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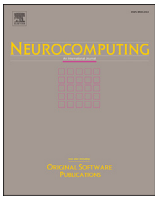

Optimizing two-machine scheduling in flexible manufacturing systems using autonomous AI and quantum computing

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HIGHLIGHTS

- A quantum processor-driven exact algorithm solves a problem of scheduling jobs on two machines in Flexible Manufacturing Systems (FMS).
- We introduce a quadratic unconstrained model for Adiabatic Quantum Computers (AQC) for solving the problem on D-Wave quantum computer.
- We propose a novel approach that leverages AAI having “solvers’ knowledge” to tackle the scheduling problem within FMS.

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ABSTRACT

This paper addresses the NP-hard problem of scheduling jobs on two machines in Flexible Manufacturing Systems (FMS), supported by Autonomous Artificial Intelligence (AAI), with the goal of minimizing the total weighted number of tardy jobs. We introduce a new mathematical programming model and quadratic binary programming for this problem. We propose a novel approach that leverages AAI with “solvers’ knowledge” to tackle the NP-hard scheduling problem within FMS. Additionally, we introduce a new quadratic unconstrained model for Adiabatic Quantum Computers (AQC) to address the two-machine permutation problem. The proposed algorithm can be executed using the LeapHybridCQMSampler or the DWaveSampler (referred to as AQC solvers). The main goal of the experiments that were conducted was to assess the feasibility of using autonomous agents and to compare the effectiveness of the proposed model. This work can be seen as a continuation of research on quantum optimization techniques for flexible production lines controlled by AI. The obtained results were compared with the state-of-the-art Gurobi solver. The results of the hybrid approach were identical to those obtained by Gurobi, optimal for small and medium-sized data, and comparable to the results of state-of-the-art metaheuristics: Tabu Search and Simulated Annealing.

1. Introduction

Today, Flexible Manufacturing Systems (FMS) represent a growing trend that minimizes production costs while supporting scalability in an uncertain business environment with changing priorities. FMS are typically associated with robotic technologies, which may or may not incorporate artificial intelligence (AI). Although robots without AI are capable of performing physical actions within the production process, their tasks typically depend on predefined programs executed in repetitive cycles and require human interventions to provide instructions. Robots should follow an optimized scheduling plan that minimizes overall production costs.

Connecting scheduling optimization and reasoning intelligence is essential. Reinforcement learning for dynamic scheduling was addressed by Hammedi et al. [20], while Bożejko et al. [11] explored quantum annealing for tardy jobs. The two-agent flowshop scheduling problem was examined by Ahmadi-Darani et al. [2], and metaheuristics for dynamic flowshop were studied in Ardakan et al. [4]. Quantum metaheuristics for scheduling were presented in Bożejko et al. [12]. Further, minimizing tardy jobs in flowshop was analyzed by Bulfin and

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