Chapter 23
Quantum-Inspired Genetic Algorithm for Workforce Scheduling in Supply Chain and Logistics Operations: A Lightweight Quantum-Inspired Genetic Algorithm

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ABSTRACT

This chapter introduces a lightweight quantum-inspired genetic algorithm (LQIGA) to tackle the challenges of workforce scheduling in supply chain and logistics operations, with a specific focus on outsourced workforce scheduling. LQIGA employs a novel lightweight qubit encoding approach, derived from quantum-inspired evolutionary algorithms (QIEA), to effectively represent complex problem constraints while maintaining flexibility. Experimental results on benchmark instances from CSPLib demonstrate the efficacy of LQIGA in consistently achieving optimal or near-optimal solutions within reasonable time-frames. Despite its lightweight nature potentially limiting control flexibility, particularly for larger-scale problems, the promising performance of LQIGA warrants further exploration. Additionally, future research directions, including quantum-inspired parallel annealing with analog memristor crossbar arrays, are discussed, highlighting the transformative potential of quantum-inspired computation in reshaping workforce scheduling and optimization in supply chain and logistics operations

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1. INTRODUCTION

Workforce scheduling plays a critical role in the supply chain and logistics industry, where efficiency and customer service are essential for maintaining competitiveness (Min and Zhou, 2002; Su and Liu, 2017). However, these industries face significant challenges due to labor shortages, which have been exacerbated by the pandemic (Kashem et al., 2004; Khor and Tan, 2023). Additionally, the pandemic has fueled the e-commerce boom, further increasing demand for services in this sector. For instance, there is a high demand for truck drivers, but finding qualified candidates is challenging. Similarly, warehouses are grappling with staffing shortages.

Improving workforce scheduling for warehouse employees and drivers is crucial for enhancing productivity and attracting skilled workers in this challenging environment. A comprehensive workforce optimization solution is key to addressing these challenges in supply chain and logistics operations (Keller et al., 2020).

(1) Workforce scheduling: Workforce scheduling involves assigning work tasks, physical locations, and other resources to individuals, a topic that has been extensively studied for several decades. However, recent global labor shortages and economic considerations stemming from the ongoing pandemic have brought renewed attention to this area from both academia and industry. Optimal workforce scheduling is not only economically beneficial but also crucial for maintaining service quality and competitiveness in the labor market (Porto et al., 2019).

Labor-intensive service industries, such as supply chain and logistics, often experience seasonal demand fluctuations and uncertainties due to global events like public emergencies. To remain competitive, these industries frequently outsource various business processes (Skipworth, Delbufalo, and Mena, 2020; Erdoğan, 2022). The competence and efficiency of these outsourced suppliers directly impact the overall effectiveness and efficiency of organizations (Dong et al., 2008). Small-scale outsourced workforce groups face significant pressure to meet increased demand, leading to a growing demand for wellbeing and fairness in work environments (Beaulieu, Roy, and Landry, 2018).

(2) Optimization in workforce scheduling: The projected workload provides a foundation for workforce scheduling, but it's often insufficient in today's volatile business environment. Planners struggle to adjust to demand fluctuations and allocate shifts effectively, especially during seasonal patterns, promotions, and holidays (Chen et al., 2023). Spreadsheets, the most common planning tool, are typically standalone and lack integration with other systems, making them inadequate for handling complex scheduling needs.

To address these challenges, many companies are turning to workforce scheduling solutions with forecasting and optimization capabilities. Advanced algorithms accurately predict workload and optimize shift assignments within minutes (Bhattacharjee et al., 2021). Scenario analysis features allow planners to compare different schedules based on various trade-offs, such as costs. Rosters are often drafted by decentralized teams and reviewed by a central planning team, which optimizes the hiring and deployment of temporary workers. These solutions also consider labor regulations and accommodate individual employee preferences. However, incorporating staff preferences into the schedule can be challenging. Mobile solutions provide a convenient way to gather employee preferences and integrate them into the schedule, enhancing flexibility and employee satisfaction.

(3) Constrained combinatorial optimization: Researchers have devoted significant effort to workforce scheduling, resulting in the development of various innovative approaches aimed at optimizing key performance indicators while satisfying problem-specific and domain-related constraints. The complexity of workforce scheduling has been identified as NP-hard constrained combinatorial optimization

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