The PRIN SPORT's web solver

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1 Introduction

2 The Block Relocation Problem

Let $\mathcal{S}$ be a system (yard) defined by w stacks of capacity (in terms of available slots/tiers) h and let $\{1, \ldots, n\}$ be a set of n blocks located in the slots of the w stacks. A *reshuffle operation* (or simply a *reshuffle*) is a movement of a block from a stack to another, while a *retrieval* is a movement of a block from a stack to the outside of the system. The stacks can store blocks according to a last-in / first-out policy. In a stack, only the topmost block is accessible and, when a block has to be retrieved, all the blocks above it have to be reshuffled. When a block is reshuffled and moved in one of the other stacks of the yard, it has to be allocated in the first slot available from the bottom to the top.

The Block Relocation Problem (BRP) consists in deciding where to reallocate every block that is moved by a reshuffle operation, in order to minimize the total number of reshuffles needed to retrieve all the blocks according to the retrieval order (1,...,n). Figure 2.1 gives an example of the BRP with a system defined by $w = 3$ stacks, $h = 3$ available slots for each stack, and $n = 6$ blocks. Starting from the initial yard, the sequence of movements of an optimal solution is reported. At each step, the next block to be moved with a reshuffle or a retrieval operation is highlighted in gray. The minimum number of reshuffles required is three: block 6 is reshuffled in order to retrieve block 1; block 5 is reshuffled to retrieve block 2; we then reshuffle block 6 to retrieve block 4. Since BRP generalizes the Bounded Coloring Problem (also known as Mutual Exclusion Scheduling) on permutation graphs, it is known to be NP-hard for any fixed $h \geq 6$. For some complexity results on BRP, Bounded Coloring and related problems, see Caserta et al. (2012), Jansen (2003), Bonomo et al. (2011), and Bacci et al. (2017).

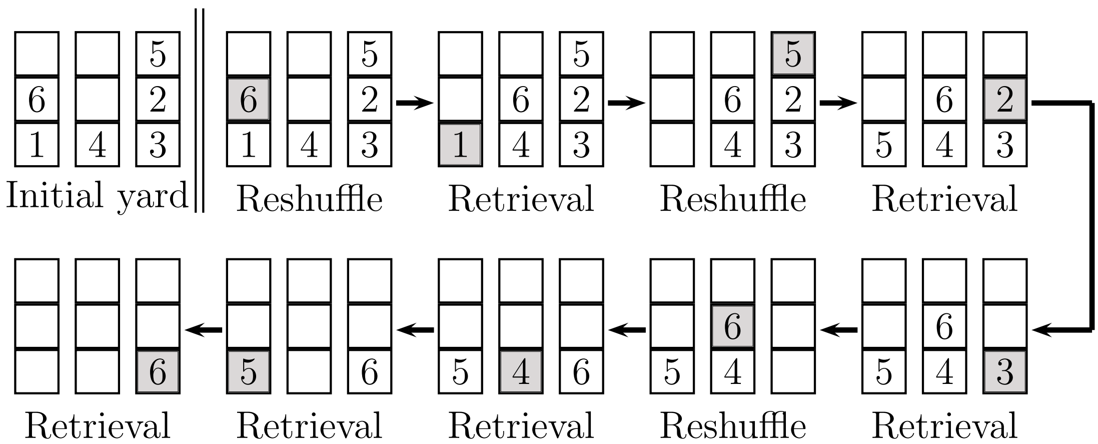

Figure 1: A representation of an optimum solution for the Block Relocation Problem.

A real world application of the BRP arises in the logistics of containers in a terminal. A container terminal is an area where containers are stored and transshipped between different transport vehicles, such as cargo ships, trains, trucks, and where they are stacked because of the limited storage space. The storage area (yard) is often divided into groups of stacks of containers, called bays, and containers are moved by yard cranes. The movements of containers may occur within the same bay or between different bays. Typically, a container yard stores at the same time thousands of containers grouped into hundreds of stacks with a storage capacity which may be up to 10 slots. Since a stack is accessible only from the top, when a container is required outside of the storage area, any container located above it has to be moved to another stack by a yard crane with a reshuffle operation. Reshuffle operations are time-consuming and they have to be avoided as much as possible. In this scenario, the Block Relocation Problem consists in finding a way to retrieve, in a given order, all the containers in the container yard so to minimize the number of reshuffle operations.

In the literature, two variants of the BRP are studied: *restricted* and *unrestricted*. In the restricted version, it is allowed to reshuffle only blocks located above the next one to be retrieved, while, in the unrestricted case, any block can be reshuffled.

Given an input instance, the PRIN SPORT's web solver at allows to compute a heuristic solution by means of the Bounded Beam Search algorithm (BBS), introduced by Bacci et al. (2018), for the restricted BRP. In Bacci et al. (2018), the BBS is compared with many other heuristic algorithms, showing to be very effective for the problem.

In Section 2.1, it s given a description of the input instance format for the BBS, while in Section 2.2 we describe the output produced by the heuristic.

2.1 Input Format

The PRIN SPORT's web solver for the Block Relocation Problem accepts an instance in the following format:

$$\begin{array}{l} w\ h\ n \\ k_1\ m_{1,1}\ m_{1,2}\ \ldots m_{1,k_1} \\ k_2\ m_{2,1}\ m_{2,2}\ \ldots m_{2,k_2} \\ \vdots \\ k_w\ m_{w,1}\ m_{w,2}\ \ldots m_{w,k_w} \end{array}$$

where

- w : number of stacks
- h : height of each stack

- n : number of blocks
- k_i : number of blocks in stack i in the initial yard, for $i = 1, \ldots, w$
- $m_{i,j}$: priority order of item located in slot j of stack i, for $i = 1, \ldots, w$ and $j = 1, \ldots, h$.

Any input file name is accepted from the web solver. For example, the input format for the instance in Figure 2.1 is the following:

```
3 3 6
2 1 6
1 4
3 3 2 5
```

2.2 Output Format

The web solver for the BRP produces a single `solutionBRP.csv` file. At the beginning of the file, the solution value and the computational time of the BBS, and the initial yard are reported. Then, a yard for each reshuffle and retrieval operation required is shown in order to present the solution. Next to each yard, it is described the item, the origin and destination stack for a reshuffle operation, and the item in case of retrieval.

In Figure 2, the output produced for the instance of Figure 2.1 is reported.

References

T. Bacci, S. Mattia, and P. Ventura. Some complexity results for the minimum blocking items problem. *Springer Proceedings in Mathematics and Statistics*, 217:475–483, 2017.

T. Bacci, S. Mattia, and P. Ventura. The bounded beam search algorithm for the block relocation problem. *Computers & Operations Research*, ?:???–???, 2018.

F. Bonomo, S. Mattia, and G. Oriolo. Bounded coloring of co-comparability graphs and the pickup and delivery tour combination problem. *Theoretical Computer Science*, 412(45):6261 – 6268, 2011.

```
                    Solution Value = 3, CPU time = 0.000498

|---|  |---|  |5|
|6|    |---|  |2|
|1|    |4|    |3|    Initial Yard


|---|  |---|  |5|
|---|  |6|    |2|
|1|    |4|    |3|    Resh Item 6 from Stack 1 to Stack 2


|---|  |---|  |5|
|---|  |6|    |2|
|---|  |4|    |3|    Retrieve Item 1 from Stack 1


|---|  |---|  |---|
|---|  |6|    |2|
|5|    |4|    |3|    Resh Item 5 from Stack 3 to Stack 1


|---|  |---|  |---|
|---|  |6|    |---|
|5|    |4|    |3|    Retrieve Item 2 from Stack 3


|---|  |---|  |---|
|---|  |6|    |---|
|5|    |4|    |---|  Retrieve Item 3 from Stack 3


|---|  |---|  |---|
|---|  |---|  |---|
|5|    |4|    |6|    Resh Item 6 from Stack 2 to Stack 3


|---|  |---|  |---|
|---|  |---|  |---|
|5|    |---|  |6|    Retrieve Item 4 from Stack 2


|---|  |---|  |---|
|---|  |---|  |---|
|---|  |---|  |6|    Retrieve Item 5 from Stack 1


|---|  |---|  |---|
|---|  |---|  |---|
|---|  |---|  |---|  Retrieve Item 6 from Stack 3
```

Figure 2: Output produced by the web solver on the instance of Figure 2.1.

M. Caserta, S. Schwarze, and S. Voß. A mathematical formulation and complexity considerations for the blocks relocation problem. *European Journal of Operational Research*, 219:96–104, 2012.

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