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Mathematical Challenges in Computational Science and Engineering

Although recent advances in computer technology have significantly pushed forward the frontiers of science and engineering, new mathematical challenges arise. In this talk, we address several aspects that are encountered in PDE-based simulations of complex physical systems.

High resolution finite element simulations are typically expensive due to, e.g., complex geometries, non-linear material laws, mixed dimensions or large spatial and temporal scales. Additionally, data uncertainties are ubiquitous in many diverse applications, such as models of subsurface flow, buildings or tumor growth.

Firstly, we illustrate characteristic challenges on the basis of specific application relevant examples. Secondly, we present ideas how to tackle such challenges algorithmically more efficiently and provide a rigorous mathematical framework for the numerical analysis based on variational principles, a priori estimates and convergence rates.

Thirdly, we focus on tumor growth

phase-field models and show how analysis and a hybrid experimental design can go hand in hand.

Existence results for the non-linear coupled system are provided by a Faedo-Galerkin approach in combination with energy estimates and compactness arguments. The hierarchical computation of posteriors in a Bayesian setting is then performed through a series of in-vitro experiments.