Stochastic Networks 2024

KTH, Stockholm, Sweden

July 1 – July 5, 2024

Location: All talks are held in room E1 on KTH campus. Breakfast, coffee breaks and lunches are held in the Ljusgård, close to E1.

Tentative schedule

July 1, Monday

8:30 - 9:00: Breakfast and registration
9:00 - 9:15: Opening remarks
9:30 - 10:30: **Emma Horton** - Genealogies of critical branching processes
10:30 - 11:00: Coffee break
11:00 - 12:00: **Jim Dai** - The BAR-approach for continuous-time stochastic systems

1:30 - 2:30: **Ruth Williams** - Stochastic Analysis of Chemical Reaction Networks with Applications to Epigenetic Cell Memory
2:30 – 3:00: Lightning poster presentations 1
3:00 – 3:30: Coffee break
3:30 – 4:30: **Peter Taylor** - A strategy for constructing tractable models of malarial superinfection
4:30 – 6:30: Poster session 1

July 2, Tuesday

8:30 - 9:00: Breakfast and registration
9:00 - 10:00: **Souvik Dhara** - Community Detection with Censoring
10-00 - 10:30: Coffee break
10:30 – 11:30: **Sen Subhabrata** - Fundamental thresholds for community detection on multi-view networks
11:30 – 12:30: **Shuangping Li** - Spectral clustering in the Gaussian mixture block model

2:00 – 3:00: **Svante Janson** - Inhomogeneous random graphs
3:00 - 3:30: Coffee break
3:30 – 4:30: **François Baccelli** - Phase transitions in unimodular random graphs

July 3, Wednesday

8:30 – 9:00:	Breakfast
9:00 – 10:00:	**Mariana Olvera-Cravioto** - Local limits and preferential attachment graphs
10:00 – 10:30:	Coffee break
10:30 – 11:30:	**Jiaming Xu** - Recent advances on random graph matching problems
11:30 – 12:30:	**Clara Stegehuis** - Optimal structures in random networks
2:00 – 3:00:	**Adam Wierman** - Learning Augmented Algorithms for MDPs
3:00 – 3:30:	Lightning poster presentations 2
3:30 – 4:00:	Coffee break
4:00 – 5:00:	**Laurent Massoulie** - Collaborative methods for: i) learning shared representations; ii) exploring unknown environments
5:00 – 6:30	Poster session 2

July 4, Thursday

8:30 – 9:00:	Breakfast
9:00 – 10:00:	**Niao He** - Reinforcement Learning in Mean Field Games: the pitfalls and promises
10:00 – 10:30:	Coffee break
10:30 – 11:30:	**Sid Banerjee** - Further Adventures of the Compensated Coupling
11:30 – 12:30:	**Siva Theja Magaluri** - Finite-time Tail Bounds for Stochastic Approximation of Contractive Operators

From 6:00: Banquet at Skansen

July 5, Friday

8:30 – 9:00:	Breakfast
9:00 – 10:00:	**Cynthia Rush** - Characterizing Model Selection Performance of Sorted L1 Regularization Using Approximate Message Passing
10:00 – 10:30:	Coffee break
10:30 – 11:30:	**Amy Ward** - Integrating Machine Learning and Queueing to Enhance Decision-Making: An Application in Criminal Justice
11:30 - 12:30	**Maria Deijfen** - Mean field stable matching

François Baccelli (INRIA and ENS)

Title: Phase transitions in unimodular random graphs

Abstract: The talk will survey recent results on unimodular random networks. Several applications will be discussed, including perfect simulation, unsupervised classification, and phylogenetic classification.

Short bio: F. Baccelli is a senior researcher at INRIA-ENS and an invited professor at Telecom Paris. His research is at the interface between applied mathematics and communication networks. His work on applied mathematics is focused on point processes, max plus algebras, network dynamics, queuing networks, random graphs, and stochastic geometry. His main contributions to communications are centered on congestion control, information theory, and wireless networks. He is a member of the French Academy of Sciences. He was the Math+X Simons chair in mathematics and ECE at UT Austin between 2012 and 2021. He is currently in charge of an interdisciplinary ERC advanced NEMO project on communications and network mathematics.

Siddhartha Banerjee (Cornell University)

Title: Further Adventures of the Compensated Coupling

Abstract: Around five years ago, my collaborators and I introduced the compensated coupling: a simple paradigm for designing sequential decision-making policies based on sample-pathwise comparisons to a hindsight benchmark. Our approach generalized many standard results used in studying MDPs and reinforcement learning, but also gives new policies which are much simpler and more effective than existing heuristics for a large class of widely-studied problems -- including online packing and covering, dynamic pricing, generalized assignment, online bin packing, fair allocation, bandits with knapsacks, and many others. In this talk, I will provide a brief overview of the main technique, and then try to illustrate some newer extensions that illustrate the power of the approach: 1. how to achieve constant regret (i.e., additive loss compared to a hindsight benchmark which is independent of state-space size) for a wide range of problems, and under minimal conditions, 2. how we can use it to derive tradeoff laws between different objectives, and 3. how we can incorporate side information and historical data, and achieve constant regret with as little as a single data trace.

Short bio: Sid Banerjee is an associate professor in the School of Operations Research at Cornell, working on topics at the intersection of data-driven decision-making, network algorithms and market design. His research is supported by grants from the NSF (including an NSF CAREER award), ARO, and AFOSR, and has received multiple awards including the INFORMS Applied Probability Society Best Publication award in 2021 and the Erlang Prize in 2022. He completed his PhD from the ECE Department at UT Austin, and was a postdoctoral researcher in the Social Algorithms Lab at Stanford. He also served as a technical consultant with the research science group at Lyft from 2014-18.

Jim Dai (Cornell University)

Title: The BAR-approach for continuous-time stochastic systems

Abstract: I will survey the basic adjoint relationship (BAR)-approach that has been advanced recently by Braverman, Dai, and Miyazawa (2017, 2024) for steady-state analysis of continuous-time stochastic systems. In such a system, the distributions of stochastic primitives (e.g, service times) are assumed to be general, not necessarily exponential or phase-type. I will illustrate that the BAR-approach is an effective too to prove (1) the state space collapse in a join-shortest-queue system, (2) asymptotic steady-state independence for multiclass queueing networks in multi-scale heavy traffic.

Short bio: Jim Dai is the Leon C. Welch Professor of Engineering in the School of Operations Research and Information Engineering. He also serves as the Dean of School of Data Science at The Chinese University of Hong Kong, Shenzhen. Prior joining Cornell, he held the Chandler Family Chair Professorship in the School of Industrial and Systems Engineering at Georgia Institute of Technology, where he was a faculty member from 1990 to 2012.

Jim Dai received his BA and MA in mathematics from Nanjing University, and his PhD in mathematics from Stanford University. He is an elected fellow of Institute of Mathematical Statistics and an elected fellow of Institute for Operations Research and the Management Sciences (INFORMS). He has received a number of awards for research contributions including the Best Publication Award twice, in 1997 and 2017, The Erlang Prize in 1998, all from the Applied Probability Society of INFORMS, and the ACM SIGMETRICS Achievement Award in 2018. He served as the Editor-In-Chief for Mathematics of Operations Research (MOR) from 2012 to 2019.

Jim Dai's research interests include stochastic processing networks, fluid and diffusion models of queueing networks, reflecting Brownian motions, Stein's method, customer contact center management, hospital inpatient flow management, semiconductor wafer manufacturing, and airline revenue management.

Maria Deijfen (Stockholm University)

Title: Mean field stable matching

Abstract: Consider a situation where a number of objects acting to maximize their own satisfaction are to be matched. Each object ranks the other objects and a matching is then said to be stable if there is no pair of objects that would prefer to be matched to each other rather than their current partners. We consider stable matching of the vertices in the complete graph based on i.i.d. exponential edge costs. Our results concern the total cost of the matching, the typical cost and rank of an edge in the matching, and the sensitivity of the matching and the matching cost to small perturbations of the underlying edge costs.

Short bio: Maria Deijfen is a professor of mathematics at Stockholm University. She is known for her research on random graphs and stochastic processes on graphs, including the Reed–Frost model of epidemics. Maria received her PhD in 2004. After completing her doctorate, she became a postdoctoral researcher at the Mittag-Leffler Institute, Vrije Universiteit Amsterdam, Chalmers University, and Delft University of Technology before returning to Stockholm as a junior faculty member in 2006. Prof. Deijfen was one of the 2018 recipients of the Paul R. Halmos – Lester R. Ford Award of the Mathematical Association of America for her paper with Alexander E. Holroyd and James B. Martin, "Friendly Frogs, Stable Marriage, and the Magic of Invariance", using combinatorial game theory to analyze the stable marriage problem.

Souvik Dhara (Purdue university)

Title: Community Detection with Censoring

Abstract: Recovering latent communities is a key unsupervised learning task in network data with applications spanning across a multitude of disciplines. For example, identifying communities in web pages can lead to faster search, classifying regions of the human brain in communities can be used to predict onset of psychosis, and identifying communities of assets can help investors manage risk by investing in different communities of assets. However, the scale of these massive networks has become so large that it is often impossible to work with the entire network data. In this talk, I will talk about some theoretical progress for community detection in a probabilistic set up especially when we have missing data about the network. Based on joint works with Julia Gaudio, Elchanan Mossel and Colin Sandon.

Short bio: Dr. Souvik Dhara is an Assistant Professor at the School of Industrial Engineering and Math department by courtesy at Purdue University. Previously, he has been a Schramm Fellow with a joint appointment between MIT Mathematics and Microsoft Research, Simons-Berkeley Fellow at the Simons Institute, UC Berkeley, and a Postdoctoral Research Associate at Brown University. He received his PhD in 2018 from the Department of Mathematics and Computer Science at Eindhoven University of Technology. Dr. Dhara's research interest lies at the intersection of applied probability and network science. His primary focus is to develop theoretical foundations for stochastic processes and algorithms on large-scale networks. For instance, his interests include epidemics on networks, community detection, graph representation learning. Dr. Dhara was awarded the Stieltjes Prize for his PhD thesis at the Dutch Mathematical Congress, 2019.

Niao He (ETH Zurich)

Title: Reinforcement Learning in Mean Field Games: the pitfalls and promises

Abstract: Amidst its diverse applications, multi-agent reinforcement learning (MARL) stands as a formidable challenge in general due to the "curse of many agents". Mean-field games (MFGs) have merged as a popular surrogate for modeling game dynamics involving a large population of interacting decision-makers. Despite the widespread use of reinforcement learning techniques in recent literature to address MFGs, several foundational questions persist: (1) When are MFGs good approximations of MARL problems, (2) When does learning MFGs exhibit computational or statistical tractability, (3) Can equilibrium be achieved through independent learning? This talk will explore these crucial dimensions of learning MFGs, shedding light on their fundamental limits.

Short bio: Niao He is an Assistant Professor in the Department of Computer Science at ETH Zurich, where she leads the Optimization and Decision Intelligence (ODI) Group. She is also an ELLIS Scholar and a core faculty member of ETH AI Center and ETH-Max Planck Center of Learning Systems. Previously, she was an assistant professor at the University of Illinois at Urbana-Champaign from 2016 to 2020. Before that, she received her Ph.D. degree in Operations Research from Georgia Institute of Technology in 2015. Her research interests lie in large-scale optimization and reinforcement learning, with a primary focus on theoretical and algorithmic foundations for principled, scalable, and trustworthy decision intelligence. She is a recipient of AISTATS Best Paper Award, NSF CRII Award, SNSF Starting Grant, etc.

Emma Horton (University of Warwick)

Title: Genealogies of critical branching processes

Abstract: Branching processes are pertinent to understanding many different real world processes such as cell division, population growth and neutron transport. In particular, understanding their genealogical structures can prove useful for parameter estimation, Monte Carlo simulations and scaling limits. In this talk we discuss a decomposition of the branching process known as the many-to-few formula, which allows one to understand the behaviour of a branching process in terms of a weighted subtree. I will then give two applications of this decomposition to demonstrate its use in understanding the genealogical structure of the branching process.

Short bio: Emma is currently Assistant Professor of Probability at the University of Warwick, specialising in branching processes, interacting particle systems, Monte Carlo methods, and their applications to radiation transport. Prior to this position Emma was chargée de recherché with Inria in Bordeaux, during which time she spent seven months on secondment at the University of Melbourne.

Svante Janson (Uppsala University)

Title: Inhomogeneous random graphs

Abstract: This is a survey of "Inhomogeneous random graphs" starting with their definition by Bollobas, Janson & Riordan (2007) and discussing some later developments and results, in particular the connections to graphons. I want to stress the flexibility of the model, but also its limits.

Short bio: PhD 1977 (Mathematics) and 1984 (Mathematical statistics). Professor in mathematics at Uppsala University. Random networks (graphs) and related topics, including both graph limits and other random combinatorial structures, has been my main research area for many years.

Shuanping Li (Stanford)

Title: Spectral clustering in the Gaussian mixture block model

Abstract: Gaussian mixture block models are distributions over graphs that strive to model modern networks: to generate a graph from such a model, we associate each vertex with a latent feature vector sampled from a mixture of Gaussians, and we add edge if and only if the feature vectors are sufficiently similar. The different components of the Gaussian mixture represent the fact that there may be different types of nodes with different distributions over features---for example, in a social network each component represents the different attributes of a distinct community. Natural algorithmic tasks associated with these networks are embedding (recovering the latent feature vectors) and clustering (grouping nodes by their mixture component).

In this talk, we focus on clustering and embedding graphs sampled from high-dimensional Gaussian mixture block models, where the dimension of the latent feature vectors goes to infinity as the size of the network goes to infinity. This high-dimensional setting is most appropriate in the context of modern networks, in which we think of the latent feature space as being high-dimensional. We analyze the performance of canonical spectral clustering and embedding algorithms for such graphs in the case of 2-component spherical Gaussian mixtures and begin to sketch out the information-computation landscape for clustering and embedding in these models.

This is based on joint work with Tselil Schramm.

Short bio: Shuangping Li is a Stein Fellow in the Department of Statistics at Stanford University. She received her PhD degree in Applied and Computational Mathematics in 2022 from Princeton University, where she was jointly advised by Professors Allan Sly and Emmanuel Abbé. Shuangping's research interests span probability theory, statistics, and machine learning.

Laurent Massoulié (INRIA)

Title: Collaborative methods for: i) learning shared representations; ii) exploring unknown environments.

Abstract: In a first part, based on joint work with Mathieu Even, we discuss collaborative approaches where agents who each seek to learn a model of their personal dataset can benefit from each other by learning a shared linear representation.
In a second part, based on joint work with Romain Cosson, we propose strategies for multiple agents to collaboratively explore unknown environments with improved worst-case overhead and competitive ratio.

Short bio: Laurent Massoulié is research scientist at Inria, scientific director of the Paris Inria Centre and professor at the Applied Maths Centre of Ecole Polytechnique. His research interests are in machine learning, probabilistic modelling and algorithms for networks. He has held research scientist positions at: France Telecom, Microsoft Research, Thomson-Technicolor, where he headed the Paris Research Lab. He obtained best paper awards at IEEE INFOCOM 1999, ACM SIGMETRICS 2005, ACM CoNEXT 2007, NeurIPS 2018, NeurIPS 2021, was elected "Technicolor Fellow" in 2011, received the "Grand Prix Scientifique" of the Del Duca Foundation delivered by the French Academy of Science in 2017, is a Fellow of the “Prairie” Institute and received the ACM Sigmetrics achievement award in 2023.

Mariana Olvera-Cravioto (UNC Chapel Hill)

Title: Local limits and preferential attachment graphs

Abstract: This talk is meant to provide an overview of local weak convergence techniques for a large class of directed random graphs, including static models such as the Erdos-Renyi, Chung-Lu, stochastic block model, and configuration models, as well as dynamic models such as the collapsed branching process and the directed preferential attachment graph. We explain how local limits can be used to study important structural graph properties, including centrality measures such as the PageRank distribution. We further use the insights obtained from our analysis of centrality measures to explain how static models and evolving models differ in how large degree vertices are distributed within the graph and how they shape their neighborhoods. In particular, we show that the empirically accepted "power-law hypothesis" on scale-free graphs, which states that the PageRank distribution follows a power-law with the same tail index as the in-degree distribution, holds in most static models but not in the dynamic models we study.
This is joint work with: Sayan Banerjee and Prabhanka Deka.

Short bio: Mariana Olvera-Cravioto is a Professor in the Department of Statistics and Operations Research at UNC Chapel Hill. Her research interests include random graphs, heavy-tailed phenomena, and stochastic processes on random graphs, in particular, opinion dynamics. She holds a BA in Applied Mathematics from the "Instituto Tecnológico Autónomo de México (ITAM)", a MS in Statistics from Stanford University, and a PhD in Management Science & Engineering, also from Stanford University. Prior to joining UNC Chapel Hill, she was a faculty member in the Industrial Engineering and Operations Research Department at Columbia University, and also briefly a visiting faculty in the Industrial Engineering and Operations Research Department at UC Berkeley.

Cynthia Rush (Columbia University)

Title: Characterizing Model Selection Performance of Sorted L1 Regularization Using Approximate Message Passing

Abstract: Sorted L1 regularization has been incorporated into many methods for solving high-dimensional statistical estimation problems, including the SLOPE estimator in linear regression. In this talk, we study how this regularization technique improves variable selection by characterizing the optimal SLOPE trade-off between the false discovery proportion (FDP) and true positive proportion (TPP) or, equivalently, between measures of type I and type II error. Additionally, we show that on any problem instance, SLOPE with a certain simplified two-level regularization sequence outperforms the Lasso, in the sense of having an asymptotically smaller FDP, larger TPP and smaller L2 estimation risk simultaneously. We discuss how this simplified version of SLOPE with a two-level regularization sequence, which we refer to as 2-level SLOPE, performs nearly as well as SLOPE in its full generality and has far fewer tuning parameters. Our proofs are based on a novel technique that reduces a variational calculus problem to a class of infinite-dimensional convex optimization problems and a recent results from approximate message passing (AMP) theory. With SLOPE being a particular example, we discuss these results in the context of a general program for systematically deriving exact expressions for the asymptotic risk of estimators that are solutions to a broad class of convex optimization problems via AMP. Collaborators on this work include Zhiqi Bu, Jason Klusowski, and Weijie Su (https://arxiv.org/abs/1907.07502 and https://arxiv.org/abs/2105.13302), Oliver Feng, Ramji Venkataramanan, and Richard Samworth (https://arxiv.org/abs/2105.02180) and Ruijia Wu.

Short bio: Cynthia Rush is an Associate Professor of Statistics at Columbia University. She received a Ph.D. and M.A. in Statistics from Yale University in 2016 and 2011, respectively, and she completed her undergraduate coursework at the University of North Carolina at Chapel Hill where she obtained a B.S. in Mathematics in 2010. Her research focuses on message passing algorithms, statistical robustness, and information theory.

Clara Stegehuis (University of Twente)

Title: Optimal structures in random networks

Abstract: Subgraphs contain important information about network structures and their functions. But where can we find these subgraphs in random graphs? And how likely are we to find a much larger amount of them than expected? Interestingly, these question leads to mixed integer optimization problems on random graphs that identify the dominant structure of any given subgraph. The optimizer describes the degrees and the spatial locations of the vertices that together create the most likely subgraph. On the popular hyperbolic random graph model, our optimization problem shows the trade-off between geometry and popularity: some subgraphs are most likely formed by vertices that are close by, whereas others are most likely formed by vertices of high degree. This insight makes it possible to create optimal statistics that detect the presence of an underlying spatial structure.

Short bio: Clara Stegehuis is an associate professor at the university of Twente. She works at the intersection of probability theory, graph theory and stochastic networks, with an emphasis on asymptotic analysis, stochastic process limits, and randomized algorithms. Problems she investigates are often inspired by applications in network science, physics and computer science.

Sen Subhabrata (Harvard University)

Title: Fundamental thresholds for community detection on multi-view networks

Abstract: We will discuss sharp thresholds for weak recovery in multi-view networks. Specifically, we will discuss the inhomogeneous multi-layer Stochastic Block Model (SBM) and the dynamical SBM. In addition, we provide efficient algorithms for community recovery using Approximate Message Passing. Based on joint work with Xiaodong Yang and Buyu Lin (Harvard).

Short bio: Subhabrata Sen is an Assistant Professor of Statistics at Harvard University. Prior to Harvard, he completed his PhD from Stanford Statistics, and was subsequently a Schramm postdoctoral fellow at Microsoft Research New England and MIT. His current research focuses on high-dimensional statistics, inference on networks and spin glasses. Subhabrata has received the NSF CAREER Award, an AMS Simons Travel grant and Bernoulli Society New Researcher Award (Hon. Mention).

Peter Taylor (University of Melbourne)

Title: A strategy for constructing tractable models of malarial superinfection

Abstract: Superinfection, that is the concurrent presentation of separately-acquired infections, is an important feature of several infectious diseases. A particularly pertinent example is malaria. Population-level compartment models allowing for malarial superinfection may take the form of countably infinite systems of ordinary differential equations, which poses complications for simulation and analysis. Here, we present a novel strategy for deriving tractable systems of integrodifferential equations for epidemic models of malarial superinfection. Our approach is predicated on the fact that we can characterise the within-host dynamics using a network of infinite-server queues with a time dependent batch arrival rate that is a function of the intensity of mosquito-to-human transmission. We shall illustrate this approach in the context of the classical model of superinfection for Plasmodium falciparum malaria. By observing that the classical deterministic compartment model has the same form as the Kolmogorov forward differential equations for an infinite server queue, we recover a reduced system of integro-differential equations governing the intensity of mosquito-to-human transmission. The resultant systems of IDEs are amenable to numerical solution, allowing us to explore the transient, population-level dynamics of superinfection without resorting to approximation. We can also derive threshold parameters governing the existence of non-trivial (endemic) equilibria. This approach can be generalised to account for additional biological complexity, in particular the accrual of the hypnozoite reservoir — a bank of dormant liver-stage parasites that can activate to yield repeated relapses of Plasmodium vivax malaria. It can also be used in models that take into account demography, drug treatment and the development of immunity.

Short bio: Peter Taylor received a BSc(Hons) and a PhD in Applied Mathematics from the University of Adelaide in 1980 and 1987 respectively. In between, he spent time working for the Australian Public Service in Canberra. After periods at the Universities of Western Australia and Adelaide, he moved at the beginning of 2002 to the University of Melbourne. In January 2003, he took up a position as the inaugural Professor of Operations Research. He was Head of the Department of Mathematics and Statistics from 2005 until 2010. Peter's research interests lie in the fields of stochastic modelling and applied probability, with particular emphasis on applications in queueing, telecommunications, biological modelling, economics, healthcare and disaster management. Peter is the Editor-in-Chief of {\it The Journal of Applied Probability} and {\it Advances in Applied Probability}. In 2017, he was awarded the Ren Potts Medal by the Australian Society for Operations Research, in 2018 the George Szekeres Medal by the Australian Mathematical Society and in 2019 the ANZIAM Medal. He is a fellow of the Australian Academy of Science and the Australian Mathematical Society.

Siva Theja Magaluri (Georgia Tech)

Title: Finite-time Tail Bounds for Stochastic Approximation of Contractive Operators

Abstract: Motivated by applications in Reinforcement Learning (RL), this talk focuses on the Stochastic Appproximation (SA) method to find fixed points of a contractive operator. First proposed by Robins and Monro, SA is a popular approach for solving fixed point equations when the information is corrupted by noise. We consider the SA algorithm for possibly nonlinear operators that are contractive under arbitrary norms (especially the l-infinity norm). The focus of this talk is on presenting finite sample bounds on the convergence error. First, we will briefly recap bounds on the mean square error which are obtained using a Lyapunov framework based on infimal convolution and generalized Moreau envelope. Then, we present more recent result on concentration of the tail error. A key challenge is handling the multiplicative form of the noise, which can lead to the iterates being potentially unbounded. Our tail bounds are obtained using exponential supermartingales in conjunction with the Moreau envelope and a novel bootstrapping approach. Our results immediately imply the state-of-the-art sample complexity results for a large class of RL algorithms.

Short bio: Siva Theja Maguluri is Fouts Family Early Career Professor and Associate Professor in the H. Milton Stewart School of Industrial and Systems Engineering at Georgia Tech. He obtained his Ph.D. and MS in ECE as well as MS in Applied Math from UIUC, and B.Tech in Electrical Engineering from IIT Madras. His research interests span the areas of Control, Optimization, Algorithms and Applied Probability and include Reinforcement Learning theory and Stochastic Networks. His research and teaching are recognized through several awards including the Best Publication in Applied Probability award, NSF CAREER award, second place award at INFORMS JFIG best paper competition, Student best paper award at IFIP Performance, CTL/BP Junior Faculty Teaching Excellence Award, and Student Recognition of Excellence in Teaching: Class of 1934 CIOS Award.

Amy Ward (Chicago Booth)

Title: Integrating Machine Learning and Queueing to Enhance Decision-Making: An Application in Criminal Justice

Joint work with: Bingxuan Li, Pengyi Shi, Zhiqiang Zhang

Abstract: Recidivism, or the repetition of criminal acts after being punished, is a significant problem in the U.S., where over 70% of prisoners reoffend. Incarceration diversion programs are one attempt to combat recidivism, by focusing on societal reintegration rather than incarceration. Machine learning (ML) algorithms play an important role in program admission decisions, by assigning a risk score, that helps to quantify the trade-off between the potential benefit of the program to the individual, and the risk that the individual may reoffend while completing program requirements. Since incarceration diversion programs often have limited capacity, admission decisions are made by prioritizing individuals based on this tradeoff. However, ML classifications are imperfect, resulting in potentially incorrect admission decisions. Furthermore, algorithmic bias in the machine learning model may lead to unfairness with respect to which subpopulations have the opportunity to benefit from the incarceration diversion programs. Errors in decision making and unfairness are especially worrying in this environment, as these decisions affect both the life path of an individual and society's exposure to offenders.

Motivated by the incarceration diversion program setting, we formulate an admission control problem in a queueing model with heterogeneous classes, in which an underlying ML algorithm estimates each arriving individual's class. The queueing model is a loss model with reneging from service. The loss feature replicates the fact that individuals admitted to an incarceration diversion program should begin in the program immediately. The reneging from service feature is unique compared to most reneging models in the literature and is motivated by the fact that an individual in the incarceration diversion program may either be successfully served (complete the program) or renege (recidivate while in the program). Our main theoretical results pertain to the performance of a priority score policy under imperfect estimation, and our main computational results focus on calibrating a simulation model to underlying program data.

Short bio: Amy R. Ward is the Rothman Family Professor of Operations Management at the University of Chicago Booth School of Business. She received her Ph.D. degree from Stanford University in 2001. She is a fellow of the INFORMS Manufacturing and Service Operations Management (M&SOM) Society (elected June, 2023). She is the Editor-in-Chief for the journal Operations Research (term began 1/1/2024). Earlier, she held the position of Chair of the INFORMS Applied Probability Society (term 11/2016-11/2018).

Adam Wierman (Caltech)

Title: Learning Augmented Algorithms for MDPs

Abstract: Making use of modern black-box AI tools such as deep reinforcement learning is potentially transformational for sustainable systems such as data centers, electric vehicles, and the electricity grid. However, such machine-learned algorithms typically do not have formal guarantees on their worst-case performance, stability, or safety. So, while their performance may improve upon traditional approaches in “typical” cases, they may perform arbitrarily worse in scenarios where the training examples are not representative due to, e.g., distribution shift. Thus, a challenging open question emerges: Is it possible to provide guarantees that allow black-box AI tools to be used in safety-critical applications? In this talk, I will provide an overview of an emerging area studying learning-augmented algorithms that seeks to answer this question in the affirmative. I will survey recent results in the area, focusing on online optimization and MDPs, and then describe applications of these results to the design of sustainable data centers and electric vehicle charging.

Short bio: Adam Wierman is the Carl F Braun Professor in the Department of Computing and Mathematical Sciences at Caltech. He received his Ph.D., M.Sc., and B.Sc. in Computer Science from Carnegie Mellon University. Adam’s research strives to make the networked systems that govern our world sustainable and resilient. He is best known for his work spearheading the design of algorithms for sustainable data centers, which as seen significant industry adoption (e.g. through the startup Verrus), and his work on heavy-tails, including co-authoring a book on “The Fundamentals of Heavy Tails”. He is a recipient of multiple awards, including the ACM Sigmetrics Rising Star award, the ACM Sigmetrics Test of Time award, the IEEE INFOCOM Test of Time award, the IEEE Communications Society William R. Bennett Prize, the Caltech IDEA Advocate award, multiple teaching awards, and is a co-author of papers that have received “best paper” awards at a wide variety of conferences across computer science, power engineering, and operations research.

Ruth Williams (UC San Diego)

Title: Stochastic Analysis of Chemical Reaction Networks with Applications to Epigenetic Cell Memory

Abstract: Epigenetic cell memory, the inheritance of gene expression patterns across subsequent cell divisions, is a critical property of multi-cellular organisms. Simulation studies have shown how stochastic dynamics and time-scale differences between establishment and erasure processes in chromatin modifications can have a critical effect on epigenetic cell memory.

In this talk, we describe a mathematical framework to rigorously validate and extend beyond these computational findings. Viewing our stochastic model of a chromatin modification circuit as a singularly perturbed, finite state, continuous time Markov chain, we extend beyond existing theory in order to characterize the leading coefficients in the series expansions of stationary distributions and mean first passage times. In particular, we characterize the limiting stationary distribution in terms of a reduced Markov chain, provide an algorithm to determine the orders of the poles of mean first passage times, and describe a comparison theorem which can be used to explore how changing erasure rates affects system behavior. These theoretical tools not only allow us to set a rigorous mathematical basis for the computational findings of prior work, highlighting the effect of chromatin modification dynamics on epigenetic cell memory, but they can also be applied to other singularly perturbed Markov chains especially those associated with chemical reaction networks.

Based on joint work with Simone Bruno, Felipe Campos, Yi Fu and Domitilla Del Vecchio.

Short bio: Ruth Williams is a Distinguished Professor of the Graduate Division at the University of California, San Diego. She is a mathematician who works in probability theory, especially on stochastic processes and their applications. Her current research includes the study of stochastic models of complex networks, for example, those arising in Internet congestion control and systems biology. Williams earned her B.Sc. (Hons) and M.Sc degrees from the University of Melbourne, Australia, and her Ph.D. from Stanford University. She has been awarded honorary Doctor of Science degrees by La Trobe University and the University of Melbourne. She is an elected member of the US National Academy of Sciences, an elected fellow of the American Academy of Arts and Sciences, a corresponding member of the Australian Academy of Science, as well as being a fellow of multiple scientific societies. In 2007, Williams received the Best Publication Award of the INFORMS Applied Probability Society, jointly with Amber Puha and H. Christian Gromoll. In 2016, she was awarded the John von Neumann Theory Prize by the Institute for Operations Research and the Management Sciences, jointly with Martin I. Reiman, and was awarded the 2017 Award for the Advancement of Women in Operations Research and the Management Sciences. In 2012, Williams served as President of the Institute of Mathematical Statistics, a major international professional society for the development and dissemination of the theory and applications of probability and statistics.

Jiaming Xu (Duke)

Title: Recent advances on random graph matching problems

Abstract: Random graph matching, the problem of recovering vertex correspondences between two random graphs through their correlated edge connections, is a pivotal challenge with extensive applications. This interdisciplinary problem holds great importance in areas such as network privacy, computational biology, computer vision, and natural language processing, while also raising intricate theoretical questions at the intersection of algorithms, computational complexity, and information theory. Remarkable strides have recently been made in the study of matching correlated Erdős–Rényi graphs. In this talk, the speaker will overview these recent developments, highlight key breakthroughs, and point out important directions for future investigation.

Short bio: Jiaming Xu is an associate professor at the Fuqua School of Business at Duke University. He received a Ph.D. degree from UIUC in 2014, an M.S. degree from UT-Austin in 2011, and a B.E. degree from Tsinghua University in 2009, all in Electrical and Computer Engineering. His research interests include high-dimensional statistics, networks, information theory, convex and non-convex optimization, and queueing theory. He received a Simons-Berkeley Fellowship in 2016 and an NSF Career Award in 2022.