Technische Universität Braunschweig

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Finite element procedures for efficient bridging of length scales

Lecture of

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Numerous problems in engineering and science involve partial differential equations that need to be resolved on vastly separated length and time scales. Such problems require multiscale methods to be efficient, or even tractable.
In this presentation, we will discuss the technique of Variationally Consistent Homogenization, as a quite general means of constructing two-scale schemes for computational homogenization. The derived schemes typically introduce one macroscale problem and a large set of fine-scale problems on Representative Volume Elements (RVEs). In the finite element setting, these procedures are often denoted “Finite Element squared” (FE2). They allow for accounting for the fine-scale features on the micro-scale, while satisfying the pertinent balance equations on the macro-scale, without the need for resolving all features in one single computational domain.
For linear stationary problems, computational homogenization can be conducted in an “offline" phase, whereby the effective coefficients for the macroscale problem can be pre-computed. However, for the case of a non-linear and/or transient problem, the macroscale and microscale problems have to be solved for concurrently. Although significantly more efficient than resolving the original problem one the finest length-scale, this results in extremely demanding computations. In order to further decrease the computational cost of the problem, we introduce Numerical Model Reduction (NMR) on the (discrete) micro-scale problems by adopting a reduced basis approximation.
A few applications will be highlighted to illustrate the procedures in applications of linear and non-linear problems. For the special case of linear transient problems, we also present guaranteed bounds for the error due to the NMR approximation.