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DEVELOPMENT OF AN AUTOMATIC ARRANGEMENT METHOD FOR ASSEMBLY BLOCKS IN THE SHIPYARD

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ABSTRACT

In the shipbuilding industry, ships are constructed from large, prefabricated blocks on fixed assembly workspace within a factory. The efficiency of the entire production schedule is highly dependent on how these blocks are arranged, as each has a unique geometry and a specific construction timeline. This study addresses this complex challenge by developing an optimization method for block arrangement. The proposed method utilizes the No-Fit Polygon (NFP) to handle complex geometric constraints and employs Simulated Annealing (SA) to find a near-optimal arrangement that enhances overall workflow efficiency.

1 INTRODUCTION

In modern shipbuilding, the efficient arrangement of prefabricated blocks on limited assembly workspace space is a critical factor for maintaining the overall production schedule. The arrangement is particularly critical for jig-equipped workspaces, as the support jigs are precisely configured to each block's curvature, making subsequent repositioning highly difficult. Therefore, the initial arrangement decision is critical for maximizing space utilization. However, this complex layout planning is still largely a manual, experience-based process, which struggles to keep pace with the increasing demand for production rationalization driven by digital transformation. This study proposes an automated method to address this optimization problem. We utilize the No-Fit Polygon (NFP) to manage the complex, irregular geometries of the blocks and employ Simulated Annealing (SA), a robust metaheuristic, to find a near-optimal layout. This study presents a practical application of the method, demonstrating its ability to generate a feasible schedule by effectively managing placement delays. This approach significantly reduces the time required for manual planning and enhances overall productivity by systemizing the complex scheduling process.

2 PROBLEM DESCRIPTION

The core challenge is to arrange a given set of prefabricated blocks onto a finite number of assembly workspace within a shipyard's assembly shop. This problem is governed by the physical layout and the initial state of the shop floor, which includes pre-existing blocks that are already fixed in place, acting as static obstacles for the new schedule. Each block to be arranged is defined by its unique geometry, weight, and a required production schedule. A feasible arrangement must satisfy numerous constraints, which can be categorized into two main types: physical and operational rules. Physical rules are the hard constraints dictated by equipment specifications and physical limits. These include staying within workspace boundaries, maintaining a minimum safety distance to prevent overlaps, and adhering to the capacity limits for block dimensions and weight. In contrast, operational rules represent the logic and best practices of the shipyard's workflow. These often user-defined rules include tasks such as placing designated block groups contiguously, restricting a specific block to a pre-assigned zone, or following specific placement preferences to optimize material flow. The primary objective is to find a feasible arrangement for all blocks. The method aims to place each block on its scheduled date, but if no space is available, it will systematically delay the arrangement to subsequent days until a valid position is found. The goal is to successfully schedule all blocks while minimizing the overall delay and reducing the manual planning time.

3 PROPOSED METHODOLOGY

Our proposed method solves the block arrangement problem through the hierarchical process illustrated in Figure 1. The overall workflow begins by loading the input data, which includes the geometric and schedule information for all blocks requiring arrangement, as well as the specifications of the assembly workspace. The core of the method then iterates through each block, assigning it to the most suitable assembly workspace using a metaheuristic optimization approach. For each block, the method enters an evaluation loop that assesses every available assembly workspace. This is where the No-Fit Polygon (NFP) comes into play. For a given assembly workspace, the NFP is calculated between the target block and all blocks already present. The boundaries of these NFPs provide a set of feasible candidate coordinates. Rather than a random choice, a set of pre-defined arrangement strategies is applied to select the best coordinate from these candidates, reflecting real-world logic such as proximity to a main gate or crane capacity. After evaluating all assembly workspace, the Simulated Annealing (SA) algorithm, our chosen metaheuristic, determines the optimal assignment of the block to an assembly workspace. SA intelligently explores various assignment combinations based on the calculated costs, seeking a near-optimal solution that maximizes the overall efficiency of the shop floor layout. Once the assignment is confirmed, the block is virtually arranged, and the process repeats until all blocks have been scheduled. While the current application simplifies blocks to rectangles, the NFP-based approach was deliberately chosen for its inherent scalability to handle arbitrary polygonal shapes.

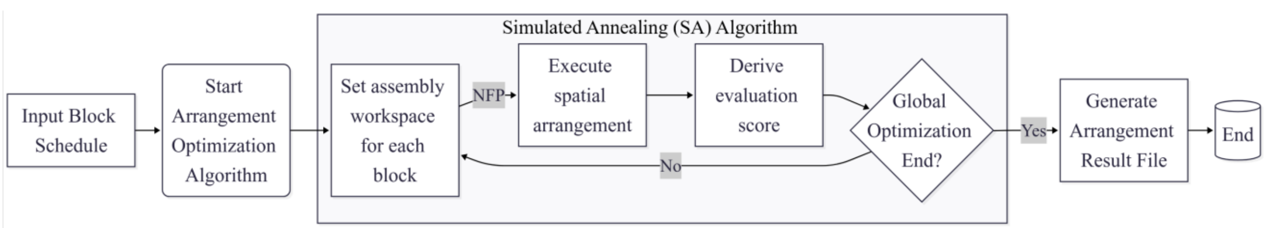

Figure 1. The overall process of the proposed method.

4 APPLICATION AND CONCLUSION

The proposed method was applied to a real-world block arrangement scenario at the assembly shop. The task involved scheduling a typical workload of a 3-to-6-month period, which includes several hundred blocks, onto the available assembly workspace, adhering to all previously defined constraints. Our method successfully generated a valid layout that satisfied all physical and operational rules. The most significant outcome was the drastic reduction in planning time: a task that typically takes several hours of manual effort by an expert planner was completed in 10 to 30 minutes, depending on the schedule's complexity. In conclusion, this study demonstrates that the NFP-based automated arrangement method is a practical and efficient solution. It not only systemizes a complex, intuition-based task but also provides a significant time-saving benefit, allowing for more agile and responsive production planning in the shipyard.

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