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ORIGINAL RESEARCH PAPER

Assembly Line Balancing with Energy Consumption Optimization Using Substituted Tiki-Taka Algorithm

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Abstract

Assembly line balancing is assigning tasks to workstations in a production line to achieve optimal productivity. In recent years, the importance of energy studies in assembly line balancing has gained significant attention. Most existing publications focused on energy consumption in robotic assembly line balancing. This paper focuses on assembly line balancing with energy consumption in semi-automatic operation. The algorithm serves to improve the exploration to achieve a high-quality solution in a non-convex combinatorial problem, such as assembly line balancing with energy consumption. A novel approach called the Substituted Tiki-Taka Algorithm is introduced by incorporating a substitution mechanism to enhance exploration, thus improving the combinatorial optimization process. To evaluate the effectiveness of the Substituted Tiki-Taka Algorithm, a computational experiment is conducted using assembly line balancing with energy consumption benchmark problems. Additionally, an industrial case study is undertaken to validate the proposed model and algorithm. The results demonstrate that the Substituted Tiki-Taka Algorithm outperforms other existing algorithms in terms of line efficiency and energy consumption reduction. The findings from the case study indicate that implementing the Substituted Tiki-Taka Algorithm significantly increases line efficiency while simultaneously reducing energy consumption. These results highlight the potential of the proposed algorithm to positively impact manufacturing operations by achieving a balance between productivity and energy efficiency in assembly line systems.

Keywords Assembly line balancing · Energy consumption · Tiki-taka algorithm

Introduction

The manufacturing sector faces high electrical energy demand and cost challenges. With a significant percentage of global electricity consumption and carbon dioxide emissions attributed to manufacturing, there is a growing need for sustainable practices in the field (Azizi 2017). Engineers actively seek solutions to reduce the operational costs associated with electrical energy usage in production lines (Priarone and Ingarao 2017).

Assembly line balancing (ALB) is a manufacturing system problem that aims to optimize the assembly layout by assigning a balanced workload to workstations (Zhou and Kang 2019). ALB problems can be classified into simple assembly line balancing (SALB) and general assembly line balancing (GALB). SALB involves assembling a homogeneous product along with a conveyor, while GALB encompasses various ALB problems, such as mixed-model ALB, U-shaped ALB, and two-sided ALB. SALB can be further divided into three types: (1) SALB-I, which minimizes the number of workstations for a given cycle time; (2) SALB-II, which minimizes the cycle time for a given number of workstations; and (3) SALB-E, which considers minimizing the number of workstations and cycle time while measuring line efficiency or smoothness index (Abdullah Make et al. 2017).

Researchers have primarily focused on minimizing the number of workstations in SALB problems, followed by minimizing the cycle time and smoothness index of workload (i.e., workload smoothing). They have also explored additional constraints, such as worker assignment and resource minimization, to make the problem models more realistic (Li et al. 2021). Energy utilization in ALB has

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