



TEXAS A&M UNIVERSITY

Wm Michael Barnes '64 Department of
Industrial & Systems Engineering

ENHANCING THE ROBUSTNESS IN REINFORCEMENT LEARNING: DOMAIN KNOWLEDGE INTEGRATION AND UNCERTAINTY QUANTIFICATION

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ABSTRACT

Reinforcement learning (RL) has become a powerful framework for solving sequential decision-making problems, particularly in complex and dynamic environments where traditional optimization techniques struggle. This work develops novel RL-based methodologies to address critical challenges in domain knowledge incorporation and statistical inference in RL, contributing to both theoretical advancements and practical applications. We first develop a domain knowledge-informed deep reinforcement learning to leverage prior knowledge and overcome slow convergence in conventional Q-learning. Theoretical results guarantee convergence for small-scale problems, while computational experiments on larger problems demonstrate superior efficiency and reward performance compared to traditional methods. The second part of this work investigates the statistical properties of RL algorithms, focusing on understanding and managing uncertainty in learning outcomes. We propose a time-varying batch-averaged Q-learning algorithm, which aggregates samples of rewards and next states to enhance stability and accuracy. We establish the asymptotic normality of the sample averaged Q-learning algorithm and introduce a random scaling method to construct confidence intervals without additional hyperparameter tuning. Numerical experiments in standard RL environments validate the algorithm's ability to achieve higher accuracy and robust uncertainty quantification compared to conventional approaches.

DR. YISHA XIANG



Dr. Yisha Xiang is an Associate Professor of Industrial Engineering at the University of Houston. Her current research and teaching interests involve data-driven decision-making under uncertainty and statistical machine learning. Her research has been funded by the National Science Foundation, including a CAREER grant, and industry. She has published articles in refereed journals, such as INFORMS journal on Computing, IIE Transactions, European Journal of Operational Research, and Naval Research Logistics. She was the recipient of the P.K. McElroy award, Stan Oftshun award, and Doug Ogden award for best papers at the Reliability and Maintainability Symposium. Dr. Xiang received her B.S. in Industrial Engineering from Nanjing University of Aero. & Astro., China, and M.S. and Ph.D. in Industrial Engineering from University of Arkansas. She serves as an Associate Editor for IIE Transactions, INFORMS Journal on Data Science, and IEEE Transactions on Reliability, and was previously on the editorial team of IEEE Transactions on Automation Science and Engineering. She has served as President of the IIE Quality Control and Reliability Engineering Division and Chair of the INFORMS Quality, Statistics, and Reliability Section. She is a member of IIE and INFORMS.