THE UNIVERSITY OF CHICAGO

Department of Statistics

DISSERTATION PROPOSAL

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Department of Statistics
The University of Chicago

Computational and Statistical Methods for Optimal Estimation and Control of Dynamical Systems

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Jones 304, 5747 S. Ellis Avenue

ABSTRACT

A plethora of contributions have been made to the field of nonlinear dynamics and chaos. Much of the work in the past has focused on learning how to classify the nonlinear systems by analyzing outputs from known systems. Challenges still remain when the generating dynamics is not or only partially known for time series data observed from some physical systems. One such challenge is to infer characteristics of the systems from observations; another is to predict the future behavior of the system or the evolution of a new point in the state space; and finally is the ultimate challenge is to control the system with limited information. In this talk, I will focus on an ongoing project which concerns a time series data set measured from a laboratory-built electronic circuit. The time series data comprises of voltage measurements simultaneously made at three points of the circuit. The measurement data exhibits low observational noise and significant nonlinear and chaotic effect. Kirchhoff's voltage law gives a nominal description of the dynamical evolution, which is found to contain consistent bias. To give a more accurate description of the underlying mechanism, we compare different approaches in modeling the dynamics inferred from the observations. We also investigate the estimations of initial state and observation error. Ultimately, we are interested in fitting a complete state space model including error components in both the model propagation and the observation.

I will also summarize the other components intended to be parts of the dissertation. These include:

1. A production cost model simulates the operation of generation and transmission systems by finding the least-cost solution to generating sufficient energy over tens of thousands to millions of periods. In practice, a temporal decomposition approach of the simulation horizon is often used for approximation. We prove an exponentially decaying error bound for this approach and demonstrate a stochastic simulation method to further save computation.
2. Maximum-likelihood-based state estimation for dynamical systems with model error raises computational challenges in memory reduction particularly for long horizon problems as encountered in data assimilation for ocean state estimation. We present a limited-memory method for maximum-likelihood-based state estimation of hidden Markov models. We prove the stability of the method and demonstrate our findings in different regimes of Burgers' equation.
3. Gaussian processes are commonly used for modeling the output of deterministic computer models. We prove properties of MLE of the scale parameter of the commonly used squared exponential covariance function. We explore the joint estimation of scale and range parameters numerically using exact computations.

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