PAMS
(Parallel Algorithms for Multiscale Simulations)

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Aim of the project

In finite element simulations microstructural effects can be considered by numerical homogenization schemes. If both, the micro and macro level, are computed by finite elements the so called FE² method is applied, see Fig. 1. It is computationally very costly, as in every macroscopic Gauß point a complete micromechanical boundary value problem has to be solved. The main advantage of the FE² method is that only on the micro level constitutive equations have to be specified. Nowadays the enormous computational cost renders 3D simulations with realistic 3D microstructures on single processor architectures almost impracticable. However, the integration loop of the macroscopic system can be parallelized, as the micro problems are independent of each other. The projects aims at analyzing different strategies for parallelizing FE² methods.

Innovation and work plan

- Parallel FE² method
- Finite Element Analysis Program (FEAP): www.ce.berkely.edu/projects/feap
- Matlab® implementation
- Efficiency studies of different environments: GPUs, OpenMP, CPUs, MPI
- Strategies for memory distribution (plasticity: history variables storage)

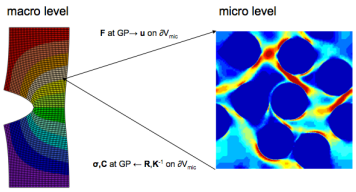

Figure 1: Rational of the FE² method

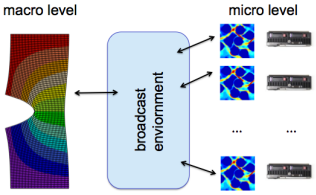

Figure 2: Parallel strategies in FE² simulations

Preliminary results

- 3D simulations with parallel FEAP 8.3
- Simulations in MPI environment (LTM cluster: http://tresca.mv.uni-kl.de/ganglia/)
- Speedup tests for nonlinear elastic problems with neo Hooke material
- Configurational mechanics (fracture) in multiscale simulations

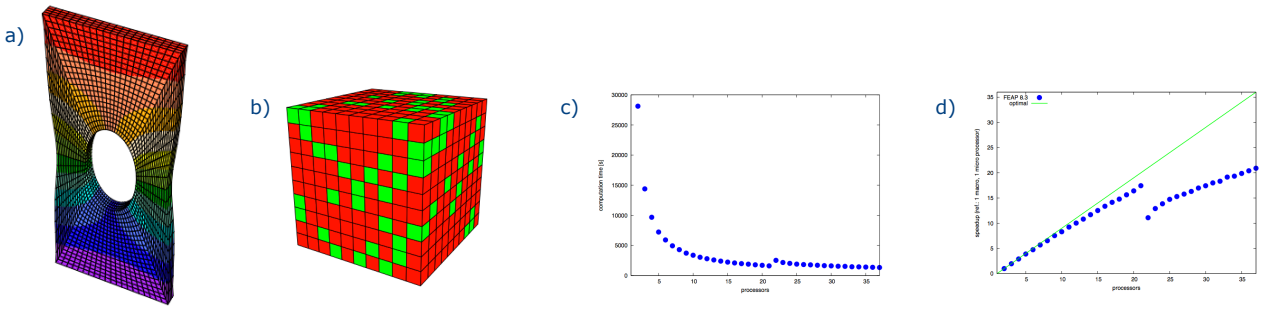

Figure 3: Parallel FE² using FEAP 8.3, a) macroscopic structure, b) microstructure, c) computation time, d) speed-up

Publications

- S. Ricker, J. Mergheim, P. Steinmann and R. Müller: A comparison of different approaches in the multi-scale computation of configurational forces, *Int. J. Fract.*, 166, pp. 203-214, 2010.
- M. Khalaquzzaman, S. Ricker and R. Müller: Computational Homogenization of Piezoelectric Materials using FE2, *Proc. Appl. Math. Mech.*, 10, 417–418, 2010.
- R. Meyer: A theory of structural stationarity in the pi-calculus, *Acta Informatica*, 46(2):87-137, 2009.
- A. Bouajjani, R. Meyer and E. Möhlmann: Deciding Robustness against Total Store Ordering. *In Proc. of the 38th International Colloquium on Automata, Languages and Programming, ICALP*, vol. 6756 of LNCS, pp. 428-440. Springer-Verlag, 2011.
- D. Baudisch, J. Brandt and K. Schneider: Multithreaded Code from Synchronous Programs: Extracting Independent Threads for OpenMP, *Design, Automation and Test in Europe (DATE)*, pp. 949-952, 2010.
- D. Baudisch, J. Brandt and K. Schneider: Dependency-Driven Distribution of Synchronous Programs, *Distributed and Parallel Embedded Systems (DIPES)*, pp. 169-180, 2010.