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INTEGRATING AI AND SIMULATION FOR INTELLIGENT MATERIAL HANDLING

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ABSTRACT

With the increasing integration of autonomous mobile robots in warehouse facilities for storage and retrieval, the need arises to make intelligent dispatching decisions to maximize operational efficiency and meet shipping deadlines. The aim of this research is to enable effective real-time, dispatching decisions taking into consideration both travel distance and due date. In particular, we develop a reinforcement learning method for task selection in a multi-agent warehouse environment. A Monte Carlo simulation approach is used to train the Artificial Intelligence model and assess its capabilities and limitations. The performance of the proposed model is compared with that of rule-based task selection methods.The preliminary experimental results indicate strong potential in employing reinforcement learning for real-time dispatch in warehouse environments.

1 INTRODUCTION

Industry 4.0 is being realized through the adoption of automation enabled by advancements in robotics, big data, and artificial intelligence (AI) along with technologies such as the Internet of Things and Digital Twin. This is enabling companies to create more efficient, adaptive, and resilient workspaces that are highly responsive to changing markets. In particular, the use of autonomous mobile robots (AMRs) is revolutionizing the material handling industry in terms of performing tasks such as storage and retrieval in warehouses. In these multi-agent (multiple AMRs) warehouse settings, there is a need to develop methods for effective AMR collaboration. In this research, we aim to develop AI methods for effective real-time, dispatching decisions in multi-agent warehouse environments.

2 MULTI-AGENT WAREHOUSE DISPATCHING

In automated warehouses, one of the difficult challenges with regard to effective use of multiple AMRs is real-time dispatching. Today, dispatching decisions are often based on rules such as highest priority or shortest distance. The shortest distance rule-based system has the advantage of reducing travel time but may lead to a situation where the storage or retrieval task is not completed on time or tasks that are furthest away in the warehouse are always given the least priority. On the other hand, the highest priority rule-based dispatching approach ensures all tasks are completed according to their ranking. However, the main drawback is that this approach often results in longer travel distances which may lead to higher costs. To overcome the drawbacks of these methods, AI-based methods can be used. In particular, reinforcement learning (RL) involves training an agent over many episodes to take desirable actions based on observations. RL algorithms have been used for rule selection for dispatching (Hu et al. 2020), task selection based on the current location of the agents (Wei et al. 2022), and layout-dependent, AMR dispatching (Malus et al. 2020). We develop a layout-independent, AI dispatching policy algorithm that overcomes some of the limitations of these methods.

3 AI AND SIMULATION APPROACH

The real-time dispatch of tasks is performed in a simulated warehouse environment. The current state of the simulated warehouse is the input to the AI algorithm approach of Deep Q Network (DQN) employed for the decision-making. The relevant information about the current state includes the distance traveled to complete each task, and the due date associated with it. The AMR dispatching decision is also feedback to the AI algorithm and is used for training the RL. The decision is executed and changes the state of the simulated warehouse. A high-level diagrammatic representation of the approach is shown in Figure 1.

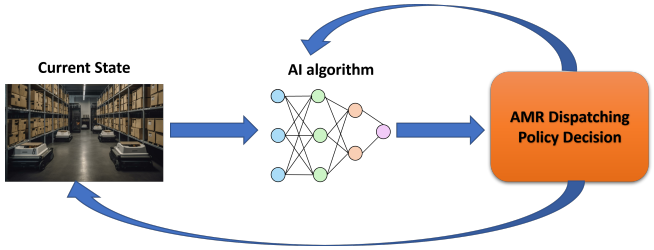

Figure 1: Diagrammatic representation of the real-time RL-based dispatch.

4 EXPERIMENTATION AND RESULTS

The RL algorithm is trained for 1,000,000 episodes where a single AMR is dispatched and 2000 episodes with multiple agents. Monte Carlo Simulation experiments of 100 episodes are used to analyze the performance of the RL-based real-time dispatch of tasks. The performance of the RL model is compared to that of the shortest trip rule-based system. The key performance measure used is the lateness in completing the task. When a single AMR is dispatched, the RL-based task assignment system reduces average lateness by 62% when due-date tightness is low and 13% with very tight due-date. When multiple agents are dispatched, RL improves on time task completion by 3% which can be improved by further training.

5 CONCLUSION AND FUTURE WORK

This research opens up vistas of possibilities in the integration of AI and simulation for material handling, particularly in the context of dispatching. For details of the AI and simulation methodology here, see our full paper in the WSC 2023 Proceedings (Bhattathiri et al. 2023). The potential outcome of this research envisions the deployment of a reinforcement learning model capable of making end-to-end decisions that involve the selection of appropriate tasks as well as other decisions such as avoiding areas of congestion during path planning and reacting to humans in the shared workspace. Incorporating these concepts into digital twin simulation models will help to move closer to the goals of intelligent material handling.

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