Research Statement

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Modern marketplaces and societal systems are undergoing substantial transformations due to automated data collection and algorithmic decision-making. My research centers around developing methodologies and algorithms for *sequential and data-driven decision-making*. I have focused on bridging theory and practice in modeling and analysis, and in particular taking into consideration *the psychological or strategic human behaviors* in systems. I leverage an eclectic set of techniques from statistics, optimization, and machine learning, and I borrow insights from economic theories and marketing literature. My research is largely motivated by real-world problems, such as those arising in online retailing [1, 2], on-demand vehicle sharing [3], and supply chain management [4, 5]. Meanwhile, I have also worked on theoretical and computational aspects of statistical methodologies [6].

1 Current Research Topics

1.1 Dynamic Pricing Under Consumer Behavior Model. Reference effects are fundamental consumer behavior models with roots from the renowned prospect theory [7] in economics and have been widely observed in reality. Due to the existence of reference price effects by consumers, retailers need to be aware of the sequential effects of current prices on future demand when designing their dynamic pricing policies.

In "Intertemporal Pricing via Nonparametric Estimation: Integrating Reference Effects and Consumer Heterogeneity" [1], we build a random coefficient logit demand model that allows arbitrary joint distributions of valuations, responsiveness to prices, and responsiveness to reference prices among consumers to fully express consumer heterogeneity. We develop a nonparametric estimation method to learn heterogeneous consumer reference effects from transaction data, and we apply a modified policy iteration algorithm to find the optimal pricing policies. We verify the effectiveness of our approach through numerical experiments on large-scale individual-level transaction data from China's leading online retailer JD.com. In "Multi-Product Dynamic Pricing with Reference Effects Under Logit Demand" [2], we generalize the demand model in [1] to the multi-product setting so that both reference effects and substitution effects are incorporated. We establish structural properties of both myopic and optimal pricing policies. We provide a complete characterization of the optimal steady state price and show that it can be computed efficiently via a one-dimensional binary search. The code and data for [1] are available through `https://github.com/hanshengjiang/Reference_Effects`.

1.2 Operations of On-Demand Vehicle Sharing Networks. On-demand and one-way vehicle sharing (e.g., car sharing, bike sharing, scooter sharing) services are emerging and environment-friendly transportation options that promise consumers more flexibility and convenience. Despite the benefits of vehicle sharing, such services still suffer from many operational difficulties and struggle to thrive. One major challenge in operating such vehicle sharing systems is matching the supply and the demand in real time across multiple locations.

In "Learning While Repositioning in On-Demand Vehicle Sharing Networks" [3], we propose an online learning method to dynamically reposition vehicles in order to minimize the total costs of repositioning and lost sales in the long run. The repositioning problem is critical in successful management of on-demand one-way vehicle sharing services, and it is challenging both analytically and computationally. The optimal repositioning policy under a general n-location network is inaccessible without knowing the optimal value function. Inspired by the base-stock reorder policy in inventory control, we propose a class of base-stock repositioning policies and prove that they are asymptotically optimal in certain limiting regimes. Existing literature on computing repositioning policies either assumes that the demand distribution is known or that uncensored demand samples are available. In contrast, we develop an online learning method to dynamically reposition vehicles without knowing the demand distribution in advance. We study the performance of our algorithm by comparing it with the best base-stock policy, and prove that the T-period aggregate regret of our algorithm is bounded sublinearly by $O\left(T^{\frac{n}{n+1}}(\log T)^{\frac{1}{n+1}}\right)$.

1.3 Supply Chain Management. One way of coordinating capacity planning in supply chains is through forecast sharing. However, the forecasters may exhibit certain asymmetric preferences toward underforecasts or overforecasts for the sake of their own benefits, and therefore the effectiveness of forecast sharing can be hindered. In "Supply Chain Forecast Sharing under Asymmetric Forecast Preferences" [4], we build a multi-period Bayesian repeated newsvendor model to depict the impact of forecast preferences on how a supplier updates its demand information and prepares its production capacity based on the shared forecast. We characterize the value of the forecast preference information by quantifying the impact of the forecast preference information on the supplier's expected profit, and we derive a finite-sample bound on its regret when compared to the expected profit if the true forecast preference information is known.

Supply chain management is constantly evolving with the advance of new technologies. Quantum computing is a rapidly-emerging technology that is expected to have transformative influences on many domains, but its practical deployments on industry problems are underexplored. In "Quantum Computing Methods for Supply Chain Management" [5], we explore how quantum computing may help to empower supply chain management and exemplify it in a classic multi-period inventory control problem. Our experiments on quantum computers hosted by IBM Qiskit and the qBraid system demonstrate the practicality of variational quantum algorithms for solving small-sized inventory control problems.

1.4 Statistical Methodology with Applications to Pricing. Mixture of regression models are useful for regression analysis in heterogeneous populations, and have been applied in diverse fields including biology, economics, engineering, epidemiology, marketing, and transportation. In "A Nonparametric Maximum Likelihood Approach to Mixture of Regression" [6], we study the nonparametric maximum likelihood estimator (NPMLE) for fitting these models, and notably our approach does not require prior specification of the number of mixture components. We establish existence of the NPMLE and prove finite-sample parametric Hellinger error bounds for the predicted density functions. We also provide an effective procedure for computing the NPMLE without ad-hoc discretization and prove a theoretical convergence rate under certain assumptions. This work provides the theoretical foundation for the nonparametric estimation method used in [1] for estimating consumer heterogeneity. The code package for this estimation method is available at `https://github.com/hanshengjiang/npmle_git`.

2 Future Research Themes

In the future, I look forward to using my theoretical toolkits to deepen my research in sequential and data-driven decision-making for a broad spectrum of operations problems. I summarize my vision for two major research themes below.

2.1 Repeated Interactions and Human Behaviors. My works on pricing under reference effects [1, 2] explore the consumer behaviors of comparing current prices with reference prices during repeated visits to online retailing platforms. My work on asymmetric forecast preference [4] considers the preferences in forecast sharing and misreporting behaviors by customers. A unifying phenomenon of these works is the repeated interactions of two or multiple sides, as well as their behavioral actions.

Aside from online retailing and supply chains, repeated interactions are ubiquitous in many marketplaces, such as ride-sharing, food delivery, auctions, and advertising. Classic approaches mainly focus on settings where people in these marketplaces as perfectly rational or completely agnostic. In practice, people are not machines, and they cannot be exactly engineered by the platforms. As humans, they may be boundedly rational in that they may change valuations based on some anchor points as described by reference effects or that they may have limited patience in waiting for a service or promotion. On the other hand, they may be intelligent and strategic in that they also learn from repeated interactions with the platform and behave correspondingly to maximize their own utility, for example, stockpiling behaviors of users during promotions.

I am fascinated with *understanding and modeling human behaviors during their repeated interactions* on the platform, and studying *how the platform should strategize to increase the overall long-term welfare of all parties* while obeying necessary practical constraints, such as fairness and privacy. Moreover, I am also interested in developing methodologies to extract useful information from real data to further tailor these strategies. I believe I am well-prepared to tackle these problems, given my academic training and my firsthand experience with real data during my three summer internships at tech companies, as well as my experience in analyzing the dataset by JD.com in my past research [1].

2.2 Transportation Networks and Smart Urban Mobility. In general, I am enthusiastic about smart urban mobility solutions, not only because they increase quality of life, but also because of the long-term environmental benefits. Motivated by my theoretical study of dynamic repositioning policies in vehicle sharing networks [3], I have been actively communicating with Gig Car Share, an on-demand car sharing company providing hybrid and electric car rentals in the SF Bay Area, Sacramento, and Seattle. In our communications, I seek to recommend my repositioning policies from [3] and seek to gain access to individual user data such as user search queries and trip lengths to conduct further analysis. I have identified abundant research opportunities in making these transportation networks perform better: *How to choose and design service regions? How to choose the size of the vehicle fleet? How to price the trips and incentivize users?* Beyond optimization from the platform's perspective, the success of these transportation networks ultimately hinges on the engagements of users and support from governments and legislation. Therefore, it is critical to design mechanisms and policies that *align with the incentives* of all stakeholders in the systems. These are all meaningful and relevant questions, and I believe addressing them will shed light on the ongoing development and future prosperity of such services.

References

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