My research interests lie in the field of applied probability and statistics. My primary research investigates problems arising in identification and control of stochastic systems. I also work on problems in applications and have recently began some projects attempting to use topological data analysis on data sets to reveal information classical statistics may obfuscate.

In 2011, I began investigating recursive stochastic approximation algorithms for identifying and tracking the time-varying parameters of a linear system whose coefficients evolve as a slowly-varying Markov Chain. This was done in conjunction with my advisor, Gang George Yin, and our colleague Le Yi Wang from the Wayne State University Department of Engineering [1]. Using martingale averaging techniques, under weak assumptions on the signals, we were able to show convergence of the estimates and parameter to sets of switching stochastic differential equations, depending on the relation of the adaptation rate of the algorithms to the transition rate of the parameter. Mean square error bounds and rates of convergence were also obtained for each case, also depending on the adaptation and transition rates.

These “slow” (referring to not so frequent jumps) Markovian models and algorithms have applications in target tracking, econometrics, and particularly in signal processing for communication networks. For example, consider the task of Blind Multiuser Detection in a wireless CDMA network [2]. Here, we have several users are trying to send their signals (say voice data) across a pair of transmitters/receivers. The transmitter (linearly) encodes each users data via a unique ‘chip’ code and transmits all users’ data as a single stream. The receiver then tries to identify the optimal linear filter which will extract only a single user’s signal (say user 1), treating the rest as noise. However, the optimal filter will vary depending on the set of active users in the system (and their chip codes). Since users enter and leave the system infrequently (in relation to the bit transmission rate), this fits the slow Markov model and the adaptive filtering algorithm in [1] can be used to identify and track the optimal decoding filter as it changes with the current active user set.

In 2012, I continued work on the slow Markov model using non-linear Sign-Error type algorithms [4]. This has the advantage of reduced computational complexity (involving simple bit shifts for multiplications), but the non-linear form of the algorithm makes analysis more difficult. Assuming slightly stronger conditions on the signals I was able to obtain convergence, rate of convergence, and mean-square error bound results.

In addition, starting from 2012, I began some projects in applied statistics. In conjunction with Zachary P. VandeGriend and Mahdi Shkoukani of the Wayne State University Medical School, I conducted some classical statistical analysis on data sets of Facial Fracture incidents coming from the Detroit Medical Center and compared this with national data sets from 1990-2010 [5]. We presented a case for a decreasing trend between 1990 and 2000 and an increasing trend from 2000-2010 using Chow Tests and simple regression models.

In 2013, I began work (along with Gang George Yin, Le Yi Wang, and Ben Fitzpatrick from Loyola Marymount University and Tempest Technologies) on a robust two-phase proce-
dure for estimation and noise attenuation in systems with unmodeled dynamics and stochastic signal errors [3]. We derived worst-case error bounds in terms of the unmodeled dynamics and variances of the disturbance and measurement errors. We are currently working on generalizing this problem to the case that the underlying system parameters vary as a Markov Chain and analyzing the error bounds of tracking.

In summer 2013, I began work with David Casbeer and Yongcan Cao of the Air Force Research Laboratory Autonomous Control Branch (as part of a STAR Development Program summer internship) investigating problems related to autonomous cooperative navigation of unmanned aerial vehicles in GPS-denied environments. We have developed an algorithm which will induce a UAV to orbit a target without any location information, using range-only measurements. We have established that the trajectory of the UAV is recurrent to the desired orbit in the presence of additive noise [6]. We are currently working on establishing a stability result and generalizing the procedure to incorporate multiple UAVs to hold a formation and rotate through a grid of unmanned ground sensors to navigate through an environment without GPS.

I am also currently working with an algebraic topologist, Michael Catanzaro, in using topological data analysis to analyze data sets. Topological data analysis is a relatively new field which uses discrete analogs of topological invariants to help identify and classify properties and relations inside finite data sets [7]. Heuristically, the advantage of TDA is that it should be less sensitive to choices of coordinates (measurements), choices of metrics (notions of distance between data points), and choices of parameters (at what level are two points said to be associated?). We are currently working with a data set from the Wayne State Medical School with the goal of identifying treatment groups based on gene expression levels and also identifying those genes which are truly responding to the treatment. We are also working on some baseball data sets to identify new classifications of types of hitters, and are formulating a project in the classification of Twitter users based on their use of “hashtags” and comparison to “following” networks. I would love to get undergraduates involved as an undergraduate research project, since I think this has a lot of potential to get students excited about practical applications of high-end mathematics.

For my full research statement, please see math.wayne.edu/ araz/research.

References


