LIDS Research Groups

2021-2022
Saurabh Amin

- **Issues:** Network Resilience, Transportation, Disaster Response, Environmental Sustainability
- **Tools:** Stochastic Control, Game Theory, Theory of Incentives, Optimization in Networks
- **Solutions:** Information Systems, Monitoring and Control Strategies, Incentive Mechanisms

**Traffic routing, incentives, and information provision during disruptions**

**Optimal allocation of flexible resources to improve resilience to disruptions**

**Modeling and operations of mixed-autonomy transportation systems**

**Using flexibility of electricity grid to improve resilience to faults/attacks**

**Strategic network interdiction to prevent routing of illegal or bad traffic**

**Crew scheduling under diagnostic uncertainty after a natural disaster**
Guy Bresler & Yury Polyanskiy

Average-Case Comp. Complexity

Information Theory & Statistical Inference

Probability

Digital Communication

LIDS RESEARCH GROUPS
2021-2022

Average-Case

Comp. Complexity

Digital Communication

Information Theory & Statistical Inference

Probability
• My group asks not just what we know, but also: how well do we know it?
• We study uncertainty and robustness -- and design fast, easy-to-use, and provably accurate decision-making tools.

Some examples:
• How many new variants can scientists to expect to find when sequencing new genomes? We provide a state-of-the-art estimate, calibrated uncertainties, and an optimal tradeoff (under a fixed budget) of quantity (# individuals) and quality (sequencing depth).
• Consider an existing famous microcredit data analysis with >16,500 data points. Our work shows that if you drop one data point, the sign of the result changes, and if you drop 15 data points, you can get a significant result of the opposite sign. In general, we provide a tool (and supporting theory) to very quickly discover: if you drop a very small fraction of your data, how much can your substantive conclusions change?
• We develop a method to enable individuals with severe motor impairments (cerebral palsy, locked-in syndrome) to type, draw, game, and generally use computers. We adapt to individual users and limited motor control using statistical inference.

We collaborate with: economists, biologists, materials scientists, HCI specialists, and more. Our methodology and theory draw on measure-theoretic probability, stochastic process theory, real analysis, optimization, statistical mechanics, and a lot of other fun math.
Luca Carlone
Sensing Perception Autonomy and Robot Kinetics

**Goal:** to develop theoretical understanding and practical algorithms to bridge the gap between human and computational (robot) perception

**Technical tools:**
- (non-convex, distributed) optimization
- nonlinear estimation & probabilistic inference
- geometry, graph theory
- control theory, machine learning

Certifiable Robustness

Real-time High-level Understanding

Robot Co-Design
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<th><strong>ENERGY</strong></th>
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<td>Markets for Energy Storage</td>
<td>Financial networks are sensitive to shocks. Interbank lending networks are crucial to allocating liquidity. Default cascades can be detrimental to national economies.</td>
<td>Community members know which of their neighbors are likely to repay a loan. We can elicit this information using clever incentives and algorithms.</td>
<td>Attempts to control the spread of the COVID-19 epidemic focus on social distancing, but testing and contact tracing should also be considered.</td>
<td>Data, an increasingly vital asset, needs to be valued in a systematic way.</td>
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<td>The power sector is in the cusp of a revolution due to increasing renewable energy penetration and transportation electrification, necessitating a complete rethinking of electricity market design.</td>
<td>The future grid will consist of millions of EVs that can double as energy storage resources. How to design efficient and incentive compatible mechanisms for EVs to sell battery service to the ISO?</td>
<td>Without carefully-designed incentive structures, integrating EVs for energy storage is counterproductive to energy-efficiency of the grid. Mechanisms to solve this issue have been devised.</td>
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<td>How many independent shocks can hit the network? How does interbank lending network function in times of market stress?</td>
<td>How do we develop incentives which are maximized with truthful reporting? How to create robustness to collusion? How to improve with online learning?</td>
<td>The effect of the network structure on the default rate and systemic loss. A method for real-time, automatic, interpretable risk assessment.</td>
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<td>How do we learn near-optimal customized policies for a large number of farms while achieving provably good performance?</td>
<td>How do we model testing/contact tracing/network structure? What are the qualitative relationships between testing and disease spread? What are the impacts of various interventions on different communities? Are there any trade-offs? Which interventions are effective?</td>
<td>We designed truncated decision scoring rules which incentivize truthfulness in most cases. We will learn more from a pending deployment in Uganda.</td>
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<td>Dynamics are independent of network structure and simple relationships/formulas determine how testing and disease spread interact. There is a trade-off between saving lives from the pandemic and from recession. The disadvantaged community tends to suffer significantly more than others.</td>
<td>Mathematical model and real time algorithms for a two-sided data market. Welfare and revenue-maximizing mechanisms for selling data to data buyers with negative externalities.</td>
<td>Given a set of policies, we can learn in finite time and perform almost as well as the best policy considered.</td>
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**Data markets** must consider interactions between and among data buyers, sellers, and intermediaries.
Aerospace Controls Laboratory
Jon How

Tools:
- Control Theory
- Optimization Theory
- Algorithms
- Graph Theory
- Machine Learning

Venues:
- AI/ML: NIPS, ICML, ...
- Control: CDC, ACC, ...
- Robotics: RSS, ICRA, ...

Projects:
- Cooperative Multiagent Reinforcement Learning
- Lifelong Learning for Distributed Intelligence
- Pedestrian Motion Prediction
- Decentralized Dynamic Task Allocation
- Multiagent Search & Rescue in Forests
- Resource-aware Spatial Perception
- Active Perception for Threat Identification

http://acl.mit.edu
Energy and Power Systems
Marija Ilic & Audun Botterud

Research Goals
- Formulate, model and simulate electric energy systems as complex dynamical systems
- Design cyber systems for enabling their performance (SCADA, markets, control, optimization)
- Develop novel analytics for future low-carbon electricity markets with high shares of renewable energy

Systems Tools
- Modeling of complex systems
- Network systems
- Optimization and control methods
- Mathematical programming
- Numerical and simulation methods
- Distributed interactive systems

Current research areas
- Microgrids (terrestrial, future aircrafts)
- Cyber-secure energy systems
- Social-ecological energy systems
- Scalable power system simulators
- Energy decision analytics
- Electricity markets
- Grid integration of renewable energy
- Energy storage and distributed energy
LIDS RESEARCH GROUPS 2021-2022

Ali Jadbabaie

Optimization for ML, Network Science, Cooperative Control and Robotics, Sensor & Actuator Selection, Distributed Estimation

Collective Action/Coordination, Social Learning, Group Decision Theory, Networks Economics, Computational Social Science

Complex Networks

Collective Behavior
Engineering Systems
Online Learning and Optimization Group
Patrick Jaillet

research: online optimization and learning problems; applied probability

focus: theory, models, algorithms

applications, contexts:
- routing, mobility, spatial explorations
- internet, dynamic resource allocations
- cyberinfrastructure security
- sharing economy
- networks
How fast can birds fly through forests? How quickly can robots navigate in cluttered environments? We analyze the performance limits for robotic vehicles operating in cluttered environments.

As driverless cars edge closer to becoming a reality, we ask the question: Can autonomous cars substantially improve performance in traffic intersections? How about all-autonomous transportation networks?

A new approach to teaching feedback control systems allows the students to instantly test their control design on a palm-size drone in the comfort of their room. Each student enrolled in 16.30 will get a Parrot mini drone.
We develop architectures and algorithms for communication networks, including:

- Wireless networks
- Machine learning in networks
- Autonomous network control
- Communication for UAVs
- Optimizing information freshness (age-of-information)
- Robustness in Power grids
- Data-center networks
**Research Focus:** Developing new models, mathematical tools, and algorithms for the analysis and optimization of technological, social, economic, financial networks and for processing large-scale data.

**Key Tools:**

- Economic Theory
- Game Theory
- Optimization Theory & Algorithms
- Network Theory

**Current Projects:**

- Bayesian Learning from Reviews
- Optimization for Machine Learning
- Systemic Risk in Financial Networks
- Network Aggregative Games
- Information and Learning in Traffic Networks
**Statistical Learning:** We study the problem of building a good predictor based on an i.i.d. sample. While much is understood in this classical setting, our current focus is large overparametrized models, such as those employed in deep learning. In particular, we study various measures of complexity of neural networks that govern their out-of-sample performance. Our recent focus is on statistical and computational aspects of interpolation methods, as well as understanding the phenomenon of benign overfitting in overparametrized models.

**Contextual Bandits and Reinforcement Learning:** In these problems, data are collected in an active manner and feedback is limited. Our work focuses on understanding the sample complexity and on developing computationally efficient methods. Among the highlights is a recent reduction from these decision-making problems to Supervised Learning.

**Online Learning:** We aim to develop robust prediction methods that do not rely on the i.i.d. or stationary nature of data. In contrast to the well-studied setting of Statistical Learning, methods that predict in an online fashion are arguably more complex and nontrivial. This field has some beautiful connections to Statistical Learning and the theory of empirical processes.
Devavrat Shah

Social Data Processing

Network Algorithms

Probabilistic Graphical Models
We work on theory, analysis, and development of mathematical models for optimization, sampling, and machine learning with a particular focus on non-convexity and geometry.

Main conferences: COLT, NeuRIPS, ICML, ICLR

http://optml.mit.edu
http://ml.mit.edu
Our research is about understanding genome packing and regulation in health and disease by developing the next generation of machine learning and statistics methods that bridge the gap from predictive to causal modeling.
Data to AI Group
Kalyan Veeramachaneni

Systems for Machine Learning
Automatic feature engineering, machine learning task generation, modeling and creating interactive developers tools.

AI for cyber security
Spanning the gamut of malware detections exfiltration, explainable and adverserial AI.

AI for software engineering
How can we transform software engineering using machine learning?

Applications
Ranging from monitoring health of satellites, water pipes to healthcare and education.

Our open source tools
Use our software to build your own AI applications.
Research Vision: Our research combines

- theoretical analysis for determination of fundamental performance limits;
- the design of practical algorithms that approach such ultimate limits; and
- experimentation, both for validation and for developing realistic models.

Network (theory)

- Interference Coexistence
- Time-aware networks
- Location-aware networks
- Intrinsic Secrecy
- Quantum Networks

Network (experimentation)

Physical layer (theory)

- UWB Diversity Adaptive Techniques
- Synchronization Acquisition
- Ranging
- Measurement Modeling

Physical layer (experimentation)
LEARNING, AUTONOMY, & URBAN SYSTEMS

Ideal impact of autonomous vehicles:
- Traffic accidents: ~94% of serious crashes
- Congestion: ~6.9 billion hours annually
- Access to mobility: +30% of population
- Energy: 31% from transportation

Actual uncertainty (with 100% adoption):
-40% to +100% energy consumption

How can we better understand and shape the impact of technology on society?

Need principled methods, informed by theory
Goal: reliable decision making (control, policy)
We are building technology faster and faster
Big, messy, complicated, structured

Reinforcement learning, machine learning, optimization, control
Vehicles, transportation systems, urban planning & policy
Autonomy
Urban systems