Computational Methods of Applied Probability in Business Analytics

In Memory of Cyrus Derman

Department of Management Science & Information Systems
Livingstone Commons Room AB second floor, Rutgers University

Breakfast. Livingston Commons - Room AB, 8:00-8:30 AM

Opening Remarks. 8:30 - 8:35 AM, Nancy DiTomaso, Vice Dean for Faculty and Research, Rutgers Business School Newark & New Brunswick.

Session 1. 8:35 - 10:35 AM. Lee Papayannopoulos, Rutgers University, Chair

Two-Stage Problems with Stochastic Order Constraints.
Darinka Dentcheva, Department of Mathematical Science, Stevens Institute of Technology.
Abstract: We consider two-stage risk-averse stochastic optimization problems with a stochastic-order constraint on the second stage decisions. The usual stochastic order, the increasing convex order and a multivariate stochastic order will be discussed. We propose decomposition methods to solve the problems and prove their convergence. Our methods exploit the decomposition structure of the risk-neutral two-stage problems and construct successive approximations of the stochastic-order constraints. Numerical results confirm the efficiency of the methods.

Talk based on joint work with Eli Wolfhagen, Stevens Institute of Technology.

Queueing Loss Models with Heterogeneous Servers and Discriminating Arrivals.
Sheldon Ross, Department of Industrial and Systems Engineering University of Southern California.
Abstract: We consider an n server queueing loss model where customer i service times are exponential with rate $\mu_i$. Each arriving customer has a vector $(X_1, \ldots, X_n)$ where $X_i$ is the indicator of the event that server i is eligible to serve that customer. The vectors of successive arrivals are assumed to be independent with a common distribution. Arriving customers can be assigned to any currently idle server that is eligible to serve the customer; if there are no such servers then the customer is lost. Assuming that the random vector $(X_1, \ldots, X_n)$ is exchangeable, we find the optimal policy that minimizes the proportion of customers that are lost both when the service rates $\mu_i$ are known and, in the case of Poisson arrivals, when they are unknown and only no-memory rules are allowed. One no-memory rule would be to assign an arriving customer to a randomly chosen idle-eligible server; another would be to assign to the idle-eligible server that has been idle the longest; a third is to assign to the idle-eligible server that has been idle the longest.

Andrzej Ruszczynski, Department of Management Science & Information Systems Rutgers University.
Abstract: We present the concept of a dynamic risk measure and discuss its important properties. In particular, we focus on time-consistency of risk measures. Next, we focus on dynamic optimization problems for Markov models. We introduce the concept of a Markov risk measure and we use it to formulate risk-averse control problems for two Markov decision models: a discounted infinite horizon model and an undiscounted transient model. For both models we derive risk-averse dynamic programming equations and a value iteration method. We also develop a risk-averse policy iteration method and we prove its convergence. We propose a version of the Newton method to solve a non-smooth equation arising in the policy iteration method and we prove its global convergence. Finally, we present some examples.
Computational methods for multi-armed bandit problems based on elementary row operations. Eugene A. Feinberg, Department of Applied Mathematics & Statistics SUNY - Stony Brook.

Abstract: The celebrated multi-armed bandit problem provides a computationally tractable model for optimization of large-scale stochastic systems. This model is broadly used in many managerial applications including project management and resource allocation. The use of elementary row operations leads to generalizations and simplifications of the analysis of multi-armed bandit problems. It also provides new insights and leads to the development of new algorithms. This talk covers the following topics: problems with linear and exponential utilities, computation of objective functions, and problems with multiple criteria and constraints.

Talk based on joint work with Eric V. Denardo and Uriel G. Rothblum.

Break.

Session 2. 10:50 - 11:20 AM. Xiaodong Lin, Rutgers University, Chair


Abstract: There are many applications which require collecting information, where the time or cost required to make a measurement may be high. These problems arise in both online settings (learn as you go), primarily under the umbrella of multiarmed bandit problems, and offline settings (learning in a simulation or laboratory), which it is known under names such as stochastic search or ranking and selection. These communities have evolved independently with very different vocabularies. In this talk, I will introduce the knowledge gradient policy, which can be thought of as steepest ascent for learning problems, which maximizes the marginal value of information (but with exceptions). The knowledge gradient provides a simple and elegant bridge between the online and offline learning communities. This makes it possible to adapt powerful ideas that were first developed for offline problems to online applications, including learning with correlated beliefs, learning with parametric belief models, optimizing continuous functions, and learning with a physical state (dynamic programming).

Talk based on joint work with Ilya Ryzhov and Peter Frazier.

Nonnegative and Sum-Of-Squares Polynomials in Shape constrained estimation. Farid Alizadeh, Department of Management Science & Information Systems Rutgers University.

Abstract: In many statistical learning problems, where an unknown function has to be estimated from a finite set of noisy observations, one may have some a priori knowledge of this unknown function. For instance one may know that the function must be nonnegative, or monotonic, or convex or concave. In this talk we present an application of optimization problems over some sets of nonnegative functions. Examples are estimation of arrival rates of nonhomogenous Poisson processes in one and to variables, shape-constrained nonparametric regression and shape-constrained nonparametric density estimation.

Talk based on joint work with David Papp, Northwestern University.

Scalable Graph Analysis: Clustering, Centrality Measures. Spiros Papadimitriou, Department of Management Science & Information Systems Rutgers University.

Abstract: Relationships between various types of objects arise naturally in many applications, such as the web, social networks, intelligence, information retrieval, and computer security, to mention a few. The volume of data is typically very large and this motivates the need for scalable analytics that can answer key questions such as: (i) what are the key communities of nodes? or (ii) which are the most important nodes?

With respect to the first question, we present a method that, given a bi-partite graph, can jointly discover communities of nodes, as well as the number of these communities, producing meaningful patterns that agree with human intuition. Furthermore, we show that it can also scale up to very large graphs, using Hadoop/MapReduce. With respect to the second question, we present scalable measures of centrality, to determine important nodes in a graph, which can scale up to very large graphs using MapReduce.

Lunch at Livingston Commons Faculty Dinning Hall 12:20 -2:00 PM.
Pricing in a service system with delay sensitive consumers.

**Xiuli Chao**, Department Industrial & Operations Engineering, University of Michigan.

**Abstract:** When facing multiple classes of delay sensitive customers, how should a service firm make pricing decisions if it is unable to utilize discriminatory price? If the firm can use discriminatory price, then priority has been commonly used in optimizing a firm’s revenue function. In many applications, however, the firm cannot or is not allowed to discriminate customers and it has to make a uniform decision, such as sales price, to all its customers. How does the service firm make its decisions based on the knowledge of different classes of customers? We consider this problem with both the service firm is a monopoly or duopoly, and present the optimal strategy for the service firm. We show that the strategy of the firm varies significantly, and it depends on the range of system parameters. We report the result for each and every range of the system parameters and discuss their implications.

**Talk based on joint work with W. Zhou and X. Gong.**

Inventory and Price Control under Time-consistent Markov and Coherent Risk Measures.

**Jian Yang**, Department of Management Science & Information Systems Rutgers University.

**Abstract:** We use the recently proposed concept of time-consistent Markov and coherent risk measure on the study of a risk-averse firm’s inventory and price control activities. In our different setting than where the measure is first introduced, we show the suitability of dynamic programming formulations. On this basis, we examine pure inventory and joint inventory-price control problems, both without and with fixed setup costs. The resulting model calls for worst-case analysis over a convex set of demand-distribution scenarios in every period. We achieve structural characterizations for optimal policies that are reminiscent of their risk-neutral counterparts. Monotone properties are further derived for the pricing policy when the convex risk set is a lattice with the underlying partial order for demand distributions defined in the usual stochastic sense. All results can be extended to the case with an infinite planning horizon. We also introduce the concept of optimism using a partial order for risk sets. Two risk measures thus ranked produce inventory and pricing decisions that can be ranked themselves. In addition, we show how the case where demand is censored can be similarly treated and discuss various other minor issues.

The Quest for Exact Simulation of the Stationary Distribution of Generalized Jackson Networks of Queues.

**Karl Sigman**, Department of Industrial Engineering and Operations Research Columbia University.

**Abstract:** In an attempt at deriving an exact simulation algorithm for the stationary distribution of generalized Jackson networks of queues (we will go over that briefly), we stumble across a simple variation of the FIFO M/G/1 queueing model, one for which the service time of the $n^{th}$ customer, $S_n$, depends on the length $T_{n-1} = t_n - t_{n-1}$ of the previous interarrival time (here, $t_n$ denotes the arrival time of the $n^{th}$ customer). In particular $S_n$ and delay $D_n$ (in line of) this $n^{th}$ customer are now dependent (through $T_{n-1}$). Applications could include situations where a customer’s service is lengthened (or shortened) if they arrive late. Although a seemingly simple modification of the classic M/G/1 model, we illustrate how in fact it is surprisingly complicated to analyze. For example, classic Weiner-Hopf factorization does not hold because now the underlying random walk increments are not iid.

Is mathematics able to give insight into current questions in finance, economics and politics?

**Larry Shepp**, Wharton School, U Penn.

**Abstract:** The Democrats say that if we raise taxes, we can grease the wheels of the economy and create wealth enough to recover taxes and thereby also increase employment; the Republicans say that taxation discourages investment and so increases unemployment. These arguments cannot both be correct, but both arguments seem meritorious. Faced with this paradox, one might hope that a rigorous mathematical approach might help determine which is the truth. We attempt to do this, and we reach a firm conclusion with a reasonable model which, as it turns out, favors the democratic side by showing that if money is lent to a profitable company, there is always a way to provide enough additional profit to pay the cost of the loan and to cover the profits obtainable in the absence of the loan, at least on average. More precisely, we show that for every profitable company the additional funds can be used to increase the mean discounted profits and these additional profits can be used to pay for the expected discounted cost of the loans to the company. This would appear to settle the issue, at least for a mathematician, that truth lies on the democratic side. However, there is a subtlety.

**Talk based on joint work with Michael Imerman, Lehigh University.**
Session 4. 4:15 - 5:45 PM. [Jonathan Eckstein] Rutgers University, Chair

**Some new models for heavy tailed distributions with applications to finance.**

[V. Ramaswami](#) AT&T Labs Research.

**Abstract:** The phase type distributions of Neuts have an exponentially decaying tail and therefore are inherently unsuitable for modeling heavy tailed distributions. With this in mind, we introduced the logPH distribution, whereby we model a heavy tailed random variable as the exponent of a phase type random variable. This class is dense and allows one to model a heavy tailed distribution in its entire range. We show many examples from reliability, internet performance and insurance risk to demonstrate its superior performance relative to several classical models used in the past.

**Big Data Analytics in Mobile Environments.**

[Hui Xiong](#) Department of Management Science & Information Systems Rutgers University.

**Abstract:** Advances in sensor, wireless communication, and information infrastructure such as GPS, WiFi, and mobile phone technology have enabled us to collect and process massive amounts of mobile data from multiple sources but under operational time. These so-called big data have become a major driving force of new waves of productivity growth, application innovation, and consumer surplus. The big data are usually immense, fine-grained, diversified, dynamic, and sufficiently information-rich in nature, and thus demands a radical change in the philosophy of data analytics. In this talk, we introduce some emerging big data applications and discuss the technical and domain challenges of big data analytics in mobile environments. In particularly, it is especially important to investigate how the underlying computational models can be adapted for managing the uncertainties in relation to big data process in a huge nebulous environment.

**The Class of Quasi-Skip Free Processes: Explicit solutions when successively lumpable.**

[Michael N. Katehakis](#) Department of Management Science & Information Systems Rutgers University.

**Abstract:** We define the class of Quasi-skip-free (QSF) processes, a generalization of the quasi-birth-and-death (QBD) processes. They are Markov process with states that can be specified by tuples of the form (m,i) where m represents the “current” level of the state. In addition, their probability state transition law does not permit transitions to a state with level more than two (2) units away from the current state’s level in one direction. Such processes have applications in many areas of applied probability including queuing theory, reliability, computer science and the theory of branching processes.

We discuss stability conditions for QSF processes and provide a simple condition under which a QSF process is successively lumpable (SL-QSF). We use this successive lumpability property to derive explicit solutions and bounds for the steady state probabilities of general state space SL-QSFs, and to obtain a number of simplified derivations for results that are much more difficult to establish otherwise. Finally, we present explicit solutions for the well known PH/M/n and M/PH/n queues.

*Talk based on joint work with L. Smit, Rutgers University & University of Leiden and F. Spieksma, University of Leiden, Netherlands.*