

Improving Wave Order Picking Using Swarm Intelligence and new ACO variants

The significant increase in e-commerce purchases, from 7% in 2015 to 24% globally, has intensified the need for efficient logistics. This has led companies to transform their strategies to improve costs and time without compromising service quality. **Order batching** and **multiple picker routing** are the most labor-intensive activities in **wave picking** and have the greatest impact on total dispatch time. For multinational logistics companies, it is essential to design intelligent strategies that minimize the **makespan** of the wave.

The objective of this work is to improve **picker routing** by accelerating the search for optimal routes in complex, high-demand, real-world scenarios. We developed a hybrid model that combines **Simulated Annealing (SA)** with new variants of **Ant Colony Optimization (ACO)**, specifically **Rank-Based Ant System (RBAS)** and **Max-Min Ant System (MMAS)**. These strategies were accelerated using **multi-GPU** approaches to handle high computational loads and avoid local minima.

Our experimental results, conducted on a real-world dataset of 122,000 orders, show that the **RBAS** variant consistently outperforms the base **AS** algorithm, achieving up to a **2.25% reduction in makespan** for scenarios with a moderate number of items (70 items), and maintaining superior performance in the most complex cases (90 items). This validates the effectiveness of our hybrid approach and highlights its potential to improve logistical performance in real-world scenarios.

Keywords: E-commerce, Wave Picking, Metaheuristics, Warehouse Efficiency, ACO.

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