MODELLING FOR ENGINEERING & HUMAN BEHAVIOUR 2019

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Instituto Universitario de Matemática Multidisciplinar
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Contents

3

A Heuristic optimization approach to solve berth allocation problem

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1 Introduction

One of the main consequences of Globalization is the development of international trade (imports and exports). This fact leads to an increase in vessel transports and container manipulations. To get an idea about the magnitude of the problem, while in Busan port (South of Korea) in 2011 they were operating more than 10000 twenty-foot equivalent unit (TEU, unit to measure containers), in April of 2013 they were handling 18000 TEU, almost twice.

The requirements for hub ports have also changed and developing new strategies in container manipulations is becoming really important. Some shipping lines require new performance levels from terminal as a part of the contract conditions, as the throughput rate per berth, the turnaround time of a vessel or the increment of the rate containers movements, among others [2].

The aim of this contribution is the development of a new approach to find the optimal planning of docking the vessels. Berth planning is defined as the process of establish the best outline of the vessels in the corresponding berths and the display of Quay Cranes (QC) in order to minimize the cost of the terminal and maximize the service of the containers movements. It is a complex problem because the QC deployment is closely linked with the best berth outline.

In the literature, depending on the initial display of the vessels, we can study two different situations: the first is named Static Berth Allocation Problem (SBAP) and it considers that all the vessels are in the anchoring spot waiting to be docked; the second, named by Dynamical Berth Allocation Problem (DBAP), assumes that the vessels arrive dynamically. The interesting problem for the terminal is the second one because all the vessels arrive at different times. With the technique we propose, we can solve both problems, nevertheless, as the aim of this paper is also to study the goodness of our method, we will use SBAP because it is easier to obtain the exact solution for SBAP than for DBAP.

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This abstract is organized as follows. In Section 2 we describe the approach to establish the best planning of the berth allocation problem. Section 3 is devoted to prove the goodness of our approach. Finally Section 4 is addressed to conclusions.

2 Procedure design

In this section we explain the procedure of assigning the vessels in the corresponding berth. It is based on an optimization technique, so we need two elements: a fitness function and an heuristic approach. Without loss of generality we consider that there is only one QC per berth. The case with more than one QC per berth is analogous but taking into account different unloaded time of the vessels.

2.1 Fitness function

In the literature we can find several fitness functions [1]. Depending on which one we use, we can benefit the terminal or the shipping line, since their interests are not the same. While the main aim of the terminal is to minimize its economic cost, the aim of the shipping line is to have its vessels unloaded in the shortest time. The fitness function we use is a simplification of the one we find in [1, Section 2]. It is defined as the sum of the waiting and operating time of the vessels in the different berths, understanding as operating time the period that the vessel needs to be docking, unloading, loading and setting sail. This function has been chosen because benefits the shipping line and terminal, as it minimizes the time that vessels are waiting for and operating also it allows that the terminal could deal with more vessels.

Figure 1 shows an example of a berthing plan with two berths m_1 and m_2 and seven vessels b_1, b_2, b_3, b_4, b_5, b_6 and b_7. The squares represent the vessels and the numbers inside the squares represent the operating time of each vessel. The red numbers are the times the vessels are waiting for and operating. Then, the cost of this berthing plan is the sum of all the red numbers

$$2 + 2 + 4 + 2 + 4 + 3 + 1 + 1 + 7 + 1 + 7 + 2 = 34.$$

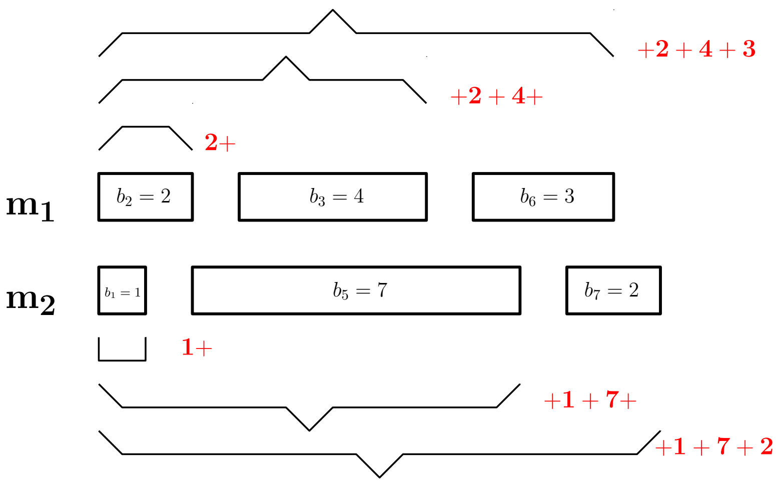

Figure 1: Example of a berthing plan and computation of its cost

2.2 Heuristic technique

This section is devoted to define the heuristic approach that allows us to minimize the fitness function given in Subsection 2.1. Our technique consists of making changes in the vessel's position and compare the new solutions with the past ones. Moreover we need to take into account some issues:

- The vessels are moving one by one, is other words, in the same iteration we can only make one movement.

- If we move a vessel and the new solution is better than the previous one, that vessel are not going to move in the next 10 iterations.

In Figure 2 we can see graphically different movements of our heuristic approach, the red lines represent the new changes in the vessels position.

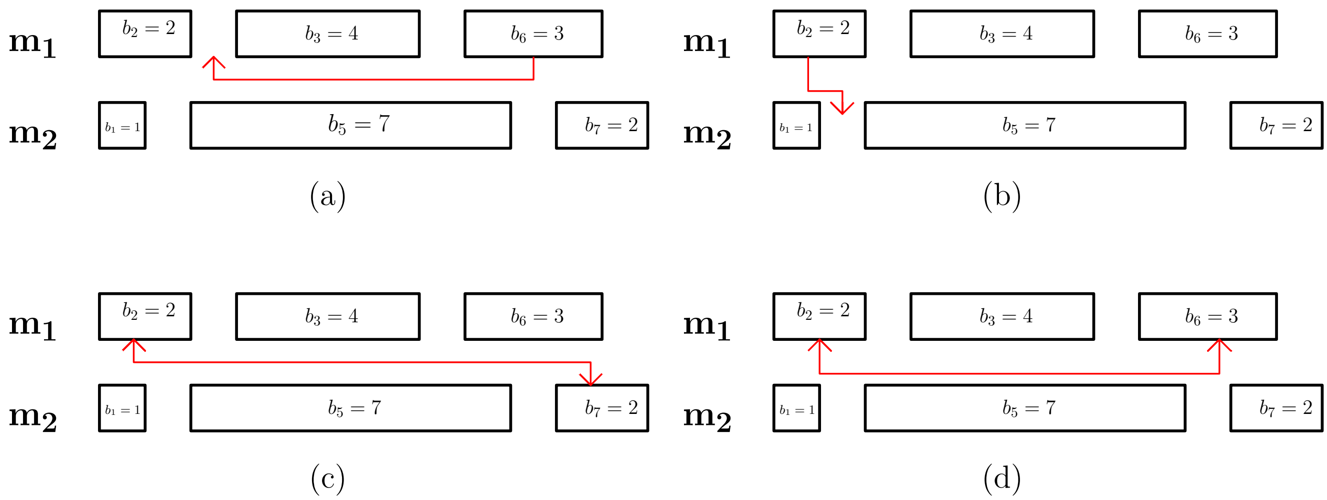

Figure 2: Different moves of the heuristic approach, for example changing the position of a vessel in the same berth (a), add a vessel in other berth (b), exchange two vessels in different berths (c), exchange two vessels in the same berth (d).

3 Results

The aim of this section is to prove the goodness of our method. To do so, we have develop an example with 4 berths and 6 vessels. Considering 6 different situations of operation times of vessels, in Table 1 we show in the first column the exact solution, in the second the best solution given by the heuristic approach and in the third the relative error. As we can see the magnitude of the relative error is 10^{-2}, thus we can verify the goodness of our approach.

	Best solution	**Heuristic solution**	**Relative error**
Situation 1	167.11	167.51	0.002387
Situation 2	165.60	165.80	0.001206
Situation 3	165.82	165.82	0
Situation 4	163.87	163.87	0
Situation 5	165.91	165.91	0
Situation 6	167.87	167.94	0.000416

Table 1: Relative error between the exact solution and the heuristic solution of the static berth allocation problem.

4 Conclusions

In this contribution we have develop a heuristic approach to find an optimal solution of berth allocation problem. In order to prove the goodness of our method we have considered SBAP and we have compared the results obtained with our heuristic algorithm and the exact solution. Their relative errors are low enough to conclude that we have develop an appropriate heuristic.

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