BERGISCHE
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Vortrag im Mathematischen Kolloquium am 29. Mai 2018:

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Computational Challenges in Inverse Problems

Inverse problems are omnipresent in many scientific fields such as systems biology, engineering, medical imaging, and geophysics. The main challenges toward obtaining meaningful real-time solutions to large, data-intensive inverse problems are ill-posedness of the problem, large parameter dimensions, and/or complex model constraints. This talk discusses computational challenges of inverse problems by exploiting a combination of tools from applied linear algebra, parameter estimation and optimization, and statistics. For instance, for large scale ill-posed inverse problems, approximate solutions are computed using a regularization method that solves a nearby well-posed problem. Oftentimes, the selection of a proper regularization parameter is the most critical and computationally intensive task and may hinder real-time computations of the solution. We present a new framework for solving ill-posed inverse problems by computing optimal regularized inverse matrices. We further discuss randomized Newton and randomized quasi-Newton approaches to efficiently solve large linear least-squares problems, where the very large data sets present a significant computational burden (e.g., the size may exceed computer memory or data are collected in real-time). In this framework, randomness is introduced as a means to overcome computational limitations, and probability distributions that can exploit structure and/or sparsity are considered. We will present numerical examples, from deblurring, tomography, and machine learning to illustrate the challenges and our proposed methods.