CASSC 2020
Student Abstracts

Volunteer Scheduling Networks: An application to the American Red Cross Disaster Response Program
Mariana Escallon-Barrios

The workforce of the American Red Cross consists of over 90% of volunteers. Their engagement and satisfaction with the program are critical in successful responses of the American Red Cross to their clients. Informed by a long-standing collaboration and comprehensive analysis of 5 years of disaster response volunteer data, we present a hybrid team-based scheduling model to increase the engagement of volunteers and maintain efficient responses at the American Red Cross in Illinois. Our proposed approach consists of assigning time slots to teams while leaving a large number of open slots for remaining volunteers. Finding the appropriate balance between these two is critical for the success of the program. We explore the positive and negative effects of removing selected time slots in the schedule.

We first present a data-driven analysis using social networks to gain a better understanding of current scheduling behavior of the volunteers. Then, we present a max-min scheduling model to balance multiple objectives and a column generation solution approach to design team schedules taking into account incident occurrence rates and volunteer scheduling behavior from past data and volunteer surveys. In the talk, I will discuss the modeling and solution approach challenges, as well as our work in data collection, volunteer survey development and analysis.

An Introduction to Averaging Methods for Nonlinear Magnetic Schrodinger Equations
Evelyn Richman

Quantum systems of charged particles in a magnetic field can be modeled by Nonlinear Schrodinger Equations. Such systems often exhibit oscillatory behavior due to the magnetic field. One might expect to obtain simplified quantum models by averaging out the oscillatory behavior, and one might further expect that the accuracy of the simplified models improves as the magnetic field strength increases. Indeed, this can be shown in many cases. In particular, we will examine models that arise e.g. in the study of fermion pairs in Bose-Einstein condensates and discuss averaging methods for obtaining simplified models. The techniques involved will include tools from functional analysis and PDE theory.

Trilateration-Based Multilevel Method for Minimizing the Lennard-Jones Potential
Jithin George

Simulating atomic evolution for the mechanics and structure of materials presents an ever-growing challenge due to the huge number of degrees of freedom borne from the high-dimensional spaces in which increasingly high-fidelity material models are defined. To efficiently exploit the domain-, data-, and approximation-based hierarchies hidden in many such problems, we propose a trilateration-based multilevel method to initialize the underlying optimization and benchmark its application on the simple yet practical Lennard-Jones potential. We show that by taking advantage of a known hierarchy present in this problem, not only a faster convergence, but also a better local minimum can be achieved comparing to random initial guess.

Fourier Bases for Permutation Puzzles
Horace Pan

Traditionally, permutation puzzles such as the Rubik's Cube were often solved by heuristic search like A∗-search and value based reinforcement learning methods. Both heuristic search and Q-learning approaches to solving these puzzles can be reduced to learning a heuristic/value function to decide what puzzle move to make at each step. We propose learning a value function using the irreducible representations basis (which we will also call the Fourier basis) of the puzzle's underlying group. Classical Fourier analysis on real valued functions tells us we can approximate smooth functions with low frequency basis functions. Similarly, smooth functions on finite groups can be represented by the analogous low frequency Fourier basis functions. We demonstrate the effectiveness of learning a value function in the Fourier basis for solving various permutation puzzles and show that it outperforms standard deep learning methods.

QMCPy: A Quasi-Monte Carlo Community Software in Python 3
Aleksei Sorokin

Quasi-Monte Carlo (QMC) methods are used to approximate multivariate integrals or expectations of random variables with complex distributions. We have created a Python QMC framework, QMCPy (https://qmcsoftware.github.io/QMCSoftware), that has five main components: a discrete distribution, an integrand, its associated measure, stopping criterion, and summary output data. Information about the integrand is obtained as a sequence of values of the function sampled at the data sites generated by the discrete distribution. The function values are averaged with chosen weights as an estimate of the integral. The stopping criterion computes the error bounds of the QMC estimates and tells the algorithm when a user-specified error tolerance has been satisfied, or to increase the number of sampling points in the next iteration. QMCPy allows researchers and collaborators in the QMC community to develop plug-and-play modules in an effort to produce more efficient and portable QMC software and applications. Each of the aforementioned components is an abstract class, which specifies the common properties and methods of all subclasses. The principal ways in which the five kinds of classes interact with each other are also defined. Subclasses then flesh out different integrands, sampling schemes, and stopping criteria. Besides providing developers a way to link their new ideas with those implemented by the rest of the QMC community, we also aim to provide practitioners with state-of-the-art QMC software for their applications. This is joint work with Fred Hickernell, Sou-Cheng Choi, Michael McCourt, and Jagadeeswaran Rathinavel.

When Pull Turns to Shove: A Continuous-Time Model for Political Opinion Dynamics
David Sabin-Miller

We have developed a modeling framework for political opinion dynamics which captures the effect of biased environments on a population. In work published Oct 1 in Physical Review Research, we show how individual tendencies for local attraction and distal repulsion combine with a discriminating environment---where each individual experiences a different 'slice' of political content---to form a population's macroscopic ideology distribution. Our approach is easily scalable to large populations and is amenable to the incorporation of future data as it becomes available. But with simple assumptions, the model is able to match empirical results by reproducing both the U.S. ideological distribution at equilibrium and dynamics under perturbation as observed in a recent experiment.

A Nonstationary Gaussian Process Model for Forecasting Solar Irradiance at Earth's Surface
Jess Kunke

Solar power is on the rise, making solar irradiance forecasting essential for ensuring future power grid stability. To forecast solar irradiance, this work proposes a nonstationary Gaussian process model to capture the advection of atmospheric features that affect irradiance. The forecast performs within the range of recent studies, achieving an average RMSE around 100 W/m^2 and predicting the total observed solar irradiance over the patch of interest with 3% error at the one-hour horizon and 9% error at the four-hour horizon. The forecast also outperforms a common baseline forecast (persistence) a majority of the time with a typical skill of 0.1-0.2. Further model developments are suggested.

Recurrent Inhibition Shapes Noise Correlations and Enhances Discrimination Performance in the Olfactory Bulb
Angelia Wang

Pattern separation characterizes the mechanisms within the olfactory bulb by which neuronal networks extract and highlight differences between similar activity patterns, allowing higher-order brain centers to distinguish between them. Previous work illustrates how spiking patterns driven by specific network connectivity within the olfactory bulb can enhance pattern separation, but the specific mechanisms and roles of recurrently-connected neurons within the bulb are not currently well understood. In this talk, we discuss how inhibition within the bulb serves to decorrelate activity patterns generated from similar stimuli, thereby emphasizing differences in how they are represented within the bulb. We explain the difference in performance through the mechanisms of noise reshaping and increased coherence within neuronal ensembles.

Improving Traffic Congestion with Autonomous Vehicles: An Agent-Based Model
Emma Zajdela

Traffic congestion is a major concern of present societies and has plagued cities around the world for millennia. Historical sources mention cases of traffic congestion within ancient cities like Rome, Pompeii and Xanten. Today, despite the advancements in infrastructure and technology, congestion remains one of the leading concerns of urban societies and is a rising problem in metropolitan areas across the globe. In the United States alone, congestion results in an annual economic loss of $305 billion, not to mention the environmental costs as fuel consumption and vehicle emissions increase when traffic is present. Contrary to popular belief, traffic jams on highways are not necessarily due to outside factors such as accidents or construction, but to the phenomenon of phantom traffic jams. A tool for congestion mitigation, which is still in its infancy, is the use of autonomous vehicles. Autonomous vehicles have been shown theoretically and experimentally to have the ability to dissipate traffic waves under restricted conditions. In this talk, I will demonstrate using agent-based simulations in NetLogo how autonomous vehicles can help dissipate traffic jams not only in one-lane, but multi-lane highway environments.