An Operating System Design and Development for Efficient Painting Process

Kuy-Hoon Chung[1]*, Tae-Hyun Baek[2], Ju-Chull Park[3], and Kyu-Kab Cho[4]

[1,2]HIRI, Hyundai Heavy Industries CO., LTD., [3]Department of Industrial Engineering University of Ulsan, [4]Department of Industrial Engineering Pusan National University

In this study, we design a scheduling system for painting shop, called HYPOS(HYundai heavy industry Painting shop Operating System) and develop a system implementing the design. The painting shop operations are currently scheduled manually by experts. Manual scheduling is a serious time consuming job and generally can not guarantee a full optimality. Building a traditional heuristic scheduling system for this problem, however, is not promising because there are various kinds of constraints to be satisfied including space allocation of shipbuilding blocks in a painting cell. We, therefore, adopt a spatial scheduling approach and develop scheduling algorithms based on field-oriented scheduling heuristics and computational geometry. And we show that the algorithms can successfully be applied to the painting shop scheduling problem.

1. Introduction

Painting shop in heavy industry provides working space for blasting and paint spray jobs for hull blocks to protect them from corrosion.

Painting stage is located between block outfitting and pre-erection stages, which are the main stream of the whole hull-block production process. The performance status of painting process influences the whole shipbuilding processes such that its low performance directly results in either chaos of the following processes or late delivery of the ship. Therefore, production scheduling at the painting stage needs more close control than others do because its operation highly depends on the weather condition and the limited space of painting cells. For this purpose, we develop a spatial scheduling system called HYPOS (HYundai heavy industry Painting shop Operating System) as an alternative for the conventional, manual one. The system tries to meet the delivery schedules given from shipyard production planning system while balancing workload and utilizing cell spaces efficiently.

The spatial scheduling, which determines production dates considering products space arrangement at a fixed workstation, have been tried variously in shipbuilding. Lee and Lee[1] studied a spatial layout of ship blocks at the curved block assembly shop in shipbuilding. Their approach was based on the works of Pérez[2] and the computational geometry theory [3]. In this study Lee and Lee employed Pérezs two-dimensional arrangement algorithm for spatial layout of convex polygons in a rectangle and extended it to three-dimensional dynamic spatial scheduling including time axis. Koh, Park, Choi, and Joo[4] also tried to developed a spatial scheduling application to shipbuilding. They divided the original problem into two-phase problems; scheduling and spatial layout. The scheduling phase devoted to find the schedules balancing workload, whereas the layout phase arranged ship blocks satisfying the determined schedules. But both Lees theoretical approach and Kohs practical one were not enough to real world application. They both suffered from a few blocks failed to be arranged on schedule, which made the whole schedules infeasible. In practice, a user-interactive computing environment with drag-and-drop facility where user arranged blocks by his own judgement on computer monitor was more operative, even though it was somewhat time-consuming job[5].

The purpose of this study is to design a practical system enabling both to maximize space utilization and to balance workload. For this purpose, various optimization and heuristic algorithms are introduced, and interactive system functions supporting decision-maker are also incorporated.

2. Approaches and System Modules

Currently, the painting shop suffers from delayed delivery. Its on-time delivery rate is usually lower than 70% as shown in the Figure 1.

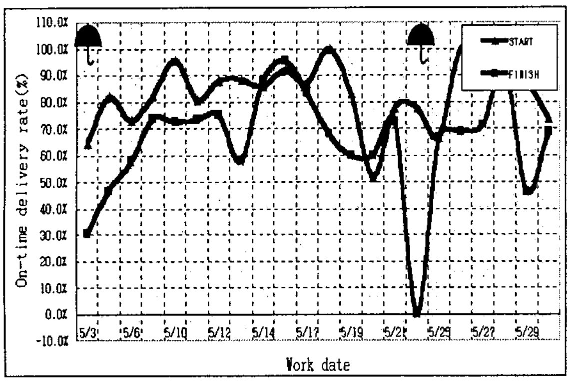

Figure 1. Typical example of ratios of on time starts and finishes in a painting shop.

2.1 Approaches

To improve the performance efficiency, we adopted the monthly and daily planning functions, the statistical analysis function, and the functions of work order releasing and gathering past records. We also developed the operating algorithm functions optimizing schedule and arrangement.

2.1.1 Monthly Planning Function

The first two causes mentioned above are mainly originated from outside sector of painting shop, thus make it impossible to control from the shop. We can possibly deal with the problems if we can forecast the amount. Monthly planning function will allow development of alternative production route in case of delaying of the original production schedule. On a monthly base, it will decide days of holiday work, hours of overtime, and outsourcing amount through the load analysis. It also determines schedules and arrangements of the shop using spatial scheduling algorithms for each month.

2.1.2 Statistical Analysis Function

This function analyzes historical data and evaluates past performance. The analyses on duration, work progress, space utilization, and manpower usage are conducted based on the historical records. The derived statistics are used to evaluate the system performance and will be used to trigger the monthly planning function as feedback data. This function coupled with monthly planning will contribute to nullify outside causes on delayed delivery.

2.1.3 Daily Planning Function

The acting plan for schedule and arrangement can be prepared only on a daily base because the finishing date of preceding stage is known with certainty just after actual finishing time. Daily planning function extracts ship block candidates from shipyard process monitoring system and provides acting schedules and prepares actual block arrangements in painting cells. To accommodate possible delays in schedule due to manpower and space limits, daily plan is developed under the time horizon of three or four days interval. This function also uses spatial scheduling algorithms similar to those used in the monthly plan.

2.1.4 Work Order Function

Work order function allocates specific tasks to each worker and gathers past records on the actually implemented tasks. It will execute the daily plan. And the accumulated historical data from the worker order function are used as a database for statistical analysis.

2.1.5 Operating Algorithm Functions

Both monthly and daily planning functions require specific schedule and arrangement of candidate blocks. Operating algorithms will determine the most promising one out of many possible schedule and arrangement alternatives. We propose two phase algorithm in which load-balanced schedules are initially developed and then blocks are arranged in cells maximizing space utilization. Some details on the algorithms are covered later in this paper.

2.2 System Modules

We propose a design scheme having three different but interacting operating modules based on the functions mentioned above. They are Planning, Dispatching, and Work Order modules.

The Planning module develops monthly and weekly operating policies of painting shop to satisfy the delivery dates given from shipyard production planning system. It analyzes capacity and load considering total work days, worker attendance figures, and weather forecast, and decides monthly production schedules. This module encompasses both the monthly planning and the statistical functions. The Dispatching module is used as a daily schedule builder. It generates acting schedules including operations, moving, and inspection, and automatically develops block arrangement drawings for painting cells using spatial scheduling algorithms. The Work Order module allocates all workers to specific jobs, gathers actual records, and triggers the various requests such as moving vehicle, and inspection.

We include another system module called DB Manager to manage and to transfer data between DB and outside system. Client programs are coded with Power Builder and Visual C++. The main data flow diagram(DFD) is shown in Figure 2.

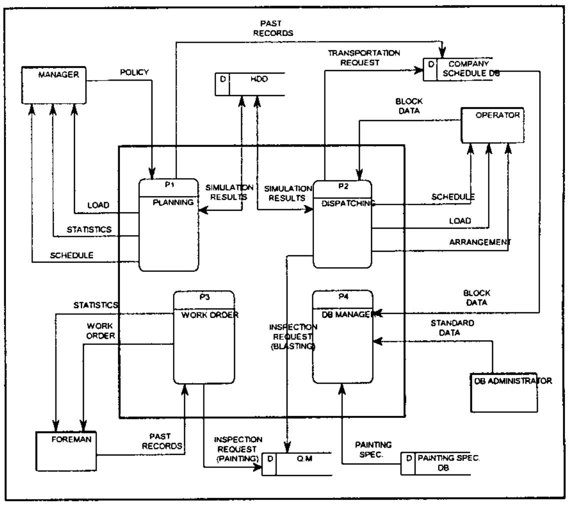

Figure 2. Main data flow diagram of the HYPOS.

3. Operating Algorithms

In this section, we present details of scheduling and arrangement algorithms, which are used for monthly and daily plans. Since algorithms used are similar to the one used in its main stream configuration, we only focus on those in a daily plan.

3.1 Operating Characteristics

Painting process is composed of blasting and painting jobs. The blasting, the initial stage of painting process, is performed in indoor cells confined by walls and roof, where several blocks are placed and being blasted simultaneously. Blocks stay one day in the blasting cells, and then altogether are moved to painting cells. The paining job is divided into several sub-processes: first spray, touch up, second spray, thickness check and revision, final touch up, and final inspection. Figure 3 shows standard painting processes.

Since a typical painting job takes five days long, the required space of the painting cells should be at least five times large than that of blasting cell to match blasting capacity. The shipyard studied in this paper has far less painting space than what required, and thus only parts of painting job can be performed in indoor cells. Considering the poor quality of the outdoor painting, shop managers try to maximize indoor painting by arranging blocks efficiently.

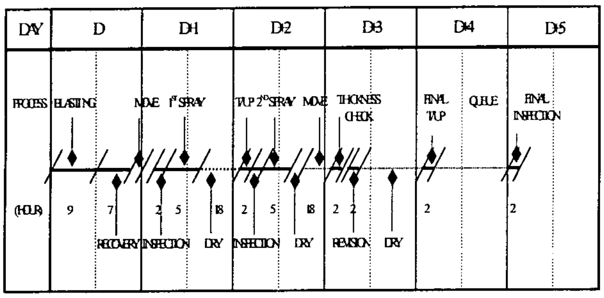

Figure 3. Standard painting processes.

A block entered to the painting shop is assigned to a worker group who takes charge of the block during the entire painting processes. The shop manager also tries to allocate block to worker groups evenly to minimize uneven workload between each worker group.

3.2 Algorithm Structure

Painting shop operating algorithms are composed of the followings;

- the block allocation algorithm that determines the number of blocks to be processed each day,
- the team allocation algorithm that allocates blocks to worker groups(team),
- the block arrangement algorithm that arrange blocks in blasting and painting cells.

Since the block arrangement algorithm is conducted simultaneously with the team allocation algorithm, the total structure of the operating algorithms is considered to have two phases which are the daily load balancing with capacity limit and the team allocation considering arrangement each day. Figure 4 shows the entire flow.

3.2.1 Block Allocation Algorithm

This algorithm distributes blocks arrived at painting shop over planning horizon trying to maximize the amount of indoor painting. Blocks allocated each day should also meet the shops capacity limits. In this algorithm we do not consider actual arrangement but considered only capacity limits such as total space available or manpower limits.

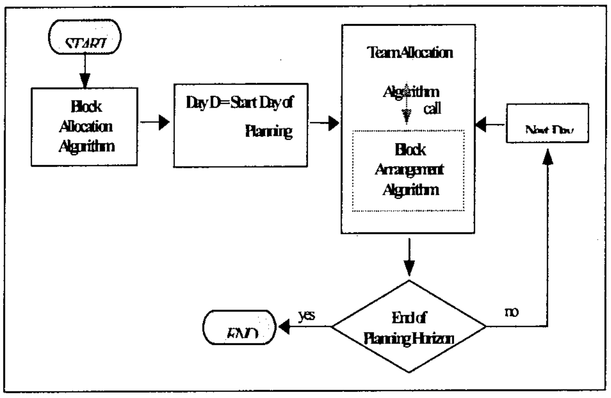

Figure 4. Entire flow of operating algorithm.

3.2.2 Team Allocation Algorithm

This algorithm allocates blocks to team to balance workload between teams while checking block arrangements. Arrangement is checked by calling the arrangement algorithm which will be described in the following section. The algorithm allocates blocks until the number of blocks allocated reaches at the target already set by the block allocation algorithm. The remaining blocks go to next day for later team allocation.

The team allocation algorithm is composed of several heuristics based on the rules currently used by a field expert of painting shop.

3.2.3 Block Arrangement Algorithm

Since a schedule plan can not be settled until arrangement, this algorithm will finalize the plan or to check its feasibility. It also optimizes the usage of indoor cells which are the critical resources in this work scope.

Block arrangement algorithm arranges blocks in cells with their actual 2-dimensional shapes. We use the same configuration space approach of the previous studies[1,2,4,5]. We only customize them to fit the painting shop environment. Thus, we do not include the details in this paper.

4. A Prototype System

We have developed a prototype system to show the image of the final system. In this prototype, some of the major functions are selected, such as.

- Daily planning function: user interactive planning functions with the drag-and-drop facility, automatic planning function using algorithms, and graphic user interfaces.
- Work order function: work order processing (blasting and painting), past record keeping, and organization chart processing.
- Operating algorithm: team allocation algorithm, and arrangement algorithm
- Database

Block allocation algorithm is not included in this prototype. Since block arrivals are usually more than capacity at these days, blocks are allocated near to the full capacity, which makes the number of blocks allocated daily being automatically determined.

5. Conclusion

In this study, a system design for operating the painting shop in shipbuilding is proposed. The system consists of three modules of Planning, Dispatching, and Work Order, which performs monthly planning and statistical analysis, daily scheduling and two dimensional block arrangement in painting shop, and allocation of workers to tasks, respectively. Planning and Dispatching modules use several optimizing algorithms for block allocation over time horizon, team allocation, and block arrangement. We build a linear IP model for block allocation over time. Heuristics based on field rules are proposed for team allocation, which checks block arrangement in its application. For block arrangement we use the configuration space approach of Pérez. A prototype system focusing daily planning and work order is also developed to test key parts of the final system.

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