LIDS

LABORATORY FOR INFORMATION & DECISION SYSTEMS

LIDS Research Groups

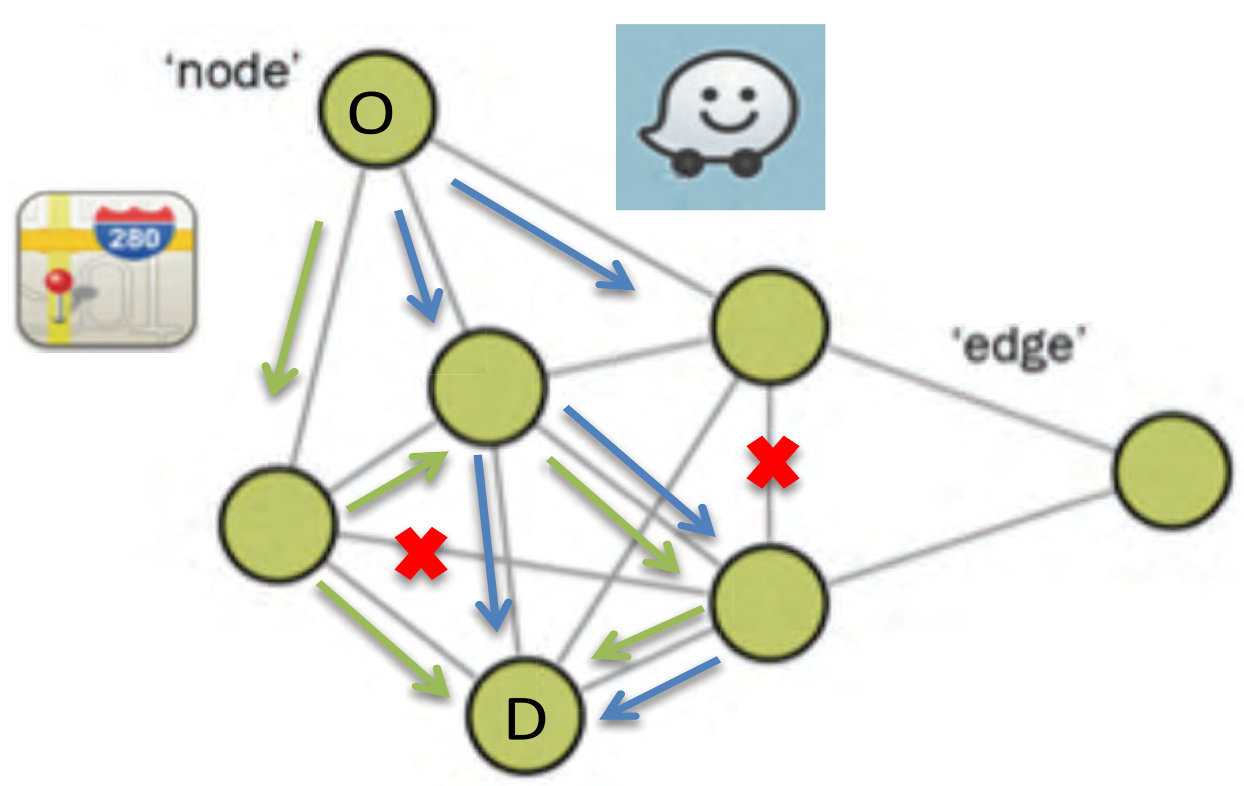
2021-2022

LIDS RESEARCH GROUPS 2021-2022

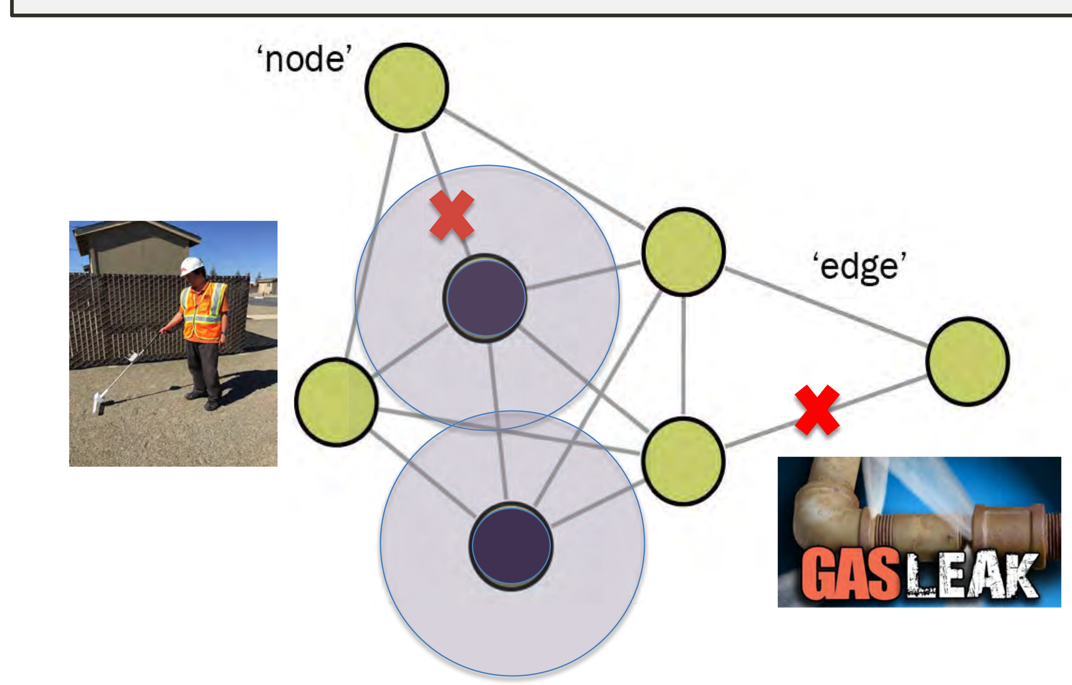
Saurabh Amin

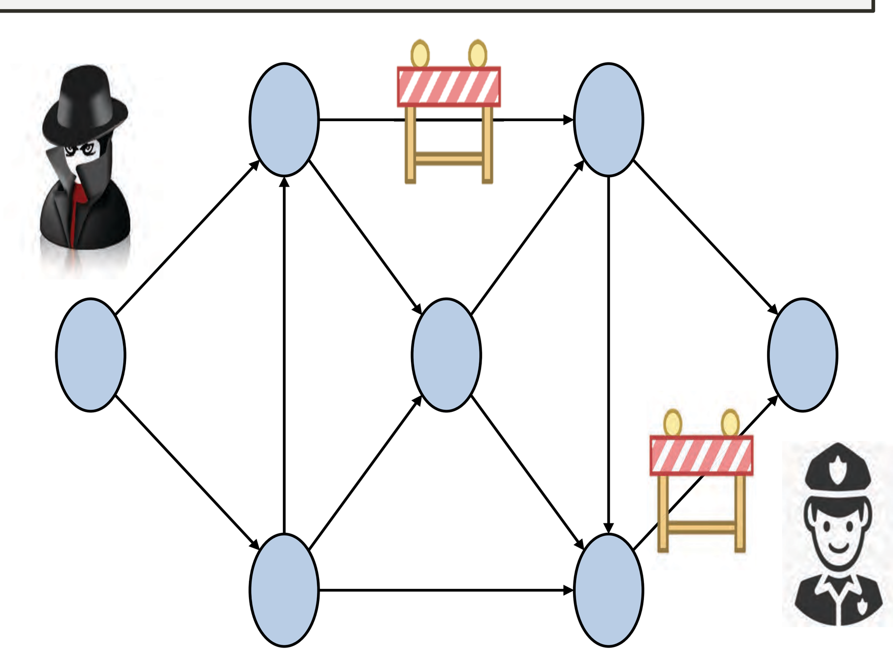
- **Issues:** Network Resilience, Transportation, Disaster Response, Environmental Sustainability
- **Tools:** Stochastic Control, Game Theory, Theory of Incentives, Optimization in Networks
- **Solutions:** Information Systems, Monitoring and Control Strategies, Incentive Mechanisms

Traffic routing, incentives, and information provision during disruptions



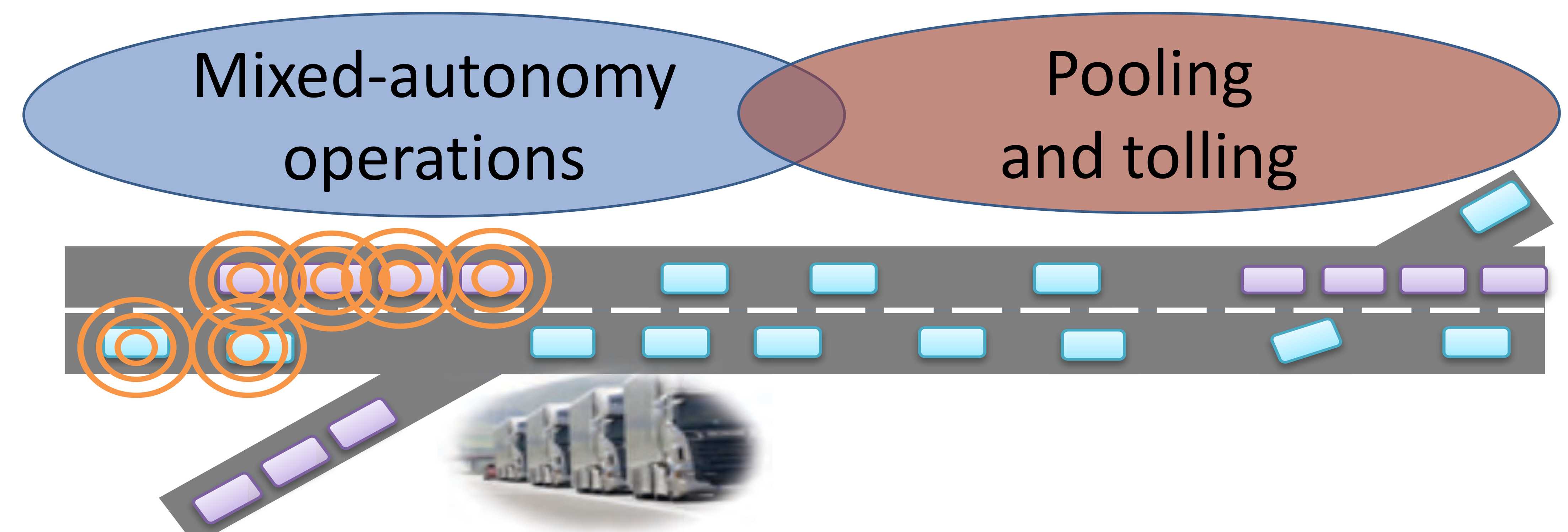
Optimal allocation of flexible resources to improve resilience to disruptions



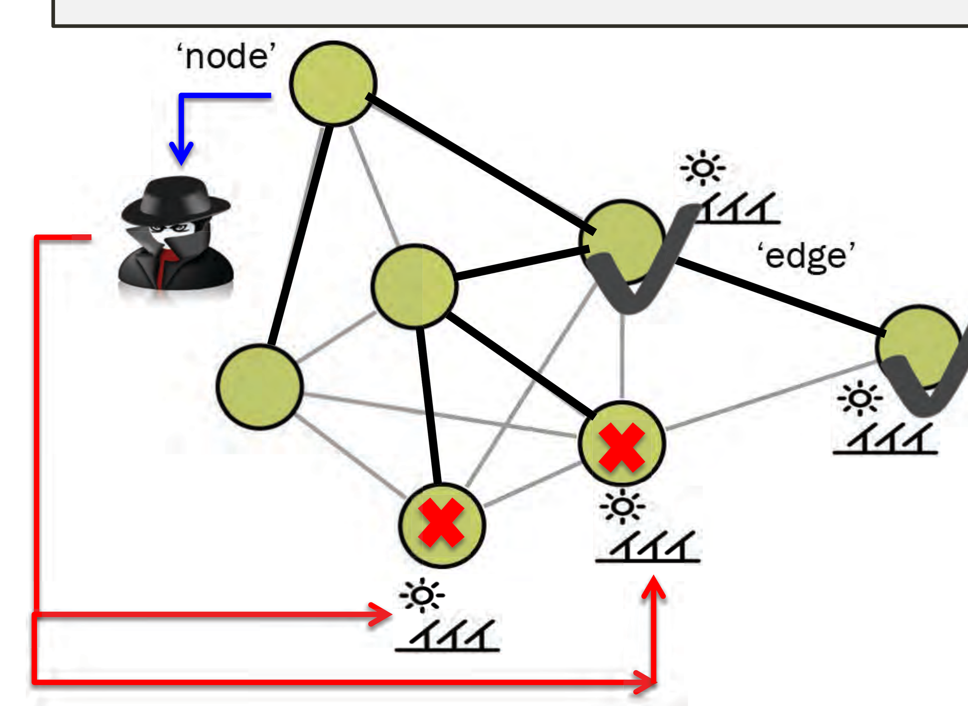


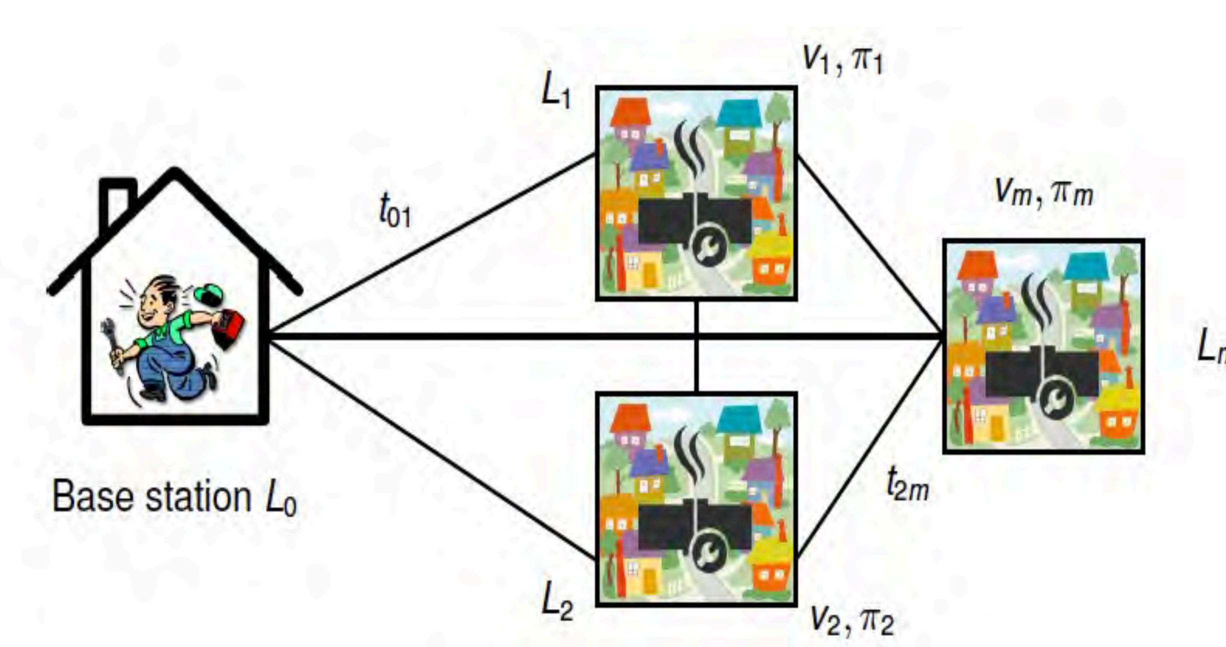
Strategic network interdiction to prevent routing of illegal or bad traffic

Modeling and operations of mixed-autonomy transportation systems



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





Crew scheduling under diagnostic uncertainty after a natural disaster

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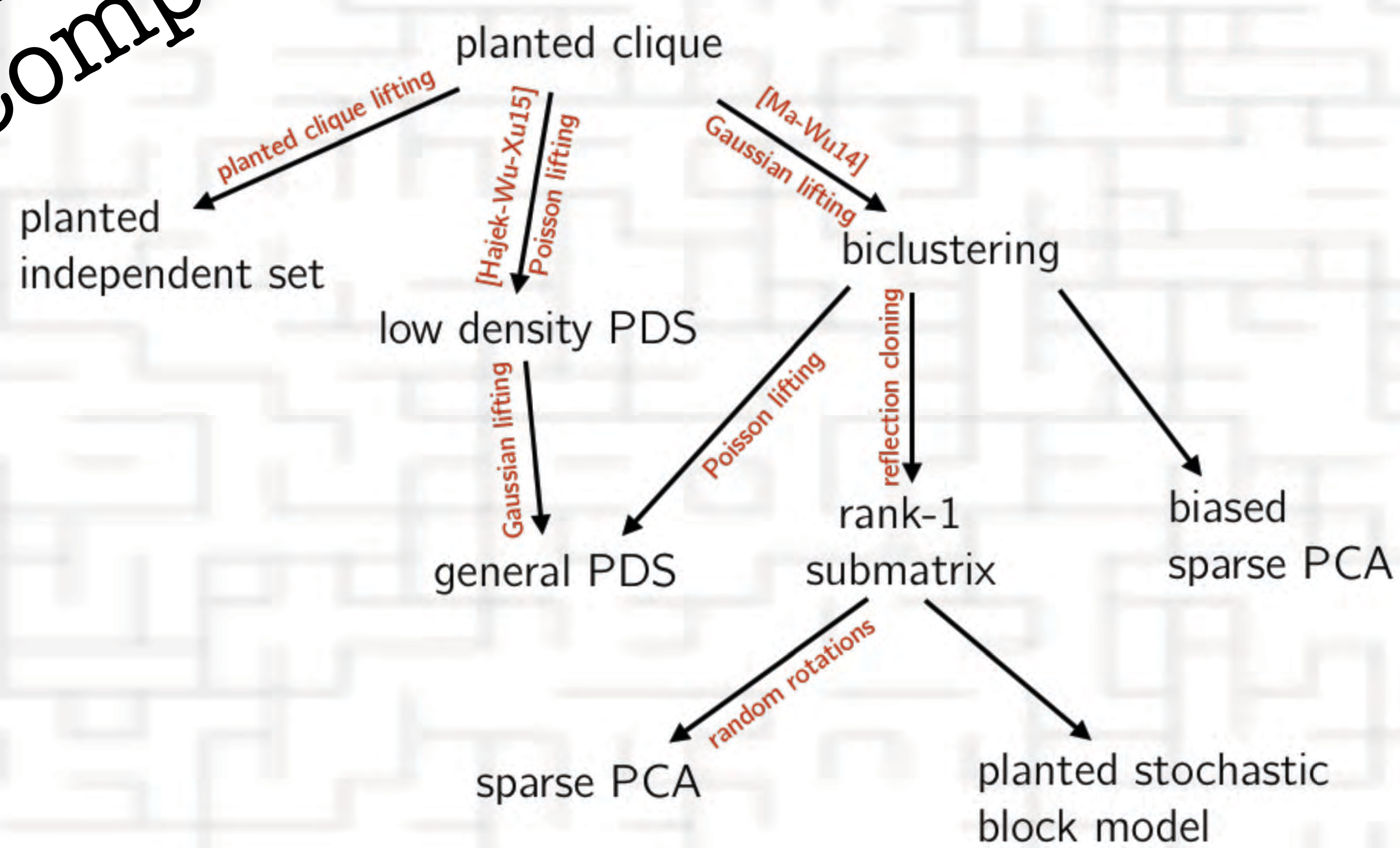
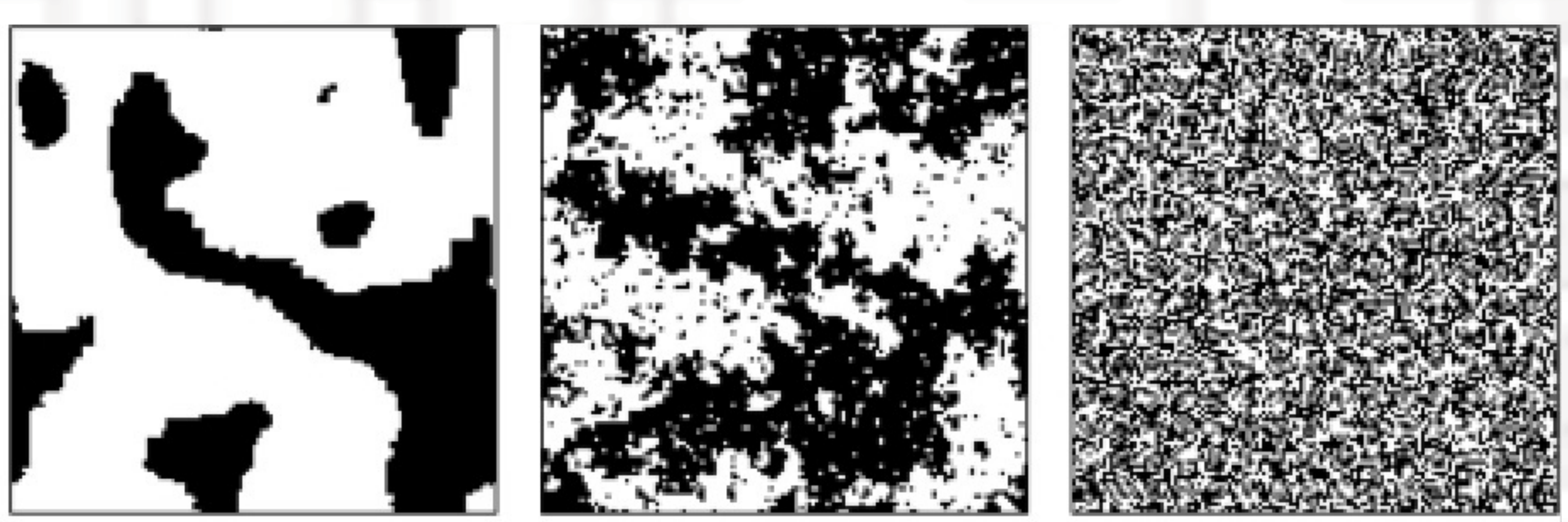
Guy Bresler & Yury Polyanskiy

Average-Case Comp. Complexity

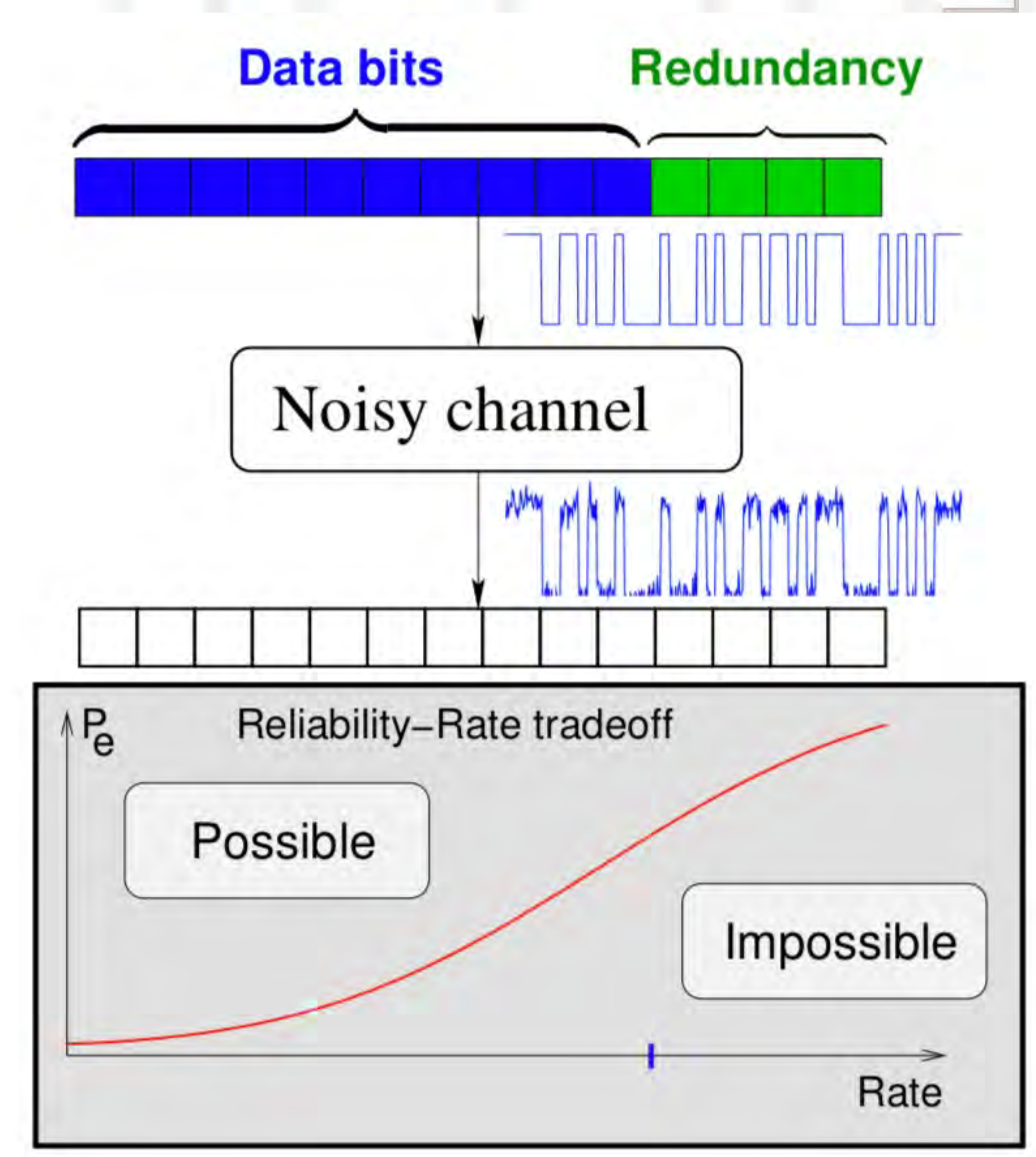


Information Theory & Statistical Inference

Probability



Digital Communication



Tamara Broderick

tamarabroderick.com

- **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.

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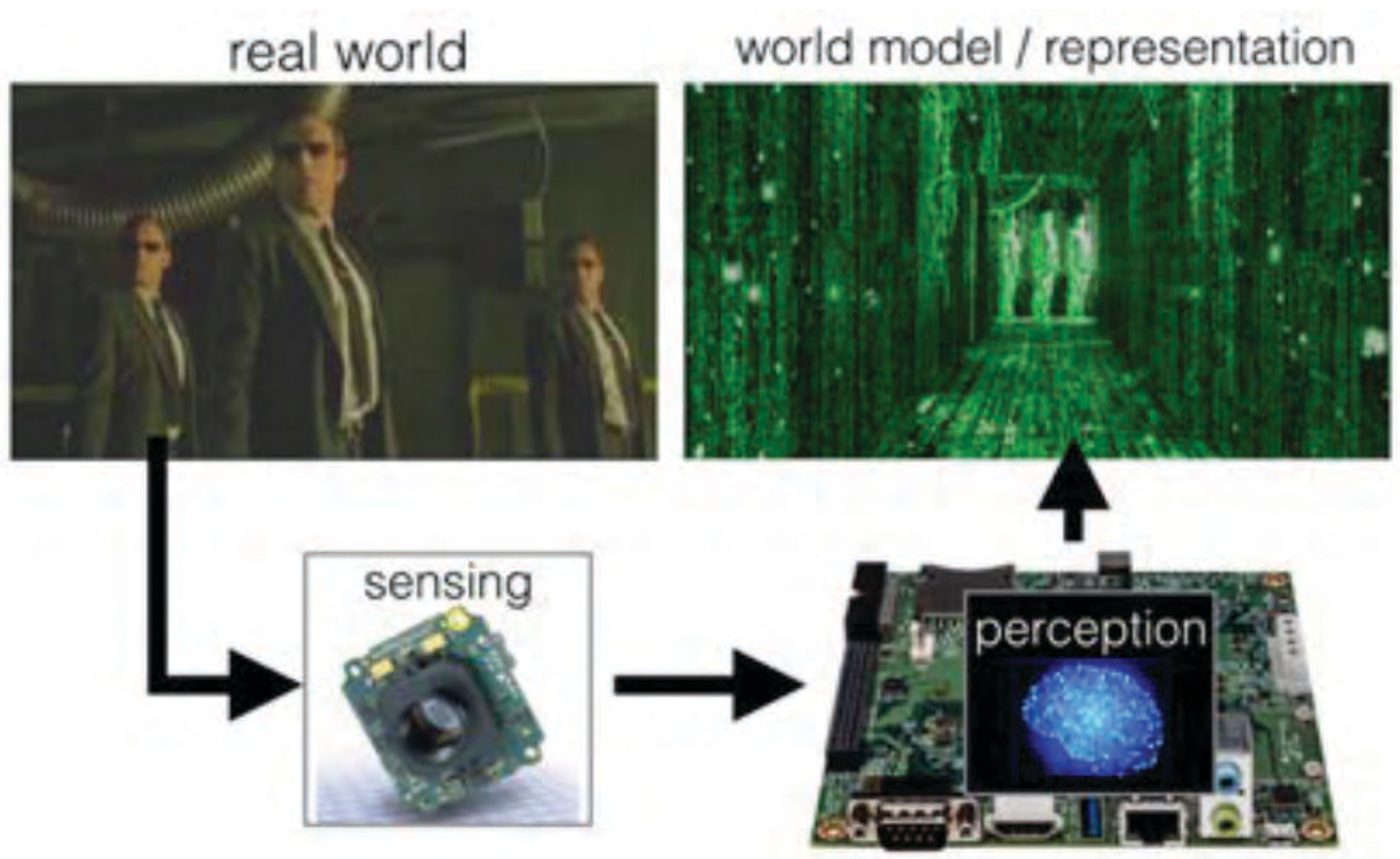
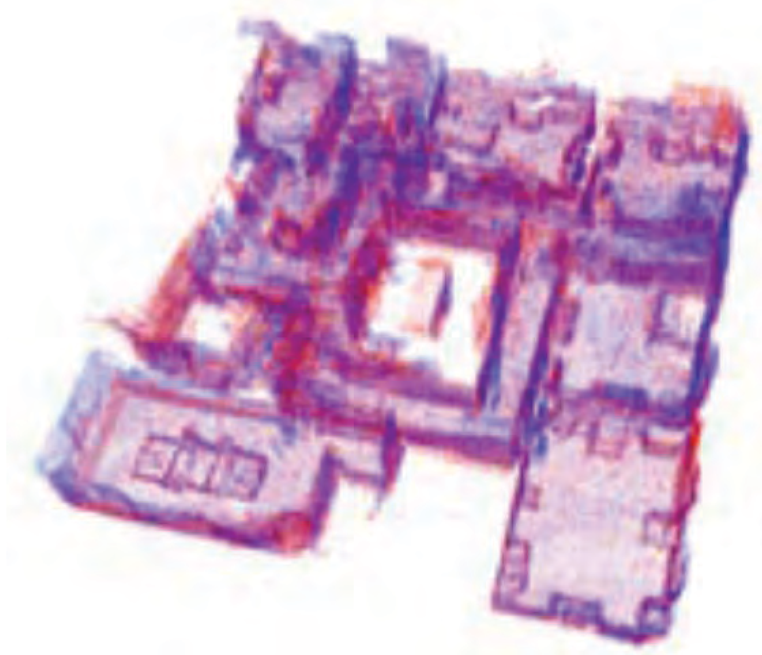
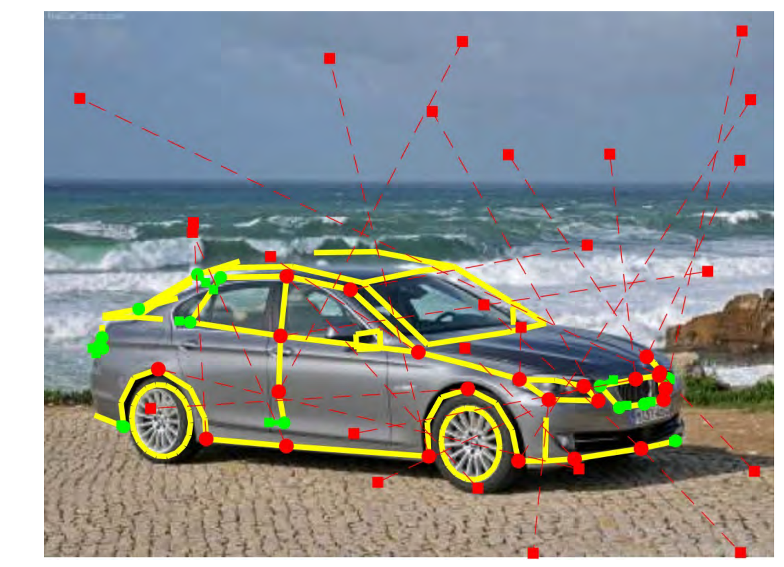
Luca Carlone

Sensing Perception Autonomy and Robot Kinetics

SPARK Lab





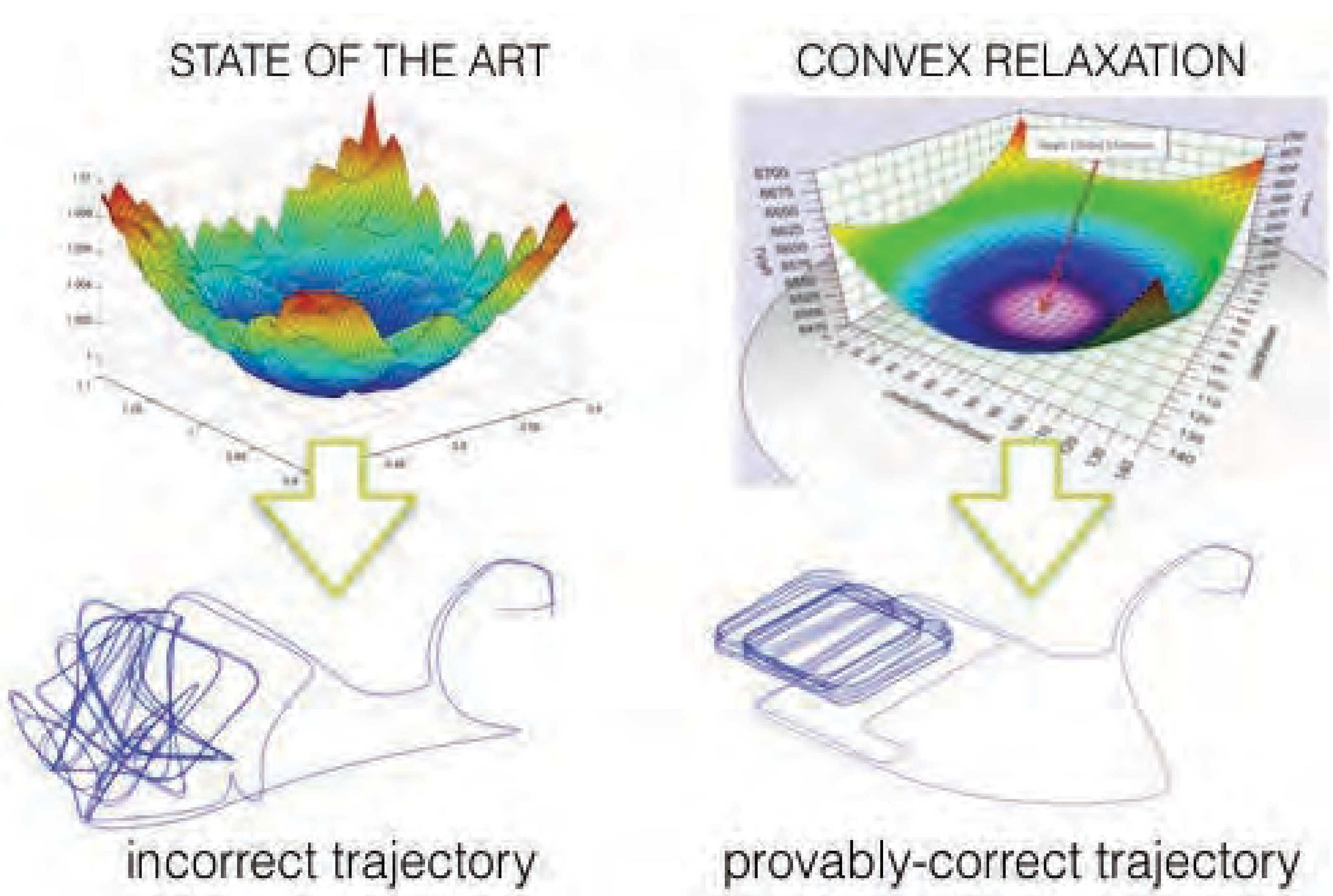


Goal: to develop theoretical understanding and practical algorithms to bridge the gap between human and computational (robot) perception

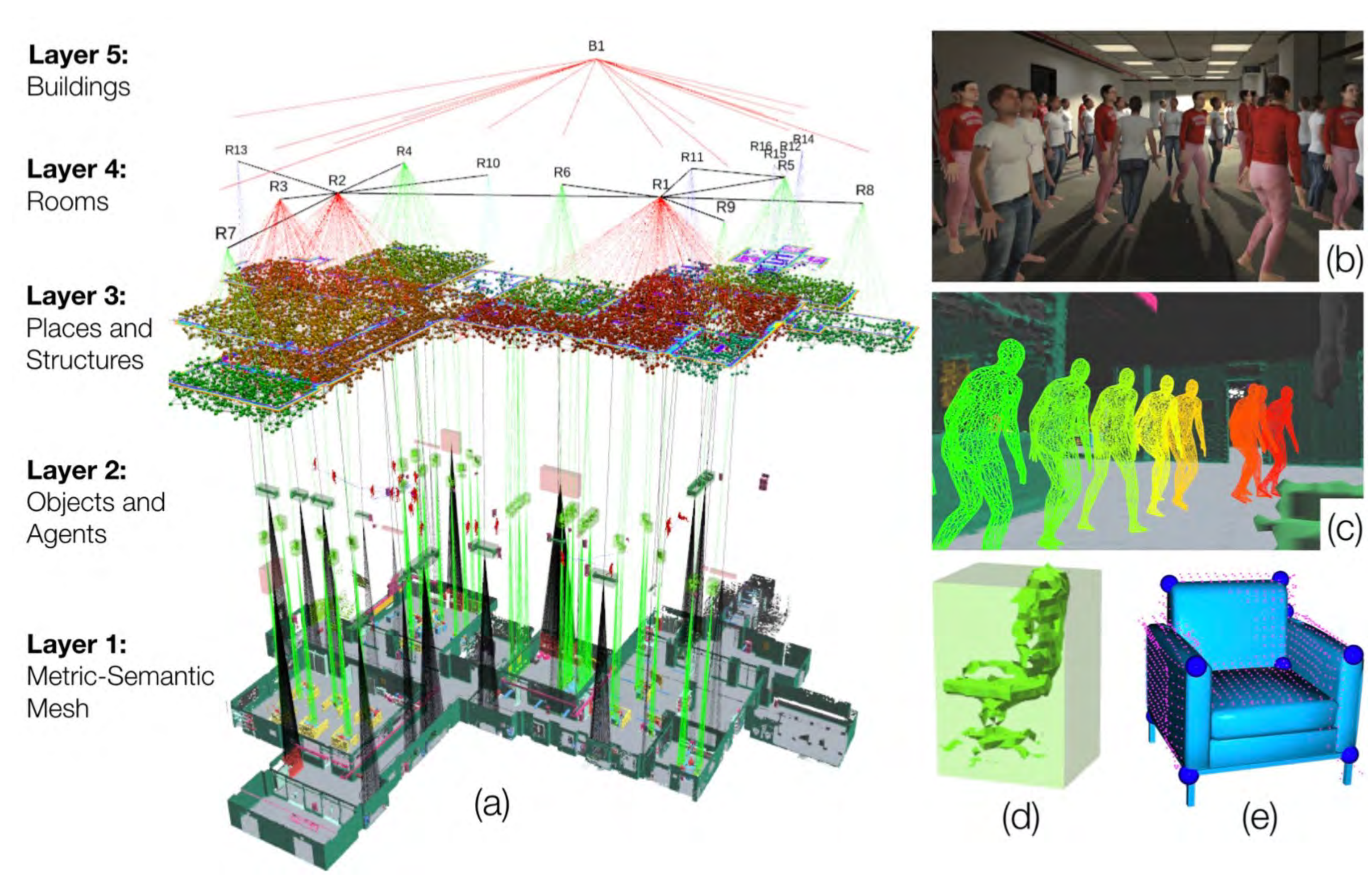
Technical tools:

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

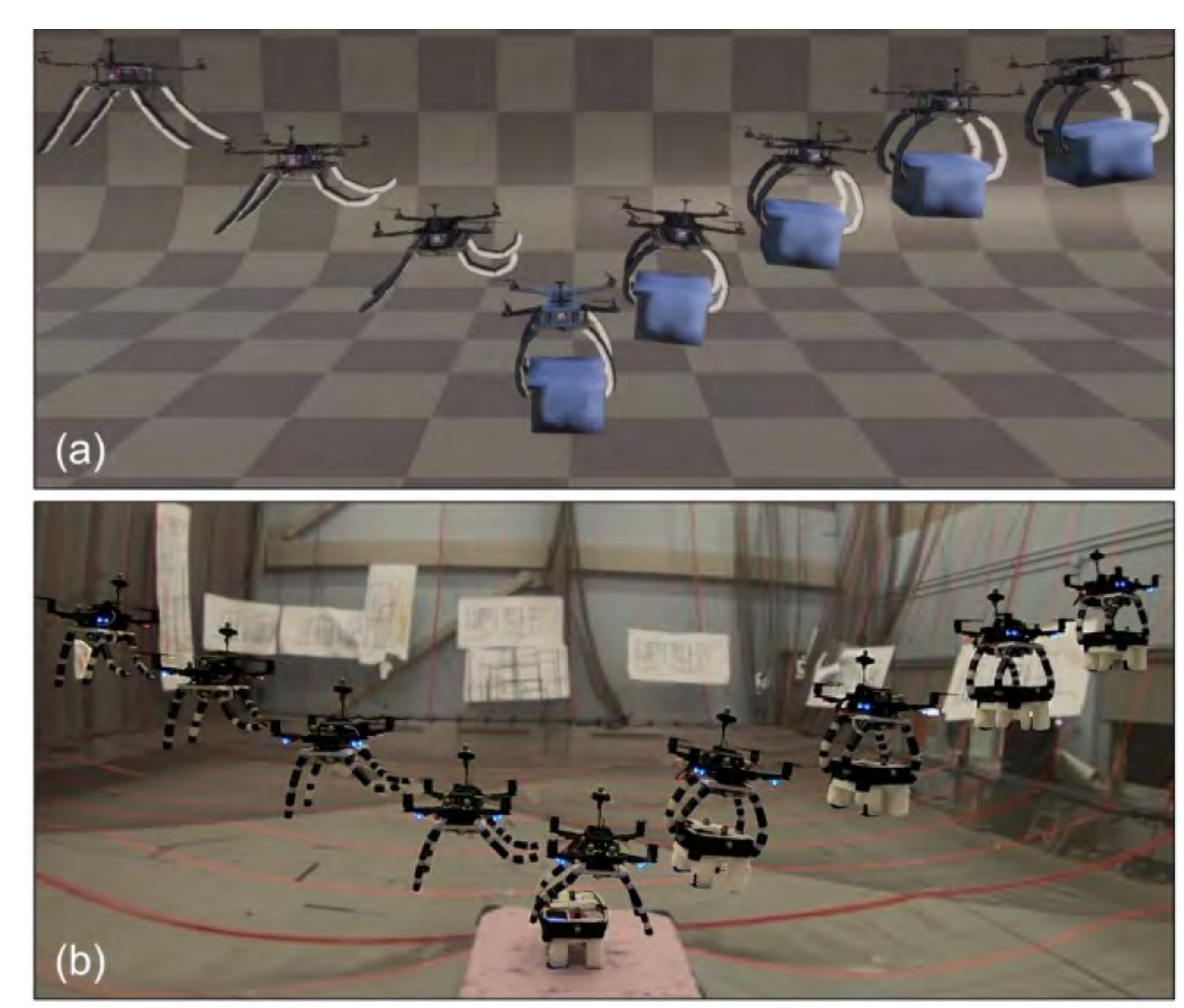
Certifiable Robustness



Real-time High-level Understanding



Robot Co-Design



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Munther Dahleh

	MOTIVATIONS	RESEARCH QUESTIONS	FINDINGS
ENERGY Markets for Energy Storage	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.	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?	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.
FINANCE Systemic Risk in Financial Networks	**Financial networks** are sensitive to **shocks**. Interbank lending networks are crucial to **allocating liquidity. Default cascades** can be detrimental to national economies.	How many **independent shocks** can hit the network? How does **interbank lending network** function in times of market stress?	The effect of the network structure on the default rate and systemic loss. A method for real-time, automatic, interpretable risk assessment.
DIGITAL FARMING Information Elicitation and ML to find creditworthy borrowers	Community members know which of their neighbors are likely to repay a loan. We can elicit this information using clever incentives and algorithms.	How to develop incentives which are maximized with truthful reporting? How to create robustness to collusion? How to improve with online learning?	We designed truncated decision scoring rules which incentivize truthfulness in most cases. We will learn more from a pending deployment in Uganda.
Reinforcement Learning for Customized Farming	Large-scale data-driven farming is hard as each farm is **a time-variant system**, and **observations are sparse** with respect to interventions and farms.	How do we learn **near-optimal customized policies** for a large number of farms while achieving **provably good performance**?	Given a set of policies, we can learn in finite time and perform almost as well as the best policy considered.
COVID-19 Testing As Control	Attempts to control the spread of the COVID-19 epidemic focus on social distancing, but **testing and contact tracing** should also be considered.	How do we **model testing**/contact tracing/network structure? What are the **qualitative relationships** between testing and disease spread?	Dynamics are **independent of network structure** and simple relationships/formulas determine how testing and disease spread interact.
Impacts of Interventions	Interventions for COVID-19 affect people differently due to **variations in age, health conditions, socioeconomic status**, and many other factors.	What are the **impacts** of various interventions on different **communities**? Are there any **trade-offs**? Which interventions are **effective**?	There is a trade-off between saving lives from the pandemic and from recession. The disadvantaged community tends to suffer significantly more than others.
NETWORKS A Marketplace for Data	Data, an increasingly vital asset, needs to be valued in a systematic way. **Data markets** must consider interactions between and among data buyers, sellers, and intermediaries.	**Robust real-time matching** mechanism to buy and sell training data for Machine Learning tasks? How to allocate and price data sets to buyers in **competition** with each other?	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.

Aerospace Controls Laboratory
Jon How

Multiagent | **Planning** | **Learning** | **Perception**

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

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Energy and Power Systems
Marija Ilic & Audun Botterud

Electrical Energy Systems Group at MIT

Energy Analytics Group

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
- Optimization and control methods
- Numerical and simulation methods
- Network systems
- Mathematical programming
- 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

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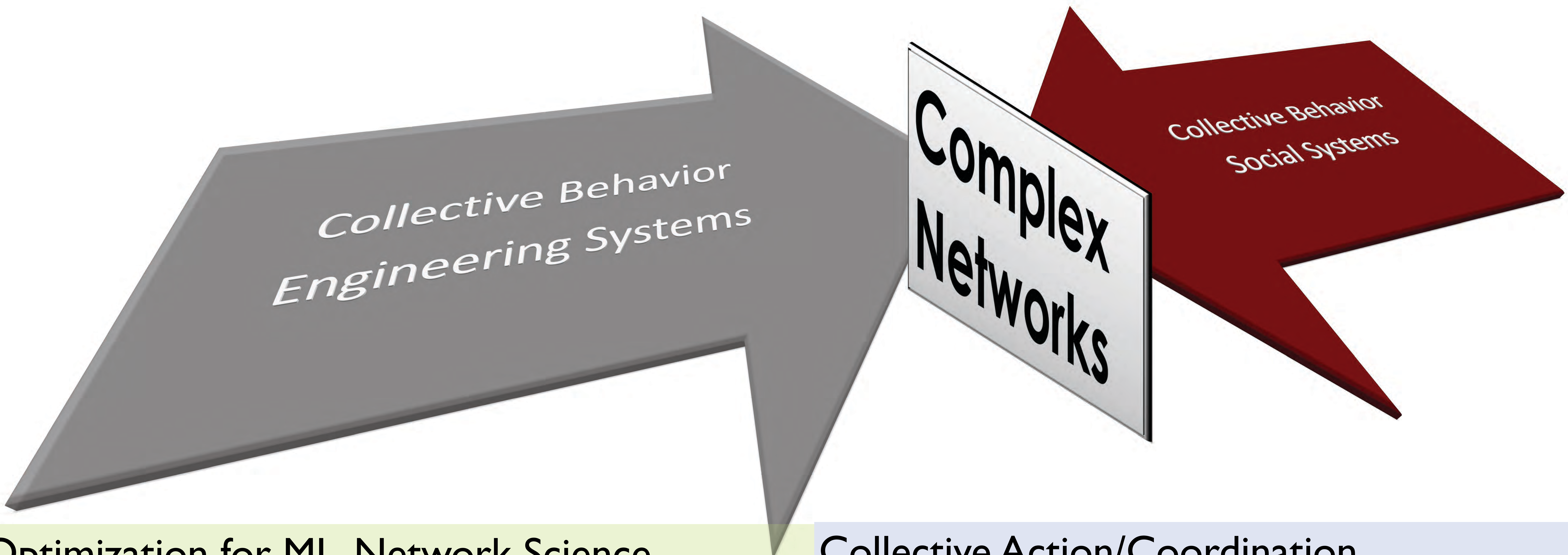
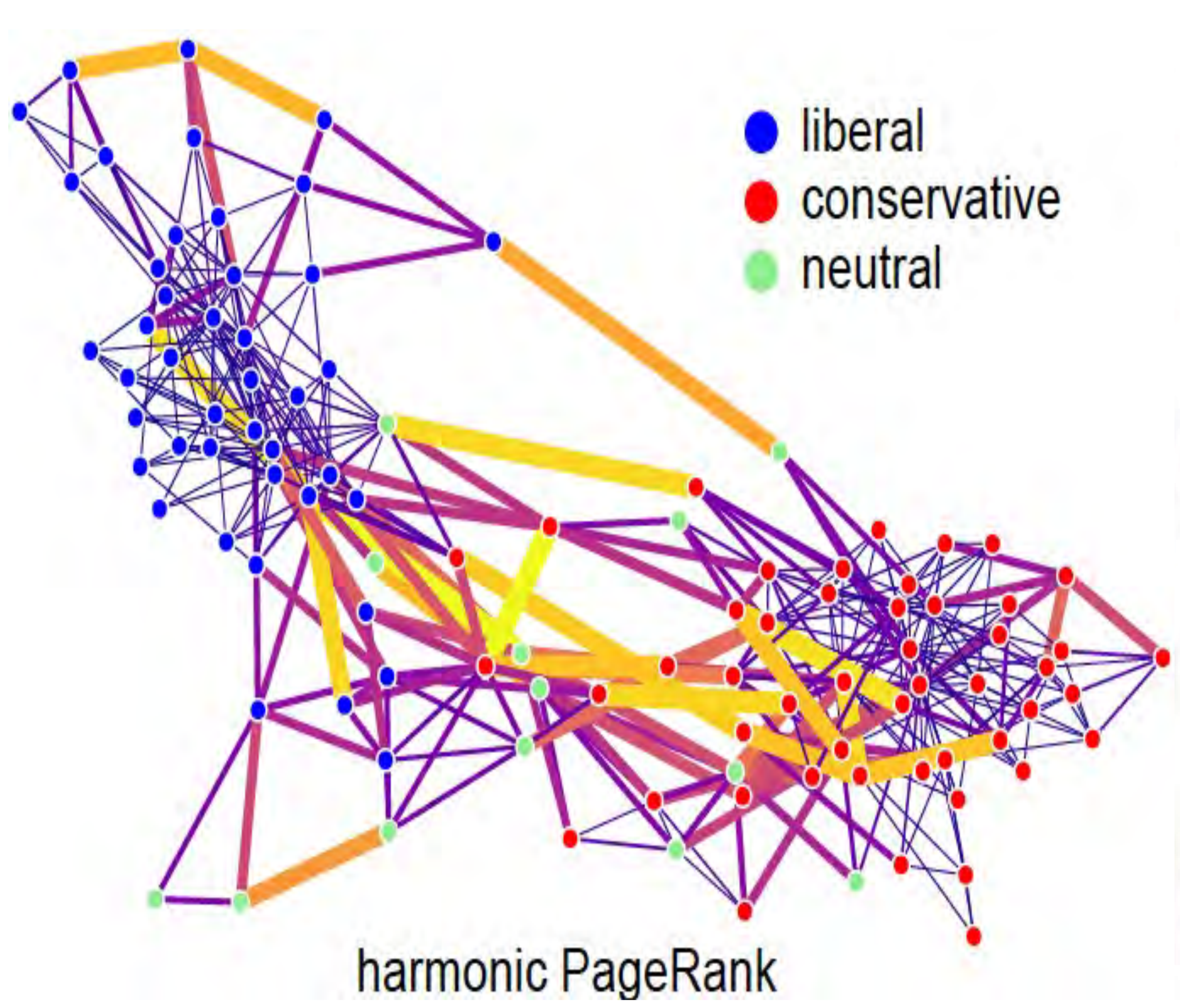
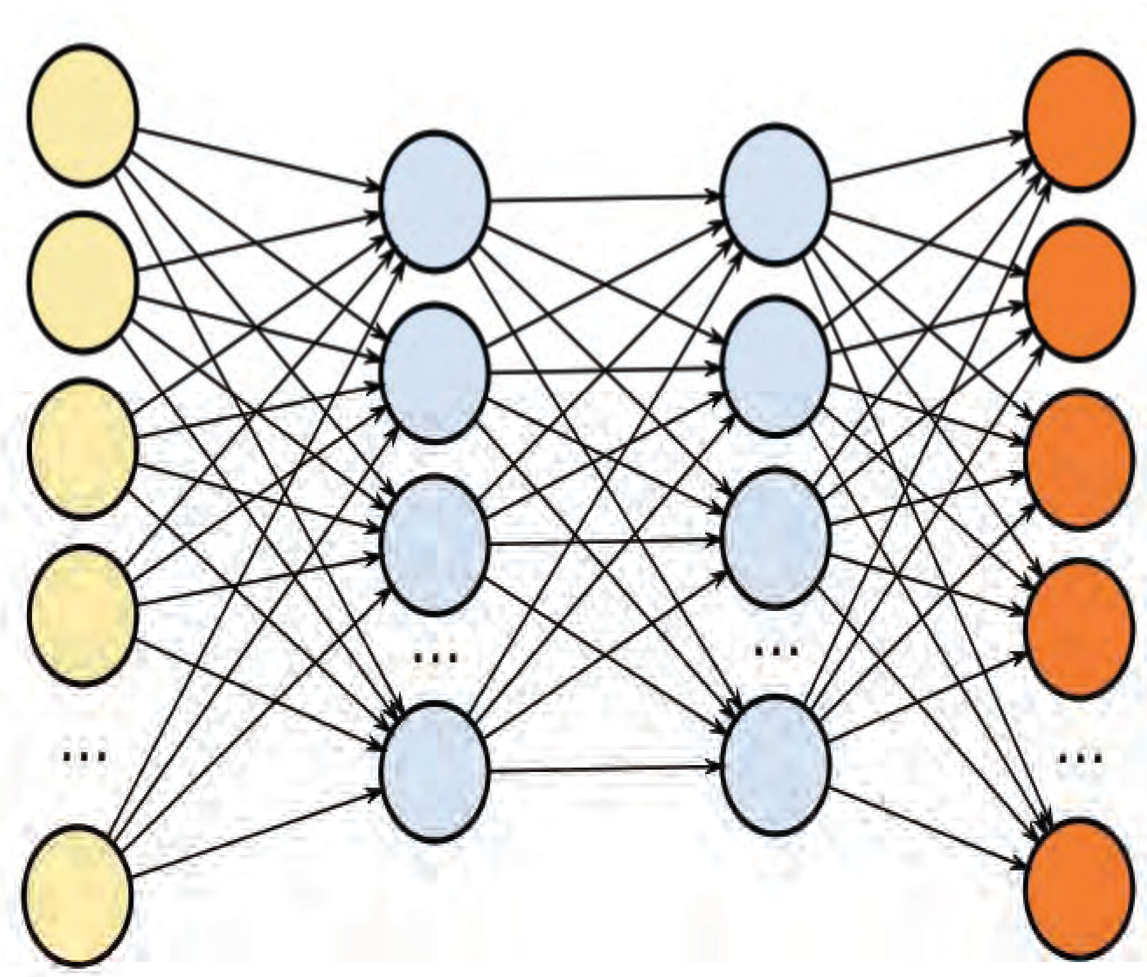
Ali Jadbabaie



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





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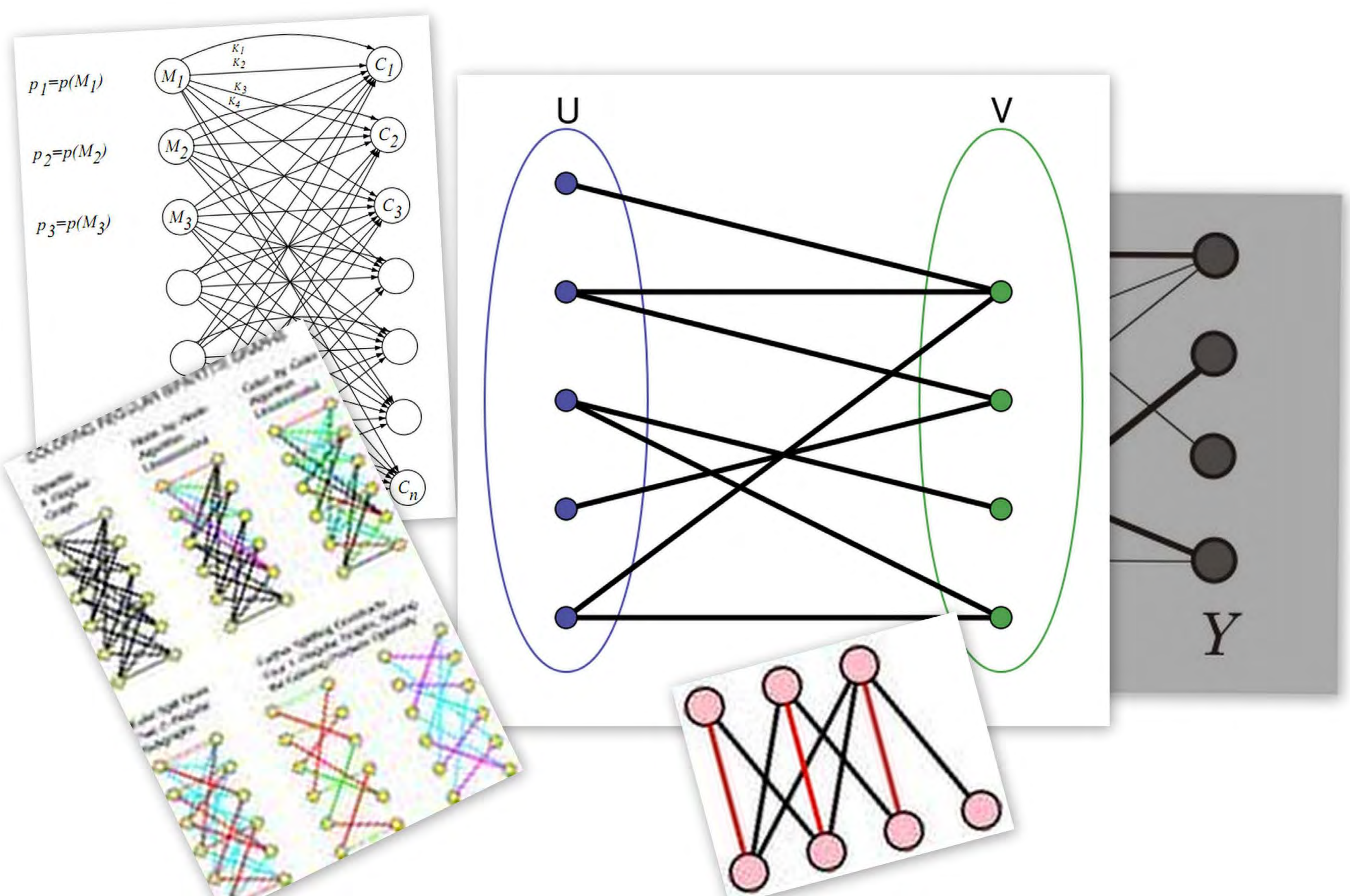
Online Learning and Optimization Group
Patrick Jaillet



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

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Sertac Karaman

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.

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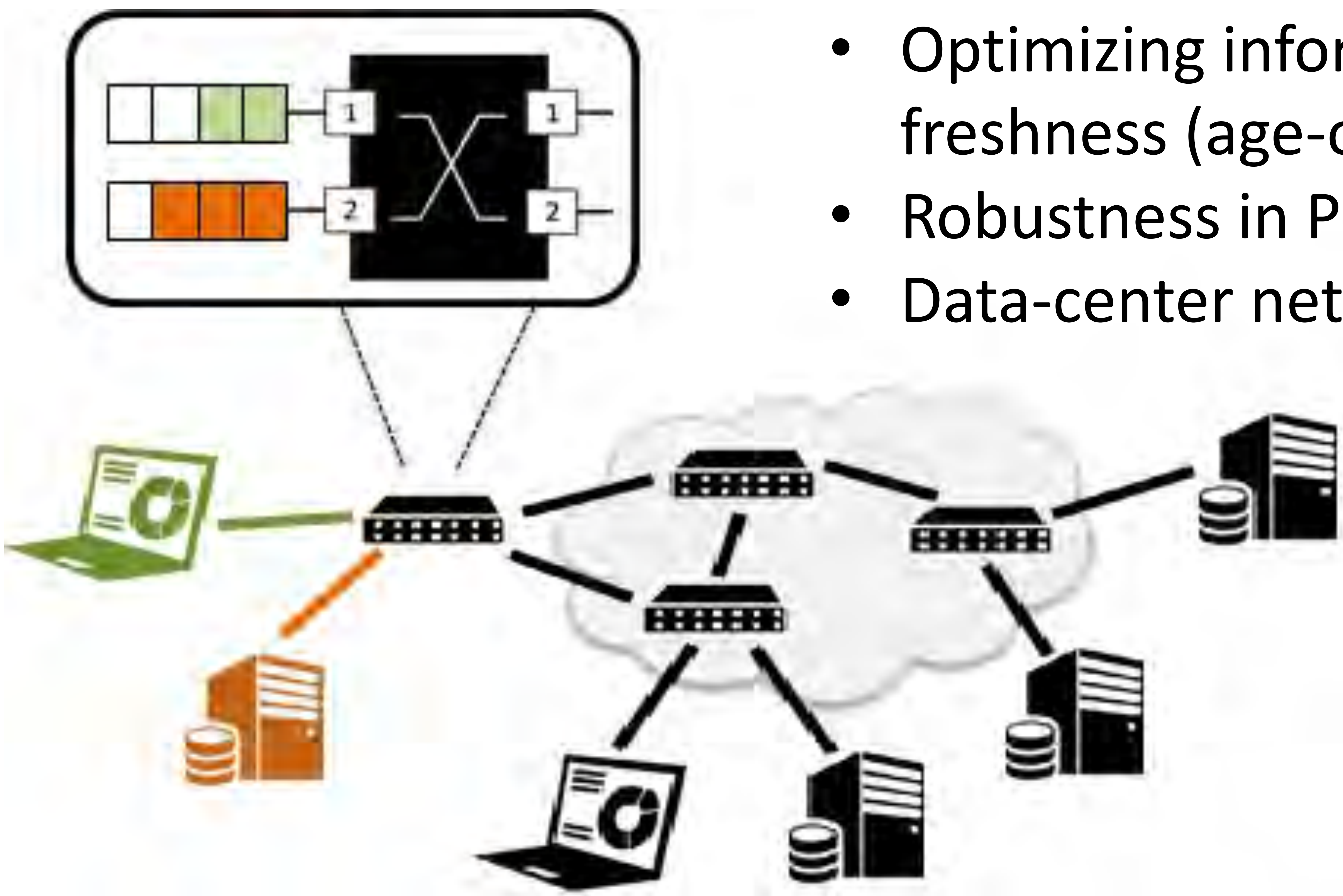
Communications and Networking Research
Eytan Modiano

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



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Asuman Ozdaglar

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

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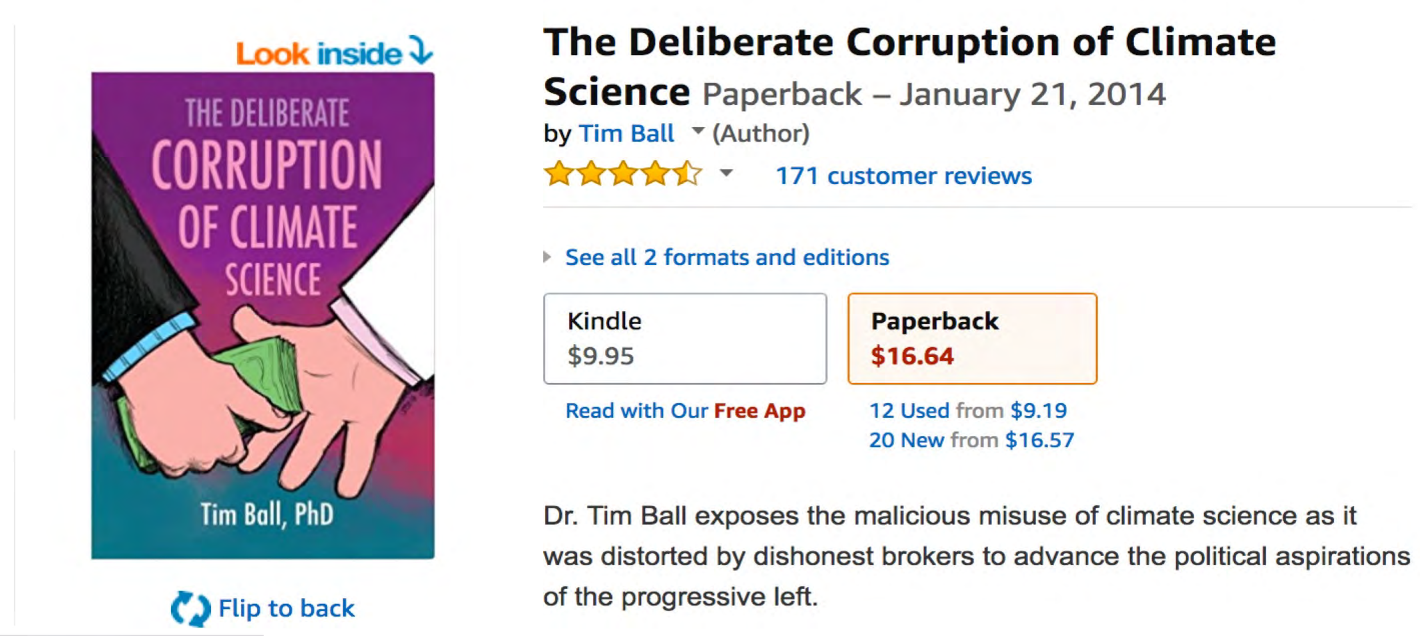

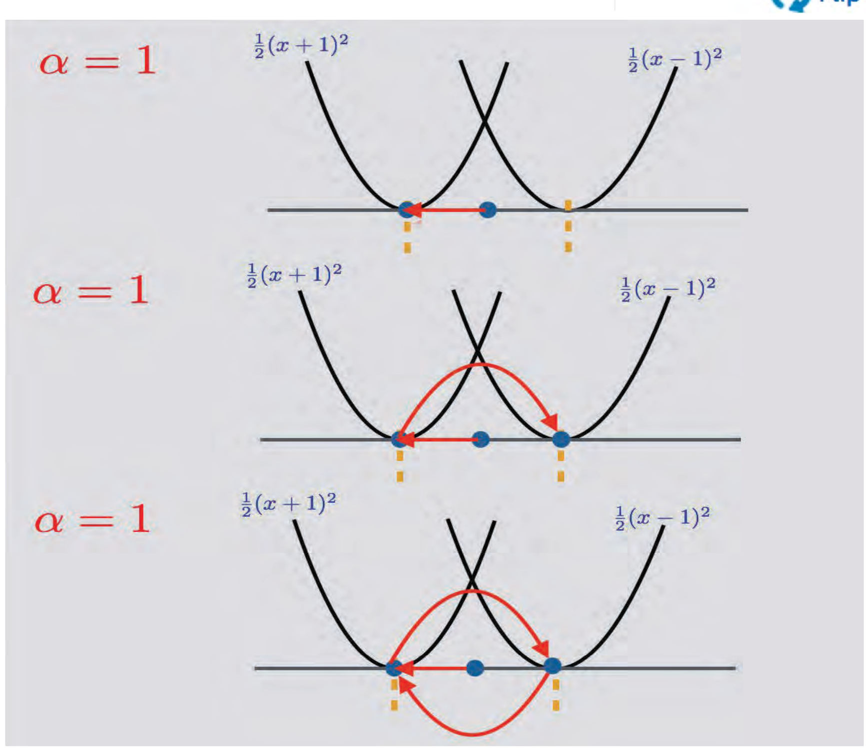

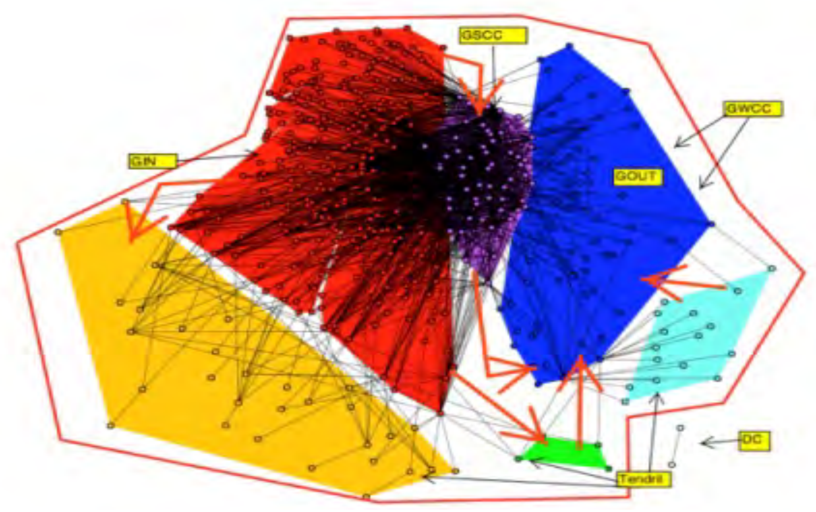

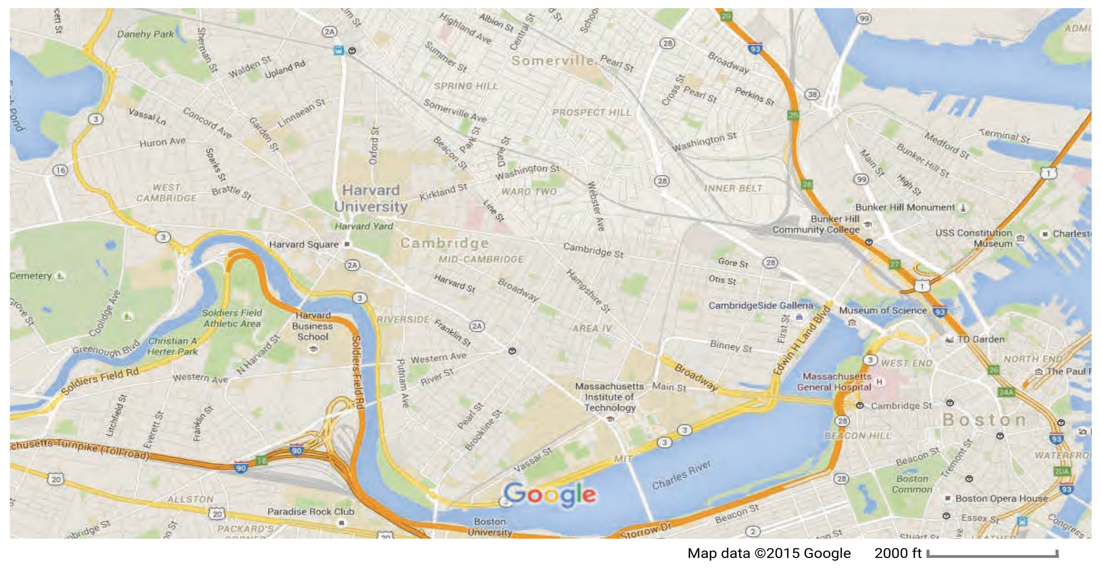

Sasha Rakhlin

Machine Learning, Statistics, and Optimization

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.

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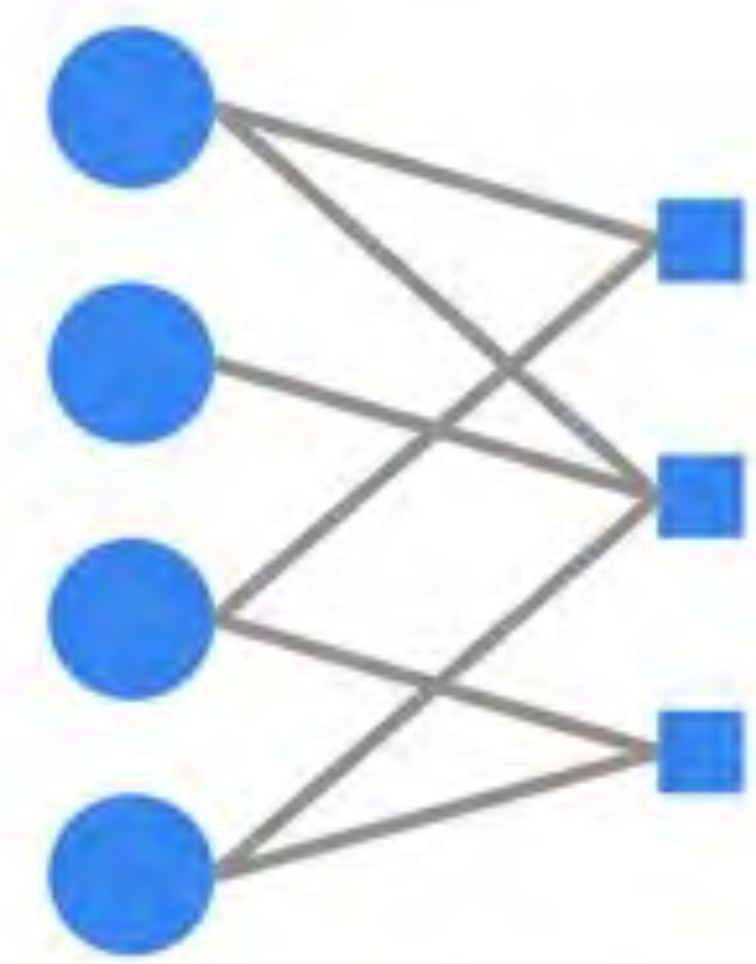
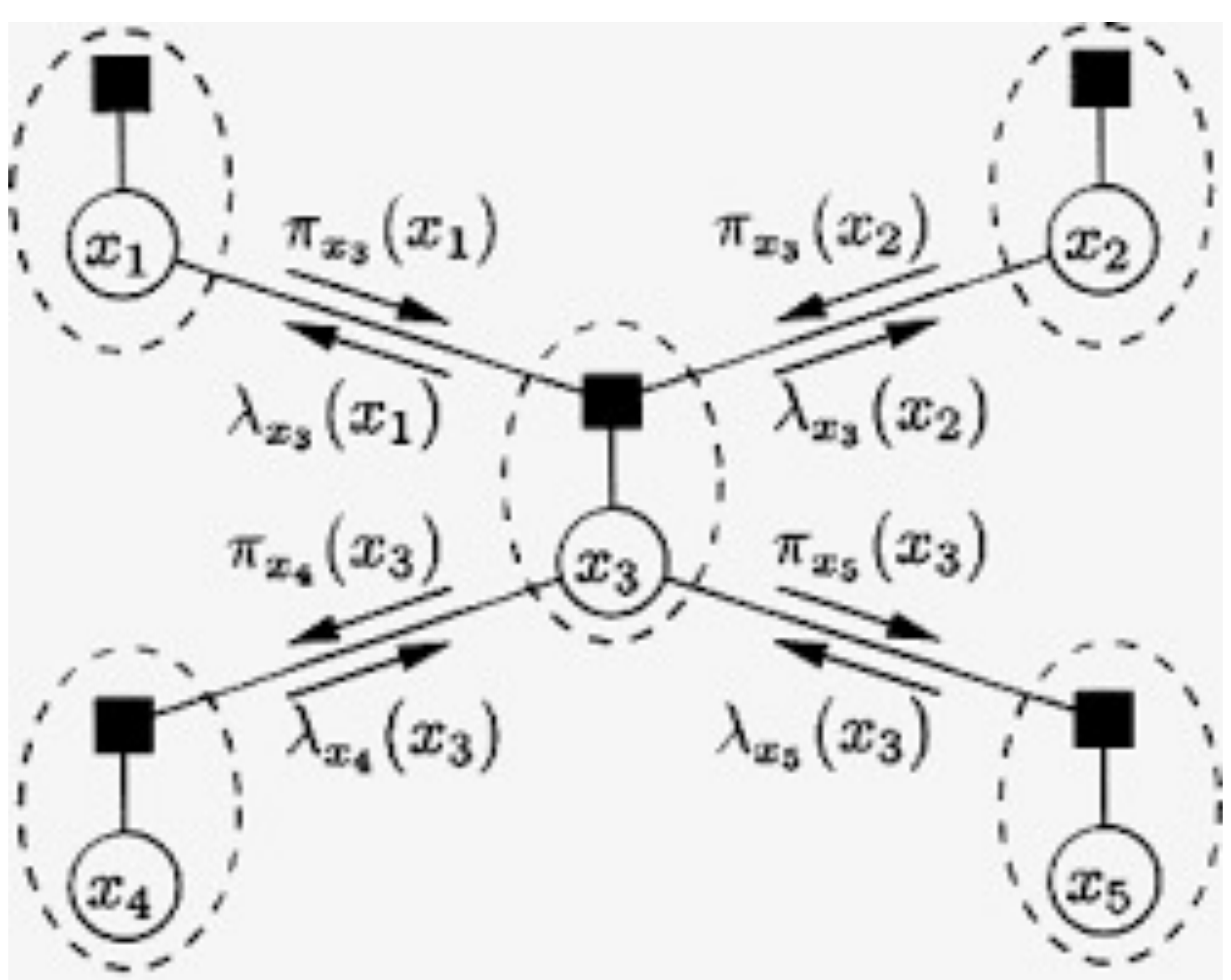
Devavrat Shah

Social Data Processing



Probabilistic Graphical Models

Network Algorithms

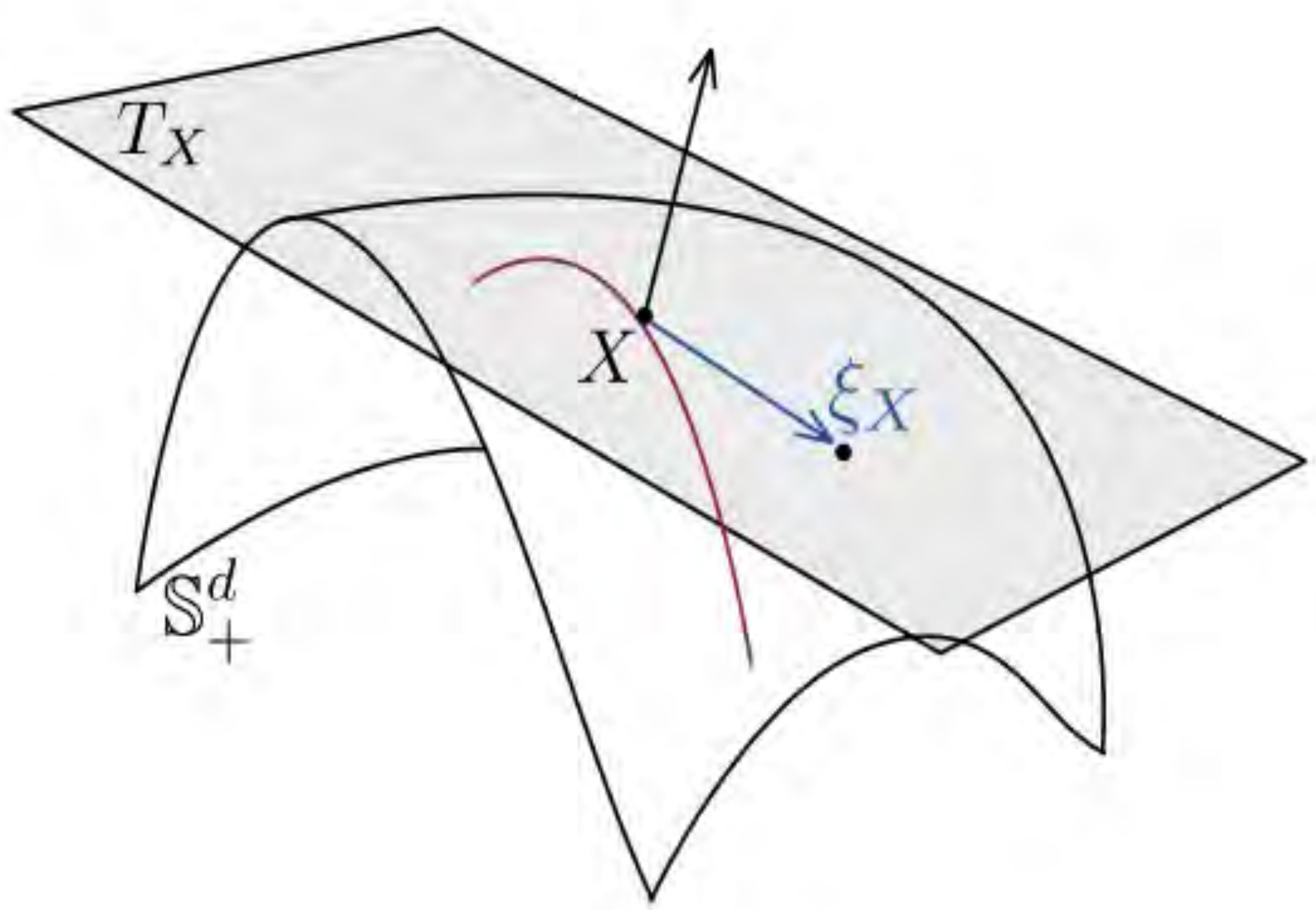


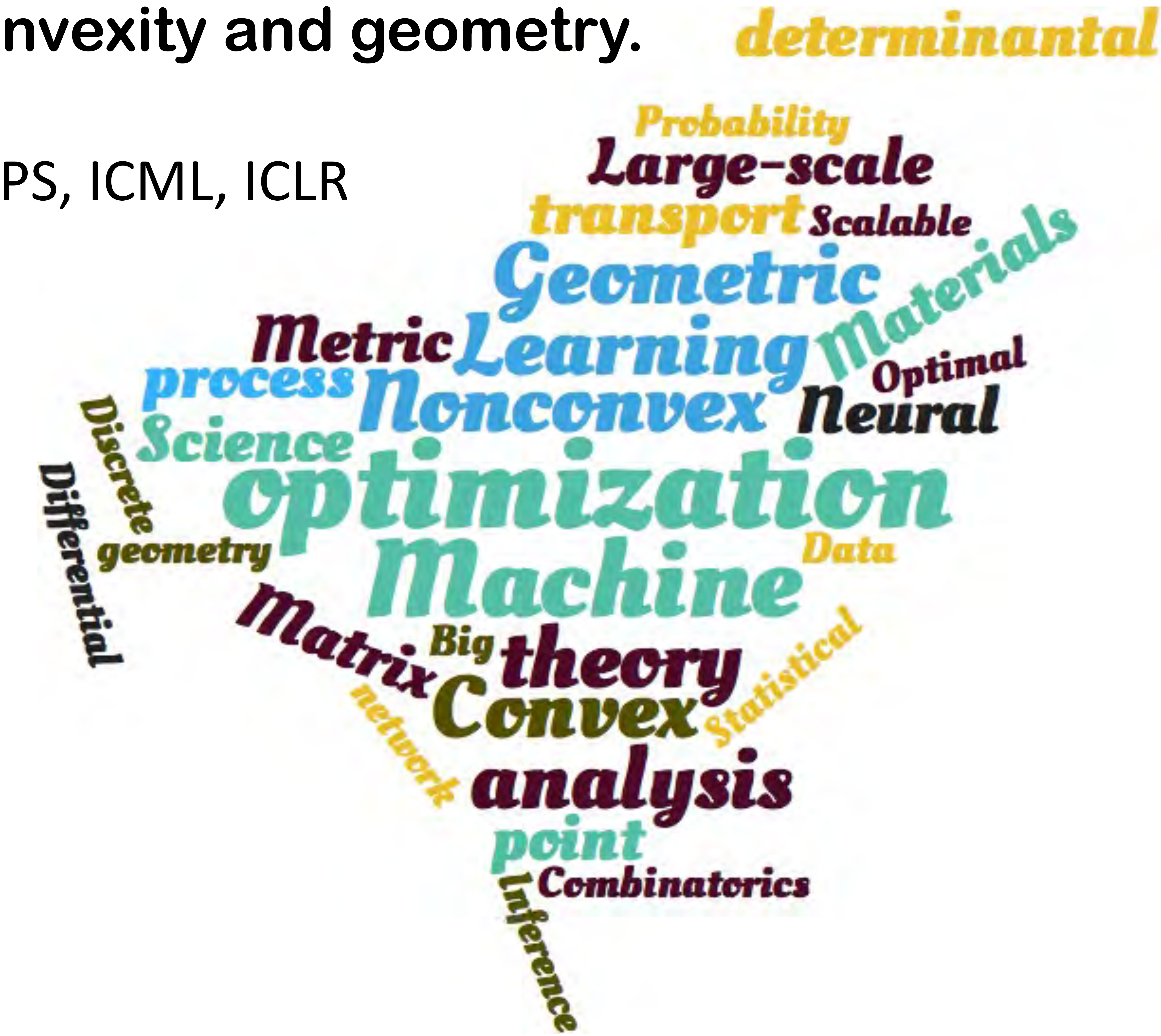
OPTML: Optimization for Machine Learning

Suvrit Sra

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

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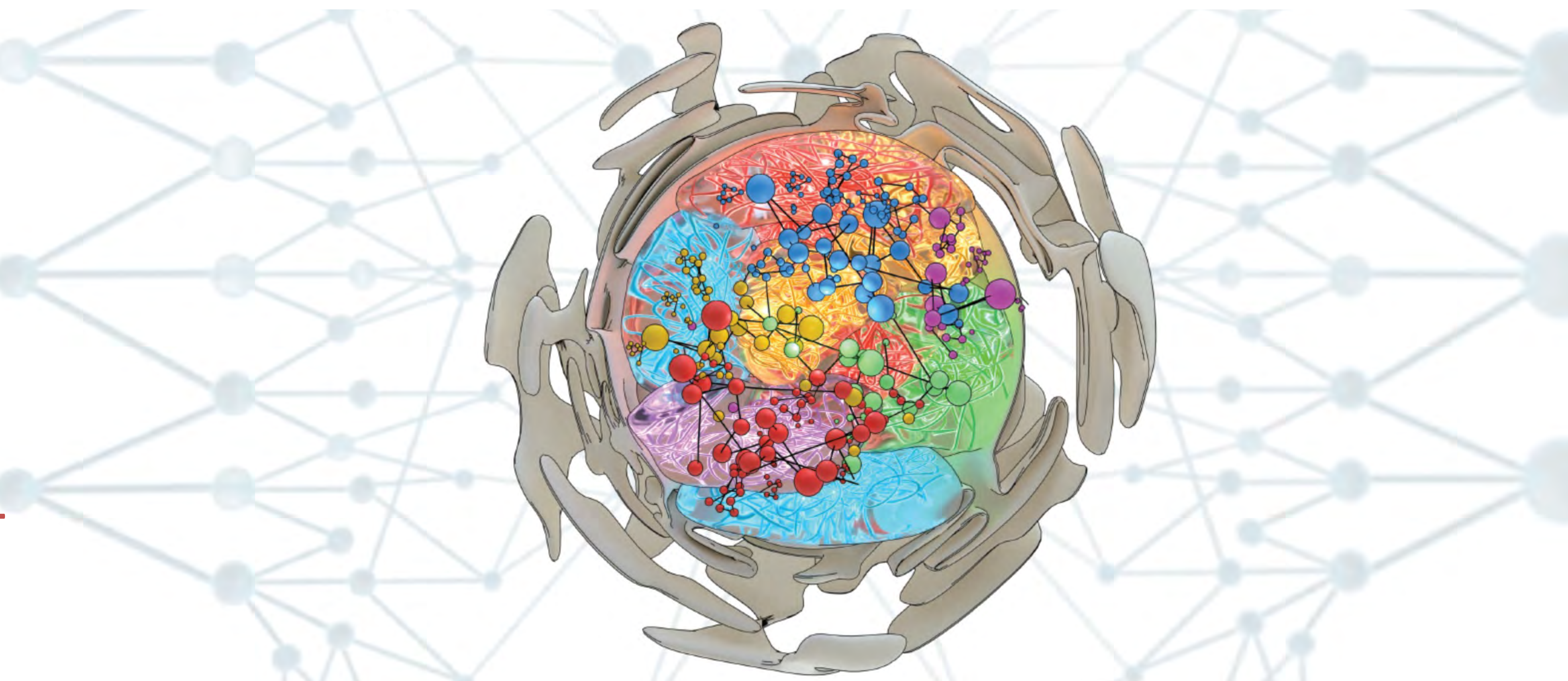
Caroline Uhler

«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.»

CAUSALITY

AUTO-ENCODERS

OPTIMAL TRANSPORT



DISEASE DIAGNOSTICS

DRUG DISCOVERY

REPRO-GRAMMING

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.

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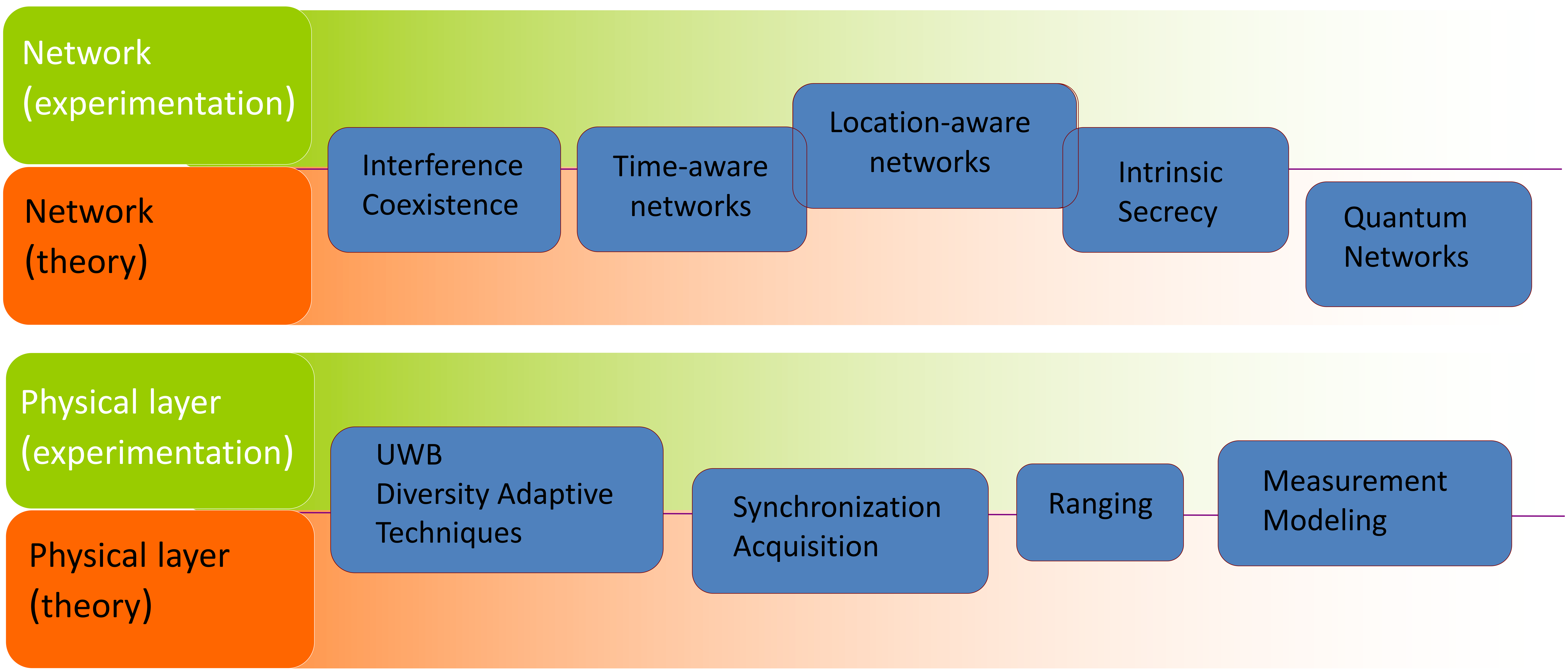
Wireless Information & Network Sciences
Moe Win

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



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Cathy Wu

LEARNING, AUTONOMY, & URBAN SYSTEMS

Ideal impact of autonomous vehicles:

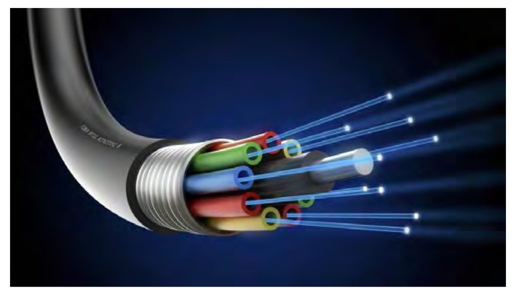
- Traffic accidents: –94% of serious crashes
- Congestion: –6.9 billion hours annually
- Access to mobility: +30% of population
- Energy: 31% from transportation

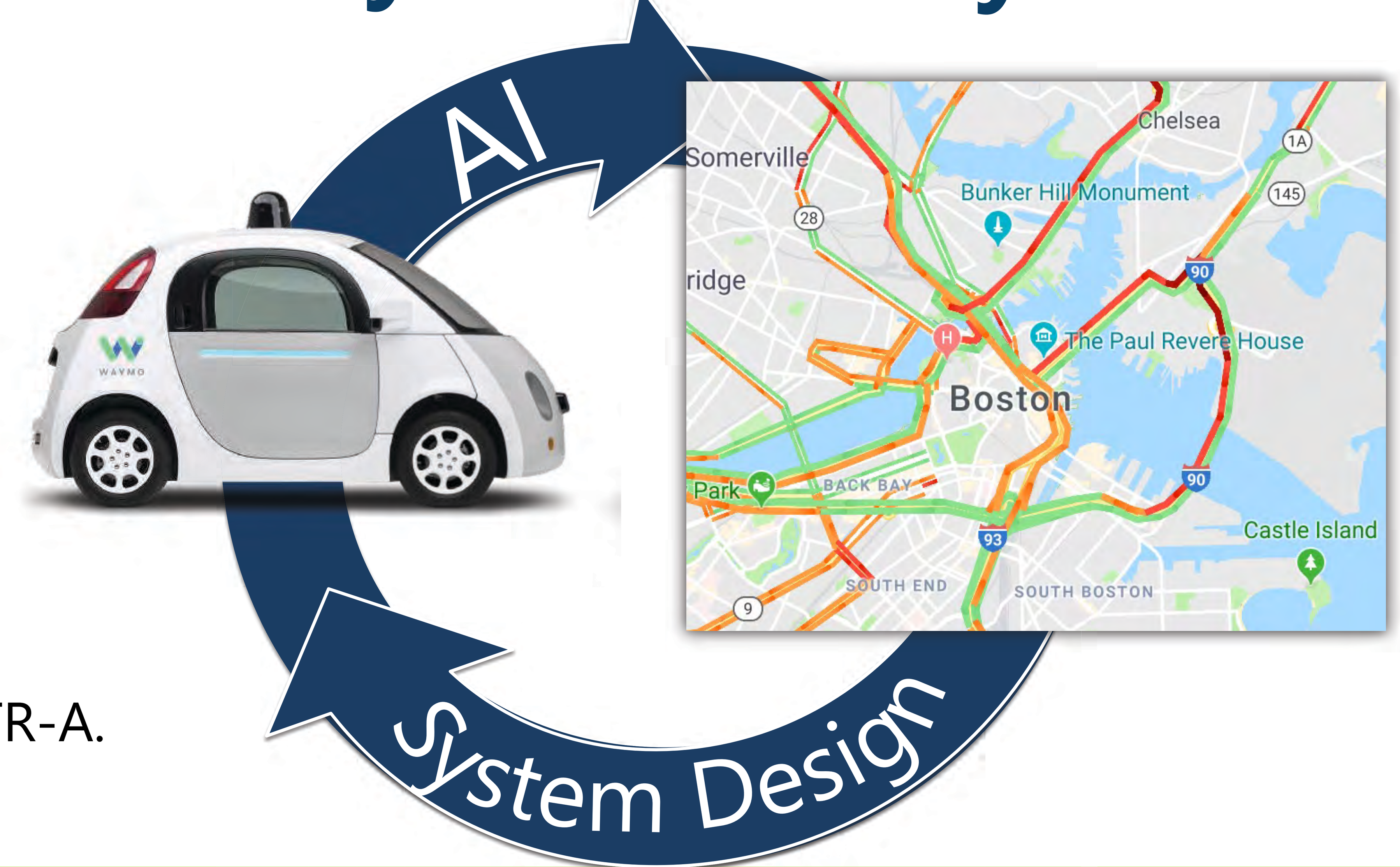
Actual uncertainty (with 100% adoption):

-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**





U.S. Energy Information Administration, 2017; U.S. Census Bureau, 2017; Wadud, et al. 2016. TR-A.