World Academy of Science, Engineering and Technology
International Journal of Industrial and Systems Engineering
Vol:19, No:02, 2025

Reinforcement Learning For Agile CNC Manufacturing: Optimizing Configurations And Sequencing

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Abstract : In a typical manufacturing environment, computer numerical control (CNC) machining is essential for automating production through precise computer-controlled tool operations, significantly enhancing efficiency and ensuring consistent product quality. However, traditional CNC production lines often rely on manual loading and unloading, limiting operational efficiency and scalability. Although automated loading systems have been developed, they frequently lack sufficient intelligence and configuration efficiency, requiring extensive setup adjustments for different products and impacting overall productivity. This research addresses the job shop scheduling problem (JSSP) in CNC machining environments, aiming to minimize total completion time (makespan) and maximize CNC machine utilization. We propose a novel approach using reinforcement learning (RL), specifically the Q-learning algorithm, to optimize scheduling decisions. The study simulates the JSSP, incorporating robotic arm operations, machine processing times, and work order demand allocation to determine optimal processing sequences. The Q-learning algorithm enhances machine utilization by dynamically balancing workloads across CNC machines, adapting to varying job demands and machine states. This approach offers robust solutions for complex manufacturing environments by automating decision-making processes for job assignments. Additionally, we evaluate various layout configurations to identify the most efficient setup. By integrating RL-based scheduling optimization with layout analysis, this research aims to provide a comprehensive solution for improving manufacturing efficiency and productivity in CNC-based job shops. The proposed method's adaptability and automation potential promise significant advancements in tackling dynamic manufacturing challenges.

Keywords : job shop scheduling problem, reinforcement learning, operations sequence, layout optimization, q-learning
Conference Title : ICIEEM 2025 : International Conference on Industrial Engineering and Engineering Management
Conference Location : Tokyo, Japan
Conference Dates : February 24-25, 2025