Towards Intelligent Sharing: Risk-Aware Decision-Focused Reinforcement Learning for Shared Parking Allocation

Liu, Xiuqi (School: Chongqing Bashu Secondary School)

Urban parking shortages impose significant economic and environmental costs, with drivers spending excessive time searching for spaces and generating substantial emissions. Shared parking, where private owners rent out unused spaces to the public, offers a promising solution. However, its effectiveness is limited by the complexity of real-time allocation and high demand uncertainty. Most existing studies apply reinforcement learning to address this problem, but due to the inherent instability of real-world parking environments and the model's inability to observe future demand, performance often remains inconsistent — which may lead to user dissatisfaction. This study investigates whether a risk-aware, decision-focused RL framework can improve allocation efficiency and robustness under uncertainty. For the model architecture, a Sparse Graph Attention Network and DeepAR model were combined to generate multi-quantile tail-risk demand estimates, injected into a Double Deep Q-Network agent's state via Feature-wise Linear Modulation, with a risk-penalizing reward function discouraging overbooking. The forecaster and policy were coupled through an end-to-end training process to avoid mismatch between demand estimation and allocation optimization. Using real-time Chongqing shared parking data for estimation, the proposed framework was evaluated in a simulated urban environment against three baselines across normal, peak, and high-uncertainty conditions. The framework outperformed all baselines in service rate, space utilization, and overall reward. Ablation studies further confirmed that each architectural component contributed to performance. These findings show that risk-aware, decision-focused learning can make shared parking platforms more reliable and efficient.

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