Research Statement

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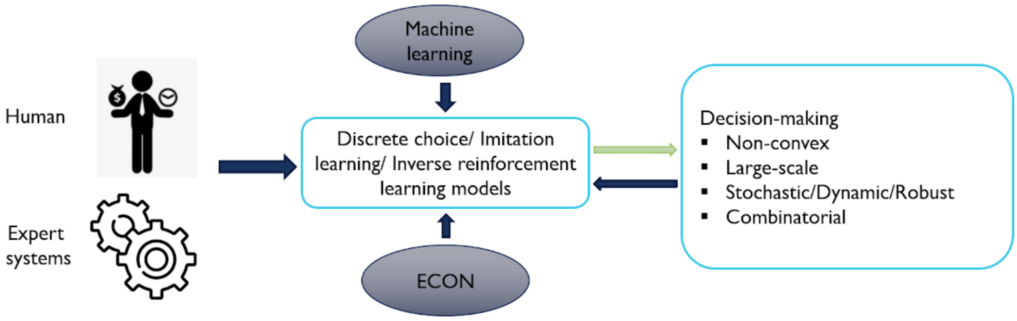
Background

I am broadly interested in models and algorithms for understanding and predicting human behavior in complex and uncertain environments, and for making use of such behavior models to support large-scale and robust decision-making. My research style is to look at the interpretability and computational issues of research problems that are related to my expertise and try to tackle the issues with viewpoints and techniques from different research areas such as econometrics, operations research, and machine learning. The figure below illustrates the main components of my research and the connections between them.



Research Areas

Behavior Modeling/ Imitation Learning

This research direction focuses on the use of discrete choice models to analyze and predict people's choice behavior. Such discrete choice models have been widely used in various research fields to describe, explain, and predict the choices of decision-makers between two or several discrete alternatives. Some examples are choosing a transport mode, buying a car, taking a route, entering or not entering the labor market, or selecting a product among a set of products offered. Discrete choice models have various applications across several domains such as marketing, revenue management, game theory, transportation planning, environmental studies, energy forecasters, and policymakers.

My work in this direction consists of several models and algorithms to predict travelers' path choice behavior in large-scale transportation networks. They are the first in the literature for consistent estimation of path choice models without generating any choice sets of paths while allowing path utilities to be correlated. Capturing the correlation is important in the context to achieve accurate predictions. The estimation of such models is however costly on large networks, and thus requires new algorithms. I have proposed several novel algorithms that allow to significantly reduce the computational cost, not only in the route choice context but also for a general class of discrete choice models with network-based correlation structures [22, 21, 20, 19, 14, 8]. I have also made fundamental theoretical contributions to discrete choice modeling that has allowed me to link that field to dynamic programming and inverse reinforcement learning, opening promising directions to advance the literature of demand modeling through the power of dynamic programming and/or machine learning techniques [15]. These connections had led to several projects that I have been running towards the goal of having more accurate, scalable, and useful behavior learning models. For example, in [2], we have proposed methods to efficiently handle the issue of missing data in route choice modeling. Our algorithm is highly scalable and robust in dealing with a huge number of missing segments in the demonstrated trajectories. In [9, 3, 1] we brought behavior/imitation learning models into vehicle routing and non-zero-sum game, and constrained decision-making problems to improve state-of-the-art algorithms. In [4] we proposed multi-agent imitation learning algorithm that achieve state-of-the-art results. There are several projects that I am advancing or plan to investigate further, for example, (i) modeling and estimating choice models with choice sets of exponential sizes, which would be relevant when, for instance, customers make multiple purchases, (ii) demand prediction using adversarial approaches, (iii) robust demand modeling under data uncertainty. Moreover, having recognized some interesting links between human behavior learning models from both econometrics and machine learning literatures, I plan to explore these connections further, aiming to bring models and techniques from both research communities into one place to build new learning models that are highly interpretable, highly scalable, and more accurate in predicting people behavior.

Human-driven Decision-Making

This direction comes naturally from my interest in decision-making and the fact that many recent works in revenue management, transportation planning and game theory have shown benefits from employing discrete choice models to build data-driven decision-making algorithms. Such approaches typically require building learning models to predict people behavior and then solving integrated optimization problems for decision-making. The main challenge lies in the non-linearity of the resulting optimization problems, making them difficult to solve in a tractable way. I have been looking at the product pricing and assortment planning, one of the key problems in revenue management. This refers to the problem of choosing a subset of products and prices of them to offer to customers so as to maximize an expected revenue that is realized when customers make purchases according to their preferences. In [18], we have proposed a practically efficient algorithm for the assortment optimization problem under various choice models. We have also developed new and general algorithms for solving a broad class of nonlinear decision-making problems that can be used for solving assortment and pricing problems [11, 10]. We are currently advancing several relevant projects, trying to tackle some open questions related to data uncertainties and realistic business constraints.

Facility location and cost planning problems are known to be of importance and have been intensively studied for decades. I have approached these problems by looking at the use of discrete choice models to capture customers' behavior. In this context, the objective is to select a set of locations to locate/operate facilities and to decide on the costs to spend on the selected facilities in a competitive market to maximize the captured demand of users, assuming that each customer chooses a facility according to discrete choice model. Under this setting, the optimization problems become much more challenging compared to existing facility/cost optimization problems that rely on simple linear demand models. In [17], we developed a new algorithm based on the outer-approximation scheme that performs better than state-of-the art algorithms in the problem domain. Along this direction, we have also made the first effort to bring a general class of discrete choice models (i.e., the GEV family) into competitive facility location [16]. The resulting problem is difficult to handle, and we have developed an efficient local search procedure with performance guarantees that outperforms prior methods. Uncertainty issues have also been explored in the context [5], and we are also developing new models and solution methods for a joint facility location and cost optimization problem under a new class of discrete choice models [6].

Discrete choice (or quantal response) models have also been widely used in Stackelberg security games (SSG) to model a bounded rational adversary with various real-world applications. The rich literature on discrete choice theory opens up promising directions to model adversary's behavior. Motivated by this, we have made one of the first attempts to bring the nested logit model from the family of discrete choice models into SSG to address shortcoming of previously-used quantal response models [12], and bring dynamic discrete choice ideas to model bounded adversary's behavior in a network [13]. We have also developed a model and solution algorithms that allow the defender to select locations to operate, thus greatly reduce the cost of being attacked [7]. Interestingly, our solution methods can be nicely used to handle assortment and pricing optimization problems with realistic business constraints. The relation is due to the analogy of set of products to set of locations/targets in SSG and of continuous prices to security allocation. Future directions would be to explore further this relation to develop general algorithms for handling both SSG and assortment/pricing problems. We are currently running some projects towards this end [11].

In summary, my current work and long-term plans are to continue developing new discrete choice and general imitation learning models, and new decision-making algorithms (prescriptive optimization) to better make use of data to do prediction accurately and make more robust and reliable decisions in different challenging settings.

Selected Publications and Outputs

[1] M. H. Hoang, T. Mai, and P. Varakantham, "Imitate the Good and Avoid the Bad: An Incremental Approach to Safe Reinforcement Learning," in *Proceedings of the AAAI Conference on Artificial Intelligence*, 2024.

[2] T. Mai, T. V. Bui, Q. P. Nguyen, and T. V Le, "Estimation of Recursive Route Choice Models with Incomplete Trip Observations," *Transportation Research Part B: Methodological*, vol. 173, no. 2023, pp. 313–331, 2023.

[3] T. V. Bui, T. Mai, and T. H. Nguyen, "Imitating Opponent to Win: Adversarial Policy Imitation Learning in Two-player Competitive Games," in *Proceedings of the 22nd International Conference on Autonomous Agents and Multiagent Systems (AAMAS)*, 2023, pp. 1285–1293.

[4] T. V. Bui, T. Mai, and T. H. Nguyen, "Inverse Factorized Q-Learning for Cooperative Multi-agent Imitation Learning," *arXiv preprint arXiv:2310.06801*, 2023.

[5] T. T. Dam, T. A. Ta, and T. Mai, "Robust maximum capture facility location under random utility maximization models," *Eur J Oper Res*, vol. 310, no. 3, pp. 1128–1150, 2023.

[6] N. H. Duong, T. T. Dam, T. A. Ta, and T. Mai, "Joint location and cost planning in maximum capture facility location under random utilities," *Comput Oper Res*, p. 106336, 2023.

[7] T. Mai and A. Shina, "Safe Delivery of Critical Services in Areas with Volatile Security Situation via a Stackelberg Game Approach," 2023.

[8] T. Mai and E. Frejinger, "Estimation of undiscounted recursive path choice models: convergence properties and algorithms," 2022.

[9] T. V. Bui and T. Mai, "Imitation Improvement Learning for Large-scale Capacitated Vehicle Routing Problems," in *Proceedings of the International Conference on Automated Planning and Scheduling (ICAPS))*, in working paper. 2022, pp. 551–559.

[10] A. Bose, T. Mai, and A. Shina, "Scalable Distributionally Robust Optimization in Non-convex Decision Making Problems," 2022.

[11] T. Mai, N. H. Duong, and T. A. Ta, "Binary-Continuous Sum-of-ratios Optimization: Discretization, Approximations, and Convex Reformulations," 2022.

[12] T. Mai and A. Shina, “Choices Are Not Independent: Stackelberg Security Games with Nested Quantal Response Models,” in *Proceedings - 36th AAAI Conference on Artificial Intelligence (AAAI)*, 2022.
[13] T. Mai, A. Bose, A. Shina, and H. T. Nguyen, “Stackelberg Network Interdiction under Boundedly Rational Adversary,” 2022.
[14] T. Mai, X. Yu, S. Gao, and E. Frejinger, “Route choice in a stochastic time-dependent network: the recursive model and solution algorithm,” *Transportation Research Part B: Methodological*, vol. 151, p. 42, 2021.
[15] T. Mai and P. Jaillet, “A relation analysis of Markov Decision Process frameworks,” 2021.
[16] T. T. Dam, T. A. Ta, and T. Mai, “Submodularity and local search approaches for maximum capture problems under generalized extreme value models,” *European Journal of Operational Research*, 2021.
[17] T. Mai and A. Lodi, “A multicut outer-approximation approach for competitive facility location under random utilities,” *European Journal of Operational Research*, vol. 284, no. 3, pp. 874–881, 2020, doi: 10.1016/j.ejor.2020.01.020.
[18] T. Mai and A. Lodi, “An Algorithm for Assortment Optimization Under Parametric Discrete Choice Models,” *SSRN Electronic Journal*, 2019, doi: 10.2139/ssrn.3370776.
[19] T. Mai, F. Bastin, and E. Frejinger, “A decomposition method for estimating recursive logit based route choice models,” *EURO Journal on Transportation and Logistics*, vol. 7, no. 3, pp. 253–275, 2018, doi: 10.1007/s13676-016-0102-3.
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[22] T. Mai, M. Fosgerau, and E. Frejinger, “A nested recursive logit model for route choice analysis,” *Transportation Research Part B: Methodological*, vol. 75, pp. 100–112, 2015, doi: 10.1016/j.trb.2015.03.015.