DISSERTATION PROPOSAL

Weizhong Zhang

"Optimizing Decisions: Algorithms and Mechanisms for Content Recommendation, Data Pricing, and Convex Relaxations"

Tuesday, December 3, 2024
9:00am
Tepper 4242

How can we optimize decision-making in complex systems? This thesis tackles the challenge through three lenses: algorithms for balancing engagement and revenue in content recommendation, mechanisms for pricing data products to maximize revenue, and characterizations of convex hulls in quadratic systems for efficient optimization.

Chapter 1: In sequential short-form content recommendation, recommendation engines must balance high-revenue items (e.g., ads) that risk user disengagement with engaging content (e.g., short videos) that retains users. We model this as an episodic reward aggregation problem, where an item's marginal utility depends on both its intrinsic reward and the continuation probabilities of preceding items, extending cascading bandit models. For cases where rewards and continuation probabilities are known, we present an almost linear-time dynamic programming solution to maximize expected rewards. In scenarios where these values are unknown, we propose an efficient UCB-style bandit algorithm to learn them, offering tight instance-dependent and worst-case regret guarantees. Finally, we validate our approach using synthetic experiments and real-world content recommendation datasets.

Chapter 2: High-dimensional data is vital for machine learning, requiring optimal design and pricing for maximum revenue. This chapter studies how sellers can tailor information products to meet buyer needs. We investigate how a monopolistic data seller designs and prices information products (termed "experiments") to maximize revenue, focusing on high-dimensional continuous state spaces and buyers with heterogeneous quadratic utilities under a uniform Gaussian prior. Despite the complexity of the experiment space, we show that the seller can achieve optimal revenue by restricting attention to simple scalar Gaussian experiments. From a computational perspective, we develop a polynomial-time semi-definite programming algorithm to construct a revenue-maximizing menu of experiments and corresponding prices.

Chapter 3: Structured nonconvex problems can often be solved via convex relaxations. This chapter examines conditions ensuring tractable and exact solutions for quadratic systems. We study the convex hull of a set S defined by potentially nonconvex quadratic inequalities and conditions under which it can be described as intersections of aggregations. Aggregations are formed by taking non-negative linear combinations of quadratic inequalities. Blekherman et al. introduced the notion of Hidden Hyperplane Convexity (HHC), a condition that characterizes the convex hull of S using specific aggregations. However, HHC is restrictive, excluding cases such as those involving diagonal matrices and failing to capture scenarios where SDP exactness holds—i.e., when the convex hull of the epigraph of the QCQP equals the projected epigraph of its convex SDP relaxation. We propose a generalized condition that extends HHC to include all cases covered by HHC and those where SDP exactness is satisfied.

Proposed Committee: Fatma Kilinc-Karzan (Chair), Ravi, and Karan Singh, and Evelyn Gong (Outside Reader)

Proposal Documents: https://cmu.app.box.com/folder/294594013346