Numerical Analysis and Scientific Computing Seminar

Learning from data through the lens of mathematical models: Bayesian Inverse Problems and Uncertainty Quantification

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Abstract: Recent years have seen rapid growth in the volume of observational and experimental data acquired from physical, biological or engineering systems. A fundamental question in several areas of science, engineering, medicine, and beyond is how to extract insight and knowledge from all of those available data. This process of learning from data is at its core a mathematical inverse problem. That is, given (possibly noisy) data and a (possibly uncertain) forward model describing the map from parameters to data, we seek to reconstruct or infer the parameters that characterize the model. Inverse problems are often ill-posed, i.e. their solution may not exist or may not be unique or may be unstable to perturbation in the data. Simply put, there may not be enough information in the data to fully determine the model parameters. In these cases, uncertainty is a fundamental feature of the inverse problem. The goal then is to both reconstruct the model parameters and quantify the uncertainty in such reconstruction. The ability to quantify these uncertainties is crucial to reliably predict the future behavior of the physical, biological or engineering systems, and to make informed decisions under uncertainty. This talk will illustrate the mathematical concepts and computational tools necessary for the solution of inverse problems in a deterministic and probabilistic (Bayesian) framework. Examples of inverse problems arising in imaging, geoscience, material engineering, and other fields of science will be presented.
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Monday, June 24, 2019, 2:00 pm
Mathematics and Science Center: W301

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