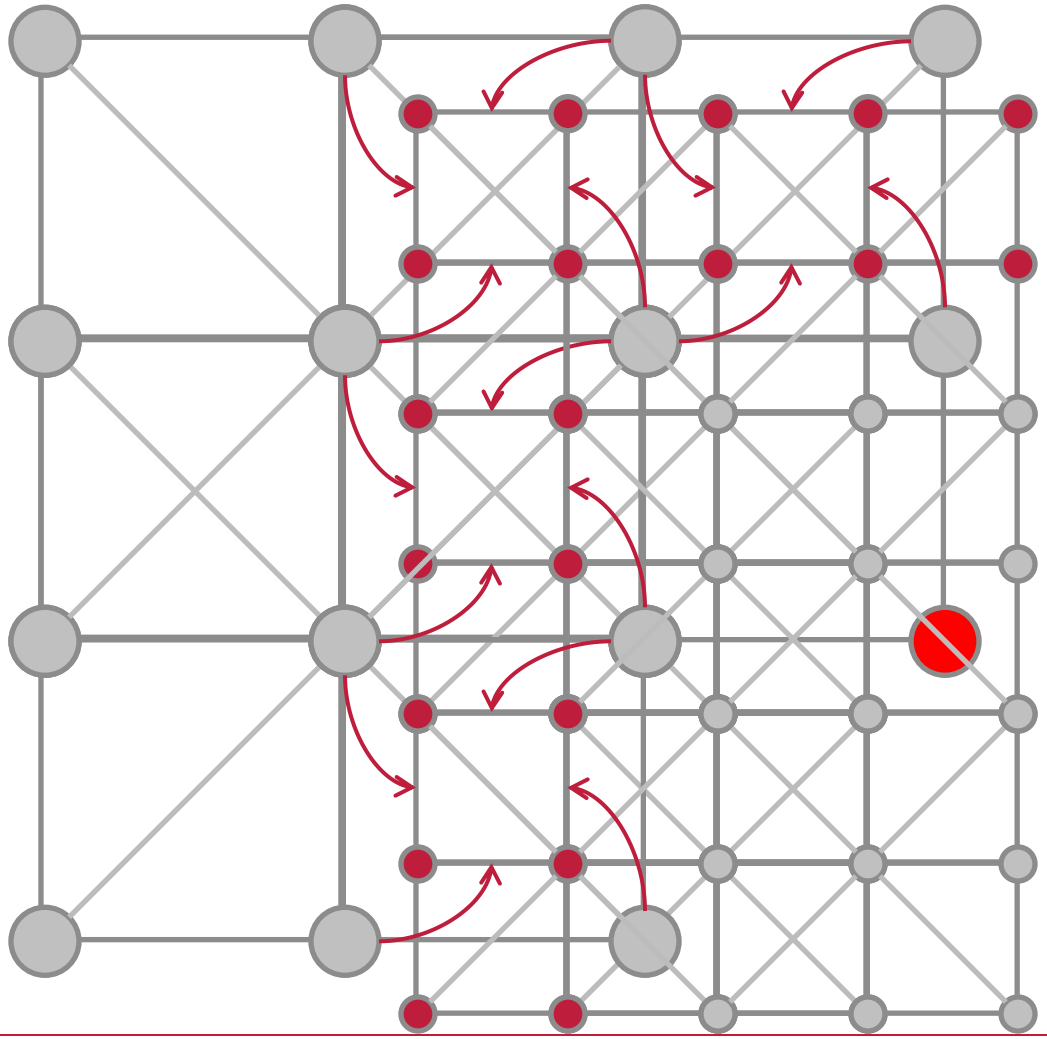
Interface node invalid

Interface node valid

Multiscale Lattice Boltzmann Method

Interface condition:

Step 6: back to state of step 1

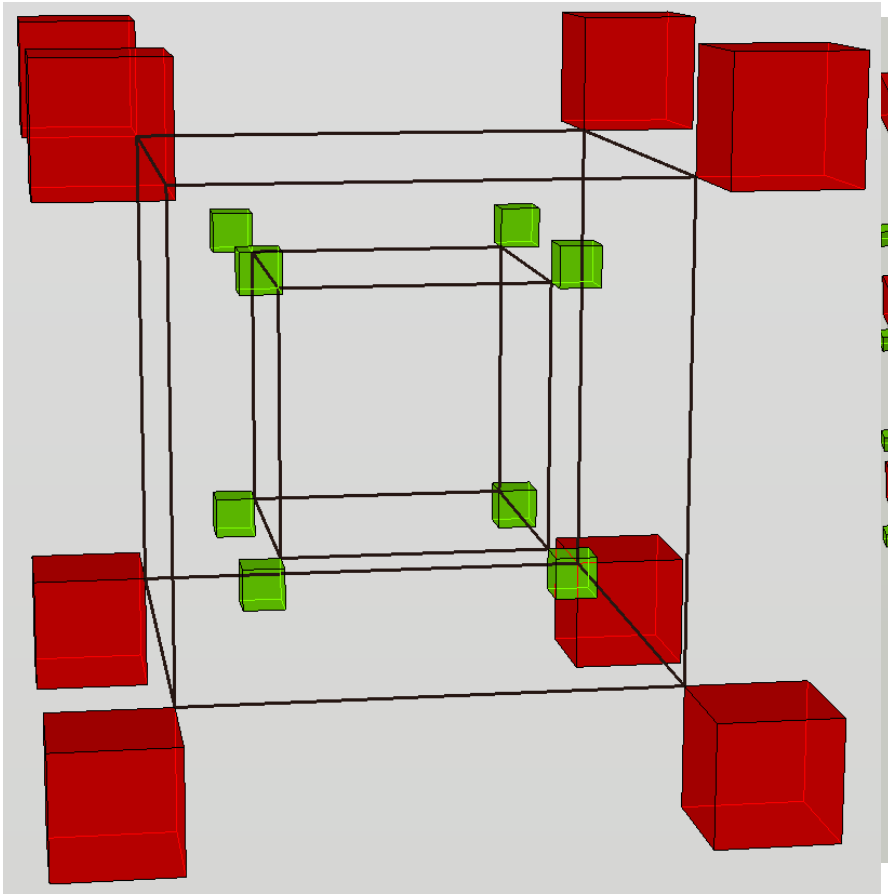


Standard node

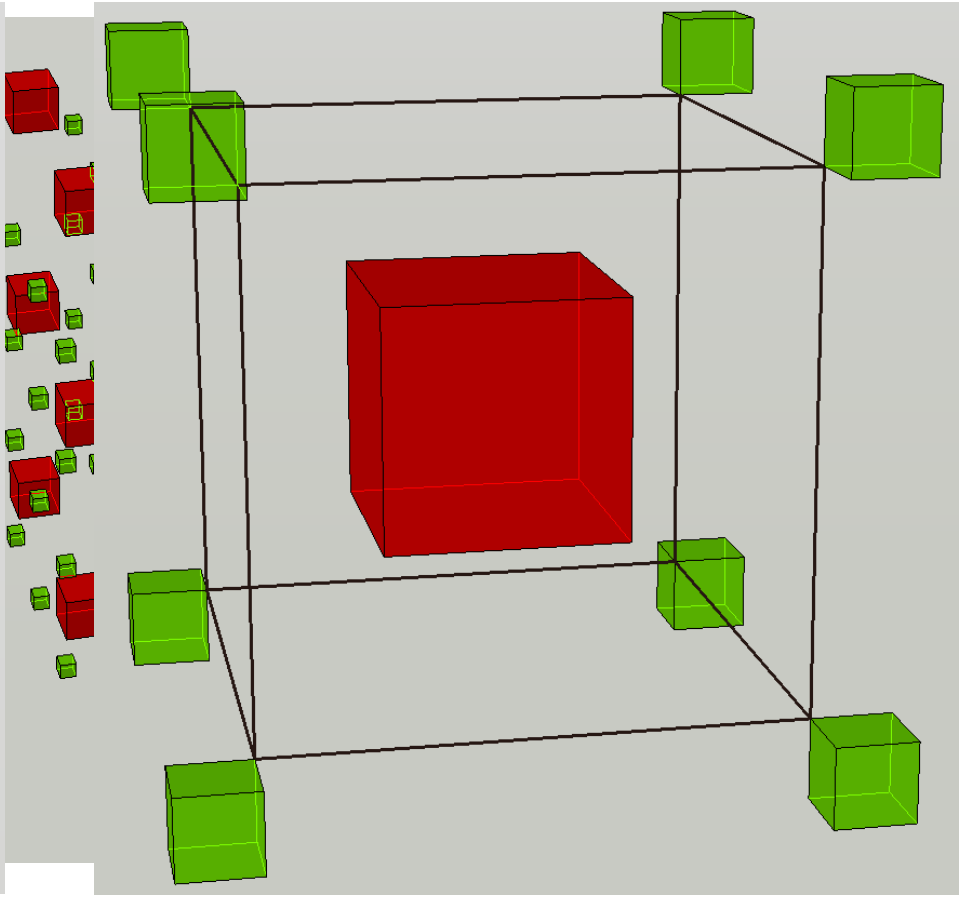
Interface node invalid

Interface node valid

The grid refinement 3D



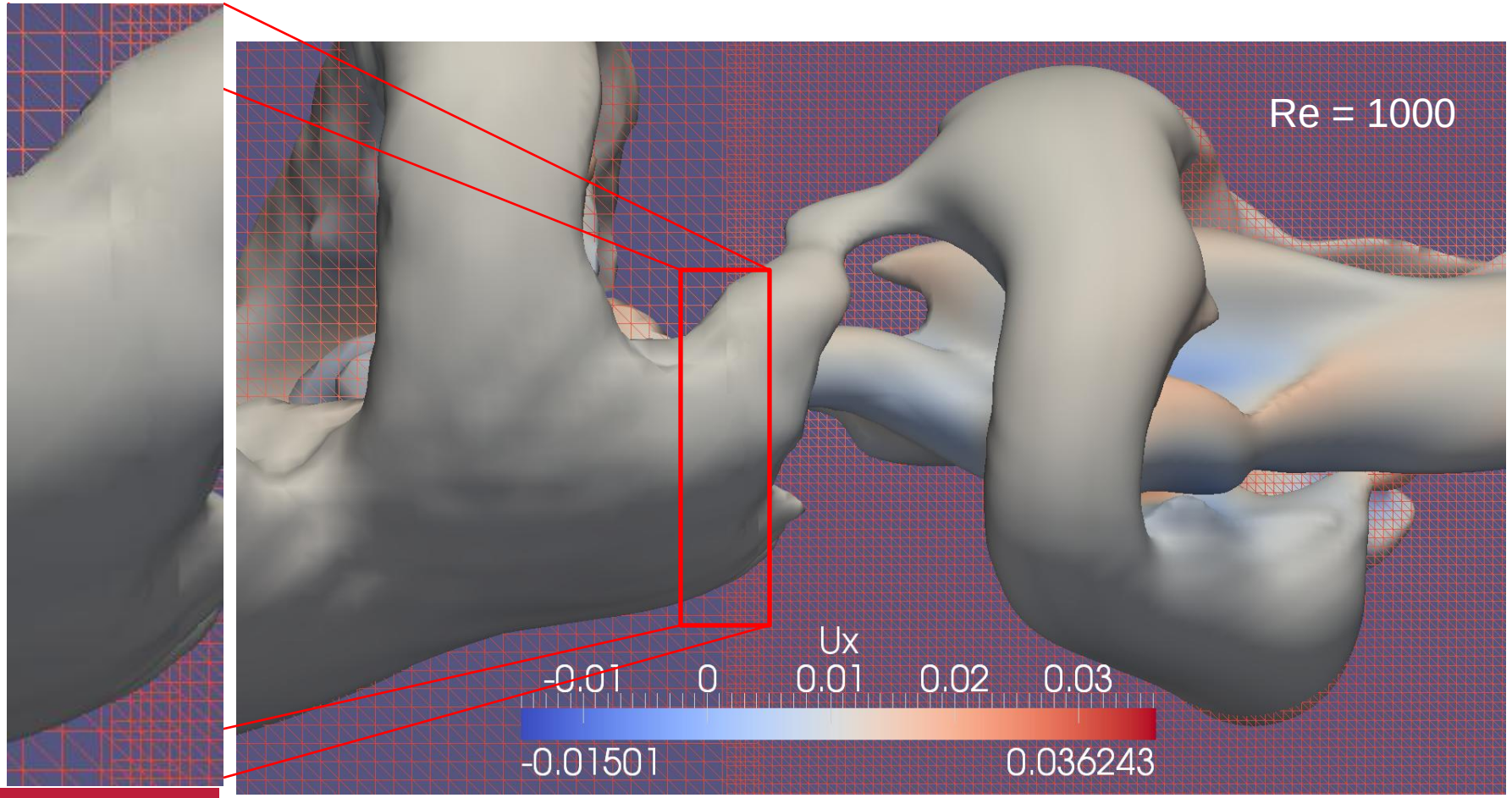
coarse to fine cell



fine to coarse cell

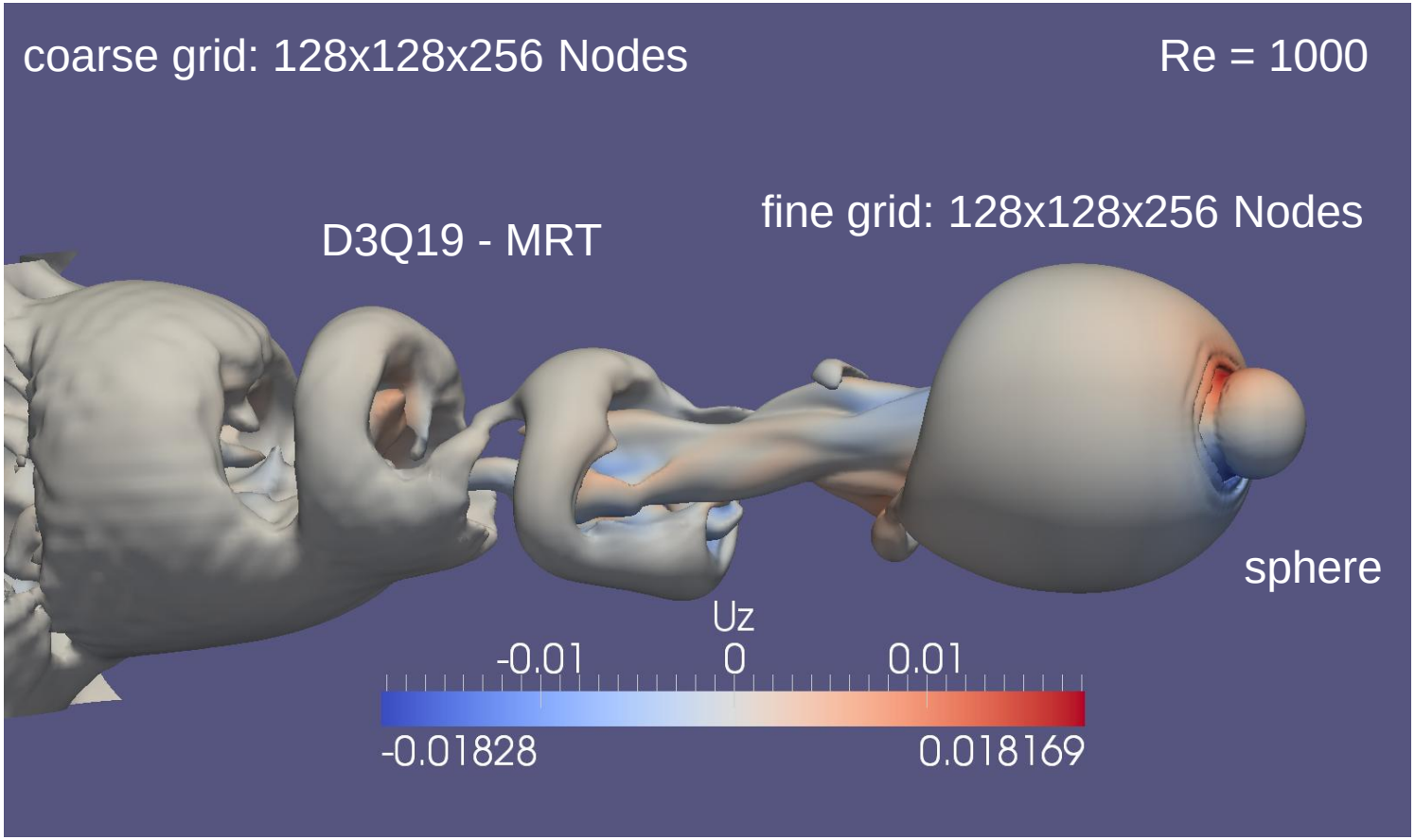
Quality of results

Testcase: channelflow around a sphere (velocity in x direction)



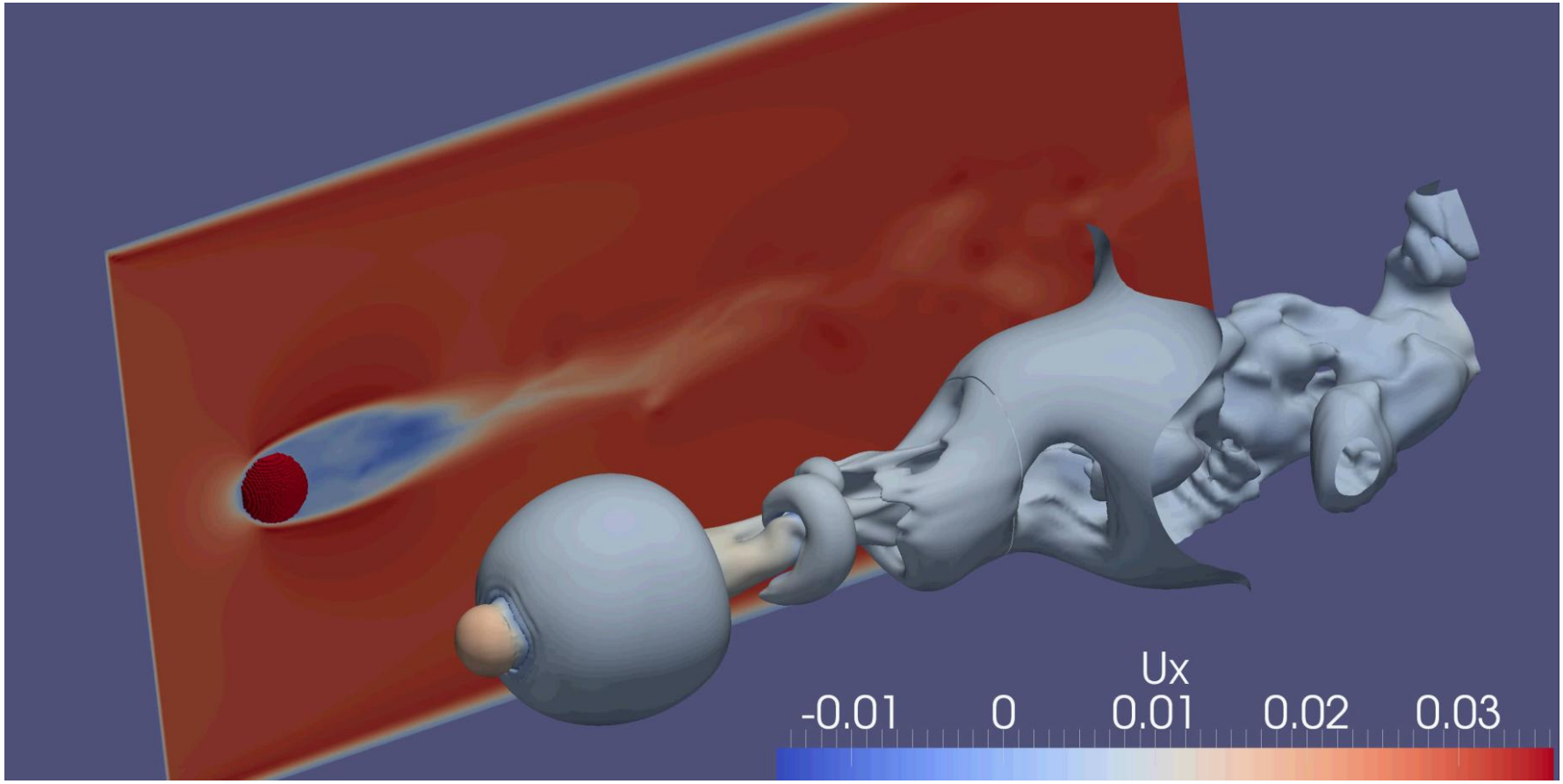
Quality of results

Difference of quality between coarse and fine grid



Quality of results

Simulation: Smoothly data transfer at the grid interface



Performance Analysis

- NUPS – number of node updates per second
- compare uniform and non-uniform case
- degrees of freedom equal
- 1.000.000 time steps
- 3 diff. Resolutions:

Uniform	Non-Uniform
256 x 256 x 144	256 x 192 x 96 x 2
256 x 128 x 144	256 x 192 x 96 x 2
128 x 128 x 144	128 x 96 x 96 x 2

Performance Analysis

	Resolution [nodes]	NUPS [x10^6]	NUPS [%]
Uniform	256x256x144	280.81	100.00
Non-uniform	2x256x192x96	242,57	86.38
Non-uniform*	2x256x192x96	212,25	75.58
Uniform	256x128x144	281.53	100.00
Non-uniform	2x256x96x96	233.59	82.97
Non-uniform*	2x256x96x96	204.39	72.60
Uniform	128x128x144	255.42	100.00
Non-uniform	2x128x96x96	201.84	79.02
Non-uniform*	2x128x96x96	176.61	69.14

* effective number of NUPS - no coarse nodes in fine grid

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Conclusion

Conclusion:

- combination of uniform LBM with grid refinement on GPGPU is possible
- compact second order interpolation allows higher Re Numbers
- time interpolation is unnecessary
- no special treatment of corners / edges
- good performance compared to uniform application

Acknowledgments

- German BMBF funding the SKALB (Lattice-Boltzmann-Methoden für skalierbare Multi-Physik-Anwendungen) project (reference ID 01IH08003E).

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