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Master thesis - *Masterarbeit*

Thesis received: XX.XX.20XX
Submission of thesis until: XX.XX.20XX
First examiner: Prof. Dr.-Ing. D. Schillinger
Second examiner: Prof. Dr.-Ing. U. Nackenhorst

Workload: 750 h (25 CP)
Duration: 6 months
Supervisor: Stein Stoter

The multiscale finite element for high performance computing

Prerequisites: a master-level class on the finite element method.
This thesis will be supervised/written in English.

Many advances in modern computational mechanics are driven by the continued increase in available computational power, and in turn much scientific research concerns the development of computational schemes that are HPC-ready (high performance computing, i.e. supercomputing). Once such technique is the multiscale finite element method. The large physical domain is meshed with a coarse grid, and each of its coarse-scale elements is subsequently meshed with much finer elements (illustrated in Figure 1). The full-scale problem is tackled by solving localized problems on each of the fine meshes and propagating the resulting information upwards to the global system of equations. Originally, communication between neighboring coarse-scale elements was introduced via oversampling of the fine-scale meshes, a suboptimal approach. Recently, we proposed an elegant residual driven iterative corrector scheme which converges to the exact fine-scale solution [1,2]. This variant of the multiscale finite element method offers tremendous parallelization capabilities, as each of the small, local, problems in each of the (potentially tens of thousands of) coarse scale elements may be solved on a separate computing core. Such a highly parallelized implementation enables computation of physical problems of an immense size.

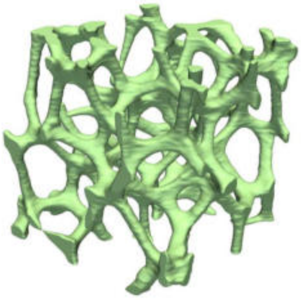

Fig 1a. A highly detailed physical system.

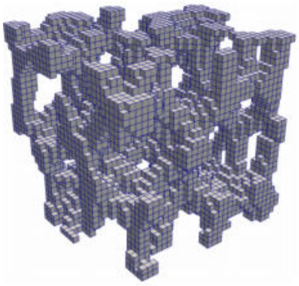

Fig 1b. Coarse mesh representation.

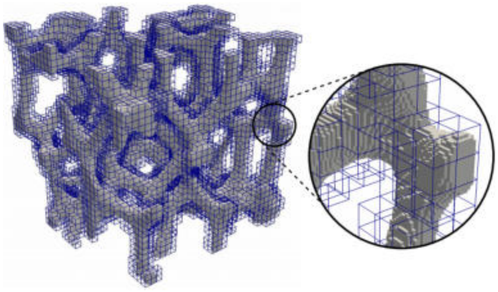

Fig 1c. Subdivision of the coarse elements into fine-scale local problems.

The objective of the thesis is to implement this theory in an HPC environment. Depending on the student's interest, we may then proceed to use the implemented framework to study a large scale problem (e.g. the linear elastic behavior of bone from CT-scan data, or a full-scale simulation of heat transfer through a metal foam from micro-CT-scan data), or we may focus on the scientific aspect of the computational method itself by comparing it's capabilities with e.g. static condensation methods. During this project, the student will have the unique opportunity to work with computer clusters with many cores and learn to program in such an environment.

Literature:

[1] L.H. Nguyen and D. Schillinger. A residual-driven local iterative corrector scheme for the multiscale finite element method. *Journal of Computational Physics*, 377:60-88, 2019.

[2] L.H. Nguyen and D. Schillinger. The multiscale finite element method for nonlinear continuum localization problems at full fine-scale fidelity, illustrated through phase-field fracture and plasticity. *Journal of Computational Physics*, 396:129-160, 2019.