LIDS@80

Large-scale, Decentralized Optimization in Networked Systems

Future Science: Data-Driven Autonomous Systems

Figure 1: **LEFT: The increasing speed at which we collect data, as well as the increasing volume and variety of that data, are profoundly transforming research in all fields of S&E. This deluge of data, from large scientific facilities, advanced cyberinfrastructure, new data analysis tools and more, is forcing scientists to ask and answer new types of questions. RIGHT: From robots on the assembly line and in the operating room to the office that travels with you 24/7, the world of work is changing. We are at the cusp on a major transformation in work that is being driven by combinations of machine learning, artificial intelligence, the internet-of-things, and robotics. Citated from: 10 Big Ideas for Future NSF Investments, https://www.nsf.gov/about/congress/reports/nsfbigideas.pdf.**

Future Research: Interdisciplinary

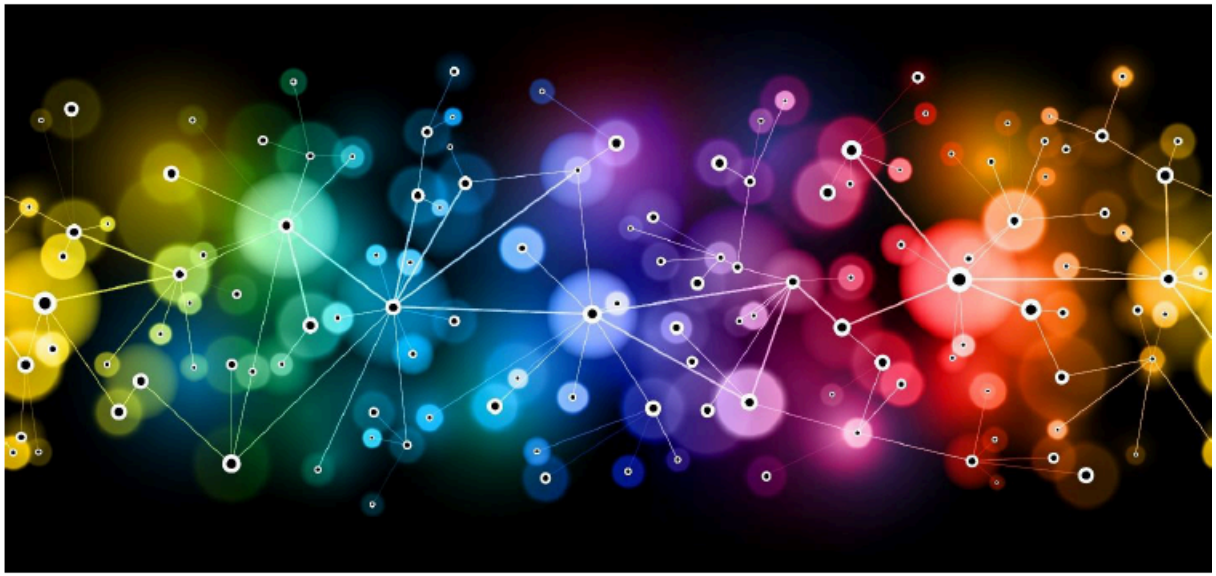

Figure 2: **The grand challenges of today –protecting human health; understanding the food, energy, water nexus; exploring the universe at all scales –will not be solved by one discipline alone. They require convergence: the merging of ideas, approaches and technologies from widely diverse fields of knowledge to stimulate innovation and discovery. Citated from: 10 Big Ideas for Future NSF Investments, https://www.nsf.gov/about/congress/reports/nsfbigideas.pdf.**

Past Research Challenges

The challenges were almost the same but for a smaller, slower, simpler systems

- The systems smaller in scale and complexity
- Smaller scale of data and speed with collecting data
- Devices with smaller processing power
- Slower internet speed

Work at LIDS: Optimization

- Lagrangian Methods studied by Bertsekas (starting in 1972)
- Augmented Lagrangian Methods studied by Berstekas and Eckstein (Ph.D.), related to the ADMM method
- Parallel Optimization - Eckstein Ph.D. thesis (supervised by Berstekas) *Splitting Methods for Monotone Operators with Applications to Parallel Optimization* (1989)
- Paul Tseng (Ph.D. supervised by Berstekas) has worked on splitting methods, parallel optimization, block-coordinate methods, asynchronous space decomposition methods, etc ..., see *https://www.mit.edu/ dimitrib/PTseng/papers.html*
- Tom Luo (Ph.D. supervised by Tsitsiklis) optimization methods and their computational complexity, see *http://ospac.ece.umn.edu/journal.html*

Work at LIDS: Methods for ML

Incremental Methods (optimization in a ring network; cyclic or randomized)

- Bertsekas, Tsitsiklis
- Ph.D. students Paul Tseng, A. Nedić (thesis on incremental methods for convex nonsmooth problems, 2002)
- Ozdaglar, Gurbuzbalaban, Parrillo - incremental aggregated methods, random re-shuffeling cyclic methods

Work at LIDS: Decentralized Computation

- Athans, Bertsekas, Tsitsiklis (Ph.D. thesis *Problems in decentralized decision making and computation* (1984) (contains consensus-based method for optimization)
- Bertsekas & Tsitsiklis book *Parallel and distributed computation: numerical methods* (INFORMS John Von Neumann Theory Prize 2018)
- Nedić and Ozdaglar (2009) proposed distributed method for optimization on graphs (consensus-based multi-agent optimization)
- Olshevsky (Ph.D. supervised by Tsitsiklis) *Efficient Information Aggregation Strategies for Distributed Control and Signal Processing* 2010
- Nedić, Ozdaglar, Olshevsky - various methods to deal with time-varying graphs (including random), directed graphs, delays, etc
- Olshevsky - network independent scalability (in the network size)