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A Multi-Fidelity Simulation Optimization Framework Applied to the Pod Sequencing Problem in A Robotic Mobile Fulfillment System

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Abstract

This study presents a multi-fidelity simulation optimization method to address the pod sequencing problem in Robotic Mobile Fulfillment Systems (RMFS), with the objective of minimizing robot travel distances. RMFS is a centrally controlled warehouse system composed of mobile robots, storage pods, and picking stations. It enhances operational efficiency by assigning pods to robots based on predefined rules and transporting them to picking stations in a specific order, thereby eliminating picker travel and improving overall throughput. Traditional approaches to the pod sequencing and assignment problem often rely on static environment assumptions to reduce computation time. However, these models fail to capture dynamic factors such as robot collisions, deadlocks, and travel conflicts, which can lead to solutions that are not applicable in real-world operations. While dynamic simulations offer more realistic representations, they are computationally intensive. Moreover, the pod sequencing problem involves a large and complex solution space, making it computationally challenging to explore thoroughly using high-fidelity models alone. To address this, the proposed method adopts a multi-fidelity simulation optimization approach that integrates a genetic algorithm to efficiently search for promising solutions. The genetic algorithm first evaluates candidate solutions using a low-fidelity model to estimate performance trends. These trends are then used to strategically select a limited number of high-quality sampling points for evaluation using the high-fidelity model. This approach significantly reduces the number of expensive high-fidelity simulations required, thereby improving solution efficiency while maintaining accuracy. Experimental results based on multiple datasets demonstrate that the multi-fidelity simulation optimization approach effectively identifies optimal pod sequences and corresponding robot travel distances, significantly enhancing decision-making in RMFS operations.

Keywords

Multi-Fidelity Simulation Optimization, Robotic Mobile Fulfillment System, Pod Sequencing, Robot Travel Distance, Genetic algorithm.

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