Games and Decisions in Reliability and Risk Workshop
May 16-20, 2016

CONTRIBUTED TALKS/ POSTERS

Contributed Talks:

Hiba Baroud
Vanderbilt University

"Quantifying Resilience-Based Importance Measures using Bayesian Kernel Methods"

Critical infrastructure systems have become increasingly vulnerable to disruptive events resulting from natural hazards, extreme weather, accidents, and manmade attacks, among others. The ability of an infrastructure to withstand these disruptive events and recover rapidly with the minimum amount of damages and losses is vital to a society's welfare and safety in the event of disasters. As a result, modeling the resilience of critical infrastructure systems became of interest to risk managers and decision makers, and evidently researchers.

The most recent advances in resilience modeling are approaches that utilize qualitative tools or simulation that rely heavily on assumptions of prior knowledge, probability distributions, and potential risk scenarios. How would resilience modeling change if we use data-driven methods? Would these methods improve decision making? Is the data currently available enough to make accurate predictions of future infrastructure resilience and inform decision making under uncertainty?

This work deploys a Beta Bayesian kernel model to assess resilience-based importance measures identifying critical components in an infrastructure network that contribute to the recovery process. Integrating Bayesian methods with kernel methods has recently garnered attention, as this tool (i) consists of a classification algorithm which provides probabilistic outcomes as opposed to deterministic outcomes, and (ii) allows decision makers to gather information from multiple sources such as experts in the field, historical events, and characteristics of the system to make informed decisions.

The model is deployed in an application to an inland waterway transportation network, the Mississippi River Navigation system, for which the recovery of disrupted nodes represented by locks and dams is analyzed by estimating their resilience importance using the Bayesian kernel model.

The goal of this work is to identify the opportunities and challenges of using data-driven Bayesian methods to analyze the resilience and inform future decision making. A sensitivity analysis and a comparison with other classical tools shed light on the benefits of the approach and its applicability in decision making.

Mark Borsuk
Dartmouth College

"Role of Risk Aversion in Climate Change Assessment"

Assessing the value of climate change mitigation requires an analysis framework that can account for society's attitude toward the risk of uncertain outcomes, especially those with low probability and high cost. For largely historical and computational reasons, this issue has not been adequately addressed by previous model-based policy analyses. Using a novel stochastic version of a tractable global climate model, our research group has demonstrated the importance of this shortcoming by showing how low probability, high cost outcomes interact with risk attitudes to strongly shape the results of quantitative analysis. Results indicate that the relatively high levels of risk aversion inferred from global investment behavior imply that the large downside risk of climate catastrophe should weigh more heavily in policy consideration than the risk of over-mitigation.

Tahir Ekin
Texas State University

"Augmented Probability Simulation based Stochastic Programming"

This talk discusses simulation based solution approaches to solve decision making problems with uncertainty. The focus will be on the use of augmented probability simulation for stochastic programs with recourse under decision dependent (endogenous) uncertainty. Augmented probability simulation is based on the idea of treating the decision variable as random and investigating the optimal decision in the joint space of decision and random variables. We present the use of Markov chain Monte Carlo and Nested Sampling algorithms for simulation from this joint distribution. An illustration is provided on a two stage news-vendor problem. We provide performance comparisons with traditional Monte Carlo simulation and present computational insights.

Kaoru Irie
Duke University

"A Statistical Approach to Sequential Portfolio Optimization with Multi-Step Forecasting"

We examine the classical idea in Bayesian decision theory of mapping a specified loss function minimization problem to that of finding the mode of a posterior distribution in a "synthetic" statistical model. In the context of sequential portfolio optimization, this idea forms a novel portfolio utility function that extends traditional Markowitz-type methods by integrating multiple-step ahead prediction. The technique in statistical modeling, such as non-Gaussian state-space models, enables us to describe the various aspects of investors' preference that include explicit penalties for transaction costs, sparsity-inducing penalties on portfolio turnover and asymmetric penalties on the deviation from the target return. The resulting computational problems are addressed using combinations of EM, MCMC and analytic filtering and smoothing. Significant practical benefits in application are realized in the studies of FX time series with the sequential forecasting based on customized dynamic dependency network models.

Janne Kettunen
George Washington University

"To Better Manage Risks in New Product Development Portfolio Selection -- Be Risk Neutral"

We investigate trade-offs between risk and return in multi-period new product development (NPD)

portfolio selection problems, where new development projects become periodically available. Our analytical and computational results show that, paradoxically, a risk-neutral NPD portfolio selection approach provides higher return and lower risk than a risk-averse selection approach. This result can explain why leading innovators tend to employ a risk-neutral NPD selection approach. The risk of the NPD portfolio can be mitigated by (i) reviewing portfolios more frequently and (ii) increasing the proportion of derivative products instead of platform products. Our results show that it is beneficial for NPD organizations, regardless of decision makers risk aversion attitude, to foster an environment that (i) elicits as many vetted new development proposals as possible, (ii) encourages generation of high risk projects, and (iii) incubates a large variety of development projects.

Authors: Janne Kettunen and Shivraj Kanungo

Jesus Palomo
Rey Juan Carlos University

"Risk Management and Game Theory: a case study on cybersecurity"

The purpose of the talk is to present risk management methods when the opponent has the ability to adapt flexibly to the different security measures put in place by a defender. A common problem that arise this situation is that the efforts and costs of implementing security measures could not be effective if the opponent shifts in threat plans. Under this conditions, game theory seems a reasonable alternative. The relevance of defining the optimal strategy, the second best alternative and the value of private information will be presented. Finally, the case study on security of online transactions of a Spanish major bank will be presented.

Edsel A. Pena
University of South Carolina

“Multiple Decision-Making”

In this talk I will revisit the problem of making simultaneous decisions and when the global Type I error of interest is the false discovery rate (FDR). Of interest is the situation where the decision functions for each of the decision problems are not exchangeable (for example, they could have different powers or different receiver operating characteristic functions). The usual approach to performing such multiple decision-making is to adopt the Benjamini-Hochberg (BH) procedure. However, if the decision functions are not exchangeable, I will provide a class of multiple decision functions whose members control the FDR and which possess better global power performance than the BH procedure.

Jian Zou
Worcester Polytechnic Institute

“Conquering Big Data in Volatility Inference and Risk Management”

The field of high-frequency finance has experienced a rapid evolvement over the past few decades. One focus point is volatility modeling and analysis for big data setting. It plays a major role in finance and economics. In this talk, we focus on the statistical inference problem on large volatility matrix using high-frequency financial data, and propose a methodology to tackle this problem under various settings. We illustrate the methodology with the high-frequency price data on stocks traded in New York Stock Exchange in 2013. The theory and numerical results show that our approach perform well while pooling together the strengths of regularization and estimation from a high-frequency finance perspective.

Posters:

Xi Chen
Duke University

"Bayesian Dynamic Modeling and Analysis of Streaming Network Data"

Traffic flow count data in networks arise in many applications, such as automobile or aviation transportation, certain directed social network contexts, and internet studies. Using an example of internet browser traffic flow through domains within a popular international news website, this paper presents Bayesian analyses of two linked models which, in tandem, allow fast, scalable and interpretable Bayesian inference. The first model is a flexible, non-stationary and non-Gaussian state-space model for streaming count data, able to adaptively characterize and quantify network dynamics effectively and efficiently in real-time. The second model is a time-varying gravity model that allows for closer and formal dissection of network dynamics. The former is fast and scalable, and maps to the second in a computationally trivial way to allow and interpret inferences on traffic flow characteristics, and on interactions among network nodes in particular.

Didem Egemen
George Washington University

"Bayesian Modelling of Virtual Age in Repairable Systems"

In this study, we are considering aging of repairable systems, which are subject to minimal, perfect or imperfect repair upon each failure. Each repair is affecting the age of the system, bringing it back to the initial value (i.e. 0) when a perfect repair is performed or leaving as it is for a minimal repair. The imperfect repair will bring the age back to an intermediate value between the ones for perfect and minimal repair. The choice of the repair policy is modeled through specification of latent random variables at each failure times. We present novel models about the aging of the repairable systems by using nonhomogeneous Poisson process with Power Law process intensity function. Model parameters are estimated by Markov Chain Monte Carlo methods within the Bayesian framework.

Co-authors: Fabrizio Ruggeriy2, and Refik Soyer1 (1The George Washington University, Washington D.C., US / 2CNR IMATI, Milano, Italy)

Babak Saleck Pay
Virginia Commonwealth University

"Stochastic Network Interdiction with Incomplete Preference"

We study the stochastic network interdiction problem with incomplete preference. Different from the traditional stochastic network interdiction model, where the attacker (follower) makes an optimal decision after the realization of randomness, we consider a situation where the decisions of both the attacker (follower) and the defender (leader) are made before the realization of randomness. From a decision analysis point of view, we assume that the decision making is driven by the expected utility. In practice, only partial information about the utility function is known based on historical data. This leads to a set of utility functions that models the incomplete preference of a decision maker. In our study, we combine robust optimization and expected utility theory and show how robust decisions are made in an adversarial setting. Specifically, we study how the defender optimally allocates the defensive efforts to minimize the worst-case expected utility of the attacker, according to the historical data on the attacker's behaviors. Experiment results on stochastic network interdiction will be shown to demonstrate the idea of our model.

Vineet Madasseri Payyappalli
University at Buffalo

"Data-Driven Resource Allocation Models for Mitigating Fatalities and Economic Losses of Fire Hazards"

Firefighting in the United States, with over a million firefighters serving in over 30,000 fire departments and 55,000 fire stations is a highly important yet largely under-researched area, especially in terms of decision making and resource allocation. According to the National Fire Protection Association (NFPA), the total cost of fire for the year 2011 in U.S. was an estimated $329 billion which was 2.1% of U.S. GDP. In the same year, the local fire department expenditures totaled $42.3 billion which is comparable to the U.S. homeland security budget. This total investment is however the resultant of autonomous investments by the many fire departments across the country, which are private companies unlike in many other countries where fire departments are government organizations. The absence of centralized decision making in investment in firefighting calls for a study to gauge the effectiveness of this investment at the national, state, county, and fire-department levels. Our aim is to address this problem by analyzing the large amount of data available from public sources such as the National Fire Incident Response System (NFIRS) to formulate data-driven decision-making models that would save firefighters' and civilians' lives and reduce economic losses. This research tries to address a problem that is important in terms of human safety and economics, and opens up an unexplored area for analysts and practitioners in firefighting and also in disaster management in general.

Beidi Qiang
University of South Carolina

"Shrinkage Estimation on System Reliability"

Shrinkage estimator was initially developed by James and Stein as a biased estimator of the mean of Gaussian random vectors. The idea of shrinkage estimator can be extended to the estimation of system reliability, when component level data are observed. In this work, we consider a general model and introduce shrinkage estimation on the component reliability under an invariant loss function. Concrete examples are discussed with simulation results and the efficiency of the shrinkage effect is studied with respect to the maximum likelihood estimator.

Andrew M. Smith
University of California, Davis

"Interdependent Network Recovery Games"

Recovery in infrastructure systems often include functional and/or physical dependencies between generators and distributors across different utility networks. These dependencies can cause desired repair decisions to be blocked, resulting in a complex resource allocation problem. Centralized optimization formulations for recovery have been developed and analyzed on real-world infrastructure networks for various objective functions. However, it is known that infrastructure operators in these interdependent systems make decisions autonomously and potentially noncooperatively (i.e., their utility functions are not necessarily correlated), which often result in suboptimal solutions. We explore and compare several game theoretic models of infrastructure recovery, and show preliminary results on real utility networks. We then discuss next steps for influencing player strategies in decentralized recovery scenarios.

Abdolmajid Yolmeh
Rutgers University

"Game Theory Research for Security Application"

The safety of the public has always been paramount and in the event of an attack, one wants to maximize the number of lives saved and minimize the damage to infrastructure. Using game theory, the study of mathematical models of conflict and cooperation between intelligent rational decision makers, we can build a game where we would divide the decision makers as attackers and defenders. If we can build a game that can simulate how an attacker and defender would act in real life, then we can use the game to better understand which structures an attacker would go for. Moreover, in the event of an attack, one can make a better public procedure to maximize life and minimize damage. The game that was built involves using various strategies to destroy the highest value node, or target, if one is an attacker in the game or if one is a defender, then the objective is to catch the attacker. Through several simulations of the game, we collected data showing that attackers are inherently greedy and when they spawn, they would rather destroy the node that they spawned at than try and go for a higher value target. Defenders will try and keep moving around the high value targets and will not spend too much time protecting the lower value targets. With these ideas in mind, we were able to come up with an algorithm that can improve the probability of the attacker being captured given a certain number of defenders.

Jing Zhang
University at Buffalo

"Stochastic Shortest Path Network Interdiction Considering Partially Strategic Attackers with a Case Study of Arizona-Mexico Border"

One of the key challenges in securing the U.S.-Mexico border is the smuggling of illicit goods and humans between Ports-of-Entry (POEs). A confluence of factors advantageous to traffickers inconsistent levels of fencing, favorable terrain, and expansive knowledge of specific pathways have contributed to the establishment of preferred routes of illicit transit, yet little is known about the strategic and non-strategic interaction between adversaries and defenders between the POEs. To address this challenge, this paper studies a stochastic shortest-path network interdiction problem where the attacker (drug smugglers, illegal immigrants, or terrorists) attempts to minimize the shortest traveling time between the origin and the destination, while the defender attempts to maximize the attacker's traveling time by allocating sensors to the arcs to detect the attacker with a limited budget. Using a probabilistic detection likelihood, as well as modeling both strategic and non-strategic attackers, we formulate a bi-level max-min mix-integer problem on a multi-modal licit and illicit transportation network along the Arizona-Mexico border. We find that compared to a fully strategic attacker, the model that considers a partial-strategic attacker leads to a lower shortest traveling time. More importantly, this gap becomes larger as the defender has a larger budget, higher detection probability, and a larger penalty coefficient. A graphical user interface (GUI) is developed to assist decision making and demonstrate the results.

Authors: Jing Zhang[1], Jun Zhuang[1], and Brandon Behlendorf[2] Department of Industrial and System Engineering, University at Buffalo[1] START, University of Maryland[2]