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OPTIMIZATION OF FLAT BLOCK ASSEMBLY LINE USING CONSTRAINT PROGRAMMING AND DISCRETE-EVENT SIMULATION

Dong Hoon, Kwak
Ki Young, Cho
Hee Chang, Yoon

Dept. of Naval Architecture
and Ocean Engineering
1, Gwanak-ro, Gwanak-gu,
Seoul, 08826, REPUBLIC OF KOREA

Jong Hun, Woo

Dept. of Naval Architecture
and Ocean Engineering
Research Institute of Marine
Systems Engineering
1, Gwanak-ro, Gwanak-gu,
Seoul, 08826, REPUBLIC OF KOREA

ABSTRACT

Scheduling of flat block assembly in a shipyard is crucial for productivity performance due to the high level of workload. This problem is commonly known as the permutation flowshop scheduling problem (PFSP) in operation research, which has been extensively studied in various papers since the 1950s. However, existing solutions often involve simplifying real-world problems with certain assumptions, limiting their practical applicability. In recent times, constraint programming (CP) has emerged as a strong alternative to exact algorithms and has been successfully applied to various PFSP, addressing the limitations of exact algorithms. In light of this, our study proposes a two-step optimization process to overcome the existing limitations composed of a CP and discrete-event simulation(DES).

1 INTRODUCTION

Hull block assembly process is one of the main processes in shipbuilding industry, where block parts and sub-blocks are assembled to form a larger block. The hull blocks can be classified into two types based on their shape: flat blocks and curve blocks. As ship size has increased, most blocks are flat blocks (Yang et al., 2019). Therefore, scheduling flat block assembly line in shipyard is crucial for overall shipbuilding performance. The scheduling problem of the flat block assembly line can be defined as a typical permutation flow-shop scheduling problem (PFSP) in operation research (OR). This paper introduces a study that applies constraint programming (CP) and discrete event simulation (DES) for optimizing flat block assembly line. CP searches for block sequencing candidates considering feasible constraints, and DES determines the optimal solution among the candidates with constraints that CP cannot consider. Although CP is widely used in scheduling optimization problems, it has limitations in reflecting all the constraints associated with actual production environments. Therefore, in this study, DES was applied to evaluate the optimal sequencing candidates output as a result of CP.

2 OPTIMIZATION STRATEGY

This study adopted two stage optimization process composed of CP and DES. Among the scheduling optimization studies, it is common to find researches that performs optimization through the combination of meta-heuristic algorithms such as genetic algorithm (GA) or simulated annealing (SA) and simulation. These studies use a model that repeats the process of exploring solutions with meta-heuristic algorithms, evaluating fitness with simulation models, and updating the value of objective function. The framework proposed in this paper, differs fundamentally in the optimization process, as it sequentially performs final evaluation through the simulation model for some solutions after the optimization technique.

Figure 1 illustrates the hierarchical scheduling process that integrates the optimization model with the simulation model. The process begins with the target blocks being fed into the optimization model, which then searches for the optimal sequence based on the objective function and the constraints. During the search, the optimization model generates feasible solutions while continuously updating the objective function. In the optimization stage, the reality is simplified due to complexity and search efficiency. Therefore, the solutions from optimization are then validated using the simulation model, which accurately reflects the reality. This integrated approach ensures that the scheduling solutions are optimal and practical when applied to real-world scenarios.

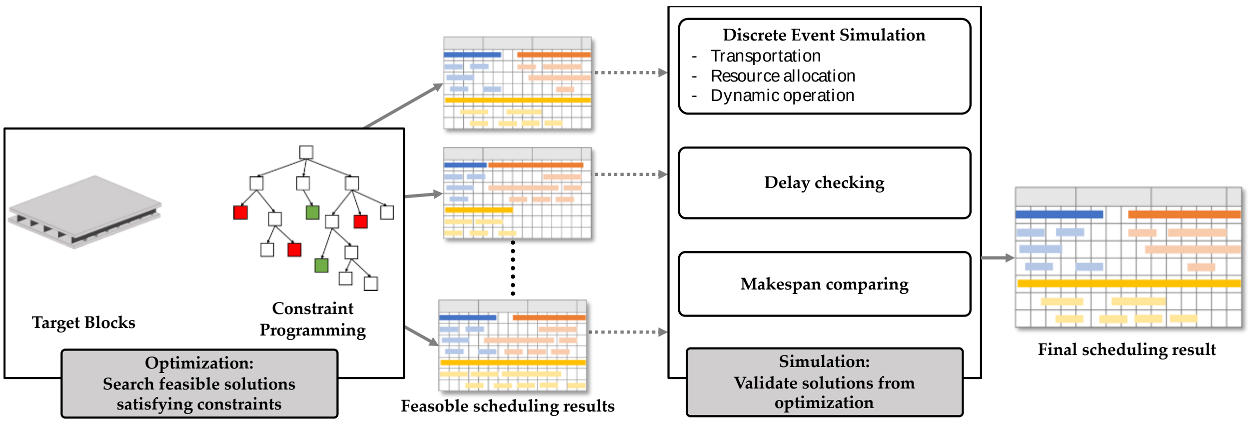

Figure 1: Process of CP and DES based optimization.

3 EXPERIMENT

Table 1 Feasibility and makespan results calculated using optimization model

Index	Makespan (CP)	Makespan (Sim)	Difference (%)	Delayed	Search period (s)
1	17,674	18,570.79	4.83	N	455.8
2	17,667	18,814.97	6.10	N	573.3
3	16,801	18,462.09	9.00	N	870.1
5	16,594	18,107.56	8.36	N	1,034.3
6	16,594	18,088.56	8.26	N	1,140.3
14	16,572	17,255.12	3.96	N	2,860.0

To evaluate the optimization performance, an experiment was conducted on 69 blocks. As a result of DES validation for the 27 solutions output by the CP model, it was found that 6 solutions were reasonable depending on whether or not there was a delay. Table 1 shows information of the 6 solutions that consist of solution index, makespan by CP model, makespan by DES, difference between makespan of CP and DES, delay or not, and search period. The 14th solution was confirmed to be the best, and the makespan difference between CP and DES proved the validity of the optimization methodology in this study .

REFERENCES

Yang, Z., C. Liu, S. Zhang, and J. Shi. 2019. “A Multi-Objective Memetic Algorithm for a Fuzzy Parallel Blocking Flow Shop Scheduling Problem of Panel Block Assembly in Shipbuilding.” *Journal of Ship Production and Design* 35(02):170–181.