The Hong Kong University of Science and Technology

Department of Mathematics

PhD THESIS EXAMINATION

Exploring Decision-Making in Reinforcement Learning: Bandits with Knapsacks, Multi-Agent Systems, and Continuous Control

By

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ABSTRACT

Reinforcement learning is a significant and rapidly evolving area of machine learning with widespread applications in domains such as robotics, game playing, recommendation systems, and autonomous control. Many reinforcement learning problems involve complex constraints and scenarios that demand the use of advanced theoretical tools. This thesis explores decision-making in reinforcement learning across three distinct settings, including single-agent contextual bandits with knapsacks (CBwK), multi-agent Markov games, and continuous-time linear systems. First, we study CBwK problem. We address the limitations of UCB-type algorithms for complex function classes by proposing a universal and optimal framework based on online regression. We further establish lower regret bounds to demonstrate the algorithm's optimality across diverse function classes. Second, we propose a novel algorithm for learning coarse correlated equilibria (CCE) in general-sum Markov games under the local simulator access, achieving an optimal accuracy bound of $O(\varepsilon^{-2})$ and removing linear dependency on the action space. Our analysis generalizes virtual policy iteration techniques, which also yields a new computationally efficient algorithm with a tighter sample complexity bound when assuming random access to the simulator. Finally, we propose the first policy gradient-based, model-free algorithm for learning the continuous-time linear systems, achieving $O(\sqrt{T})$ regret without requiring a warm-up phase. Furthermore, with state resetting, we introduce a model-free algorithm that provably stabilizes the system within finite time.

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Time : **3:00 pm**

Venue : **Room 4475 (Lifts 25/26)**

Thesis Examination Committee:

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The student's thesis is now being displayed on the reception counter in the General Administration Office (Room 3461).