Integration of Task Scheduling and Robot Mobility in Collaborative Assembly Line Balancing

Haed Tavakkoli-Moghaddam[1,2], Alexandre Dolgui[1], Simon Thevenin[1],
Öncü Hazır[2], Maher Agi[2]

[1] IMT Atlantique, Nantes, France
{haed.tavakkoli-moghaddam, alexandre.dolgui, simon.thevenin}@imt-atlantique.fr
[2] Rennes School of Business, Rennes, France
{oncu.hazir, maher.agi}@rennes-sb.com

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1 Introduction

In the dynamic and rapidly evolving landscape of modern manufacturing, particularly in automated assembly lines utilizing collaborative robots, the challenge of advanced scheduling emerges as a critical concern [1]. This challenge extends beyond mere task distribution in stations and robot directives. An efficient schedule optimizes the task assignment and sequencing in the stations, the strategic mobility of robots within and across stations, and the smart selection of processing modes and job assignments at each station [2, 3]. Addressing these multifaceted issues is vital for improving operational efficiency in manufacturing environments [4].

The core complexity of this scheduling problem manifests in several areas: precise robot allocation and movement, strict task scheduling, and decisions on how tasks are executed, whether by humans, robots, or a collaboration of both. Due to this challenge, the efficient coordination of multiple robots across multiple stations can reduce cycle time, which is the main objective. Each decision regarding robot allocation and task scheduling significantly influences the overall system efficacy [5, 6]. Figure 1 illustrates an example of our problem with the task assignment to resources that are going to be allocated in each station. Variables of the model show various aspects of the production environment, including the unique capabilities of each station, the task precedence relationships, and the processing times for different modes (i.e., human, robot, and human-robot collaboration). This comprehensive approach aims to provide a robust solution to the scheduling challenges in such contemporary automated manufacturing is proposed.

2 Problem Solving Method

To solve this scheduling and line balancing problem, our methodology utilizes Gurobi Optimizer Software to solve the Mixed-Integer Linear Programming (MILP) model. The main objective of this model is to minimizes the cycle time, and the assignment and sequence of jobs across several stations and robots.

Due to the computational complexity of the MILP model, especially in large-scale instances, we employ a meta-heuristic algorithm based on Tabu Search (TS).

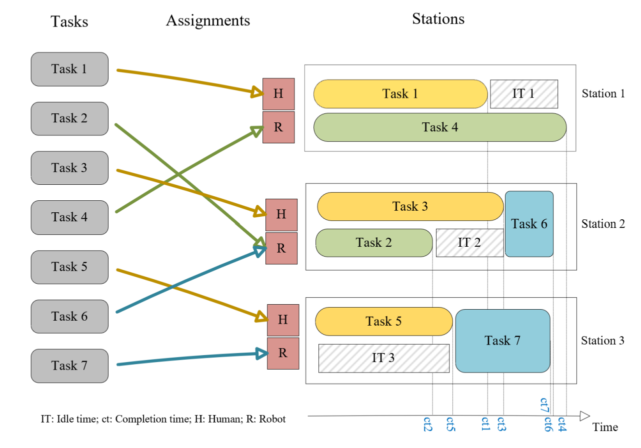

FIG. 1: Example of a collaborative assembly line with 7 tasks and 3 stations

3 Computational Experiments and Conclusion

A series of benchmark tests are performed to assess the efficacy of the MILP model with Gorubi and TS algorithm. These tests are conducted on scenarios involving 20, 50, and 100 tasks while keeping the number of stations constant. The experiments conducted in this study evaluate the scalability and adaptability of the production line. The results indicate that the MILP model demonstrates superior optimization performance in smaller instances, while the TS algorithm exhibits better scalability in bigger and more comprehensive scenarios. This suggests that there is considerable potential for its application in industrial settings to effectively address the challenges associated with automated assembly lines and robotic allocation systems.

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