Meta-Reinforcement Learning Framework for Network-Level Bridge Management

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A significant number of bridges in the United States are susceptible to failure, and one of the main factors that causes failure is overload. Severe consequences can result from bridge failure: reconstruction costs can reach billions of dollars, supply chains are disrupted, and people lose lives and jobs. Therefore, the objective of this project is to investigate whether more effective management of bridge loads and cascading failures can be achieved by employing a network-level coordination system based on RL compared to other approaches. In this regard, a simulation was conducted on three bridges with different capacity levels. The simulation was based on constant traffic flow, probabilistic traffic spikes, a traffic decay factor, and temporary capacity reductions. To evaluate the RL agent system, it was compared to three other systems: baseline (no management or coordination), local (each bridge functioned independently), and rule-based (coordination at a network level using set rules). With the RL agent management system, a 56% reduction in cascading failures was observed compared to the rule-based system. In addition, travel time remained around 19 minutes for all strategies. However, an increase in singular bridge overloads was observed in the RL system due to the agent prioritizing network-wide coordination. These findings demonstrate the reinforcement learning agent's superiority in prioritizing safety and efficiency, as it outperformed the other strategies. The RL agent provides a scalable solution to manage a network of bridges. Its efficient management can help reduce structural stress, thus preventing large-scale failures.

Awards Won:
Missouri University of Science and Technology: Summer Camp scholarships (camp tuition and travel expenses, valued at up to $1,500)