Optimization of order batching in a picking system with Carousels
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Abstract: Carousels are Automated Storage and Retrieval Systems frequently used in warehouses. The performance of warehouses with carousels is highly correlated to the order picking performance. The order picking is one of the main activities in warehouse management, consisting of retrieving the required products from their storage location to fulfil customers’ orders. A critical operation for the order picking efficiency is the order batching, namely how to regroup customers’ orders into batches before the collect. In this paper, we provide an optimization model for the orders batching problem, when the products are stored in one or several carousels, with the objective of minimizing the total completion time. We use real data in order to test and validate our models. Numerical experiments show that our model outperforms the actual batching strategy used by the considered companies.

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1. INTRODUCTION

The Automated Storage and Retrieval Systems or AS/RS are used in many warehouses of manufacturing and distribution companies. The advantages of these systems are basically the space saving and the increase in productivity. With the use of AS/RS systems, the operator (or picker) stays in front of the machine while the machine brings the product to him; he does not need to move from one storage location to another. In the literature, these systems are referred to as “Part to Picker” systems as against the “Picker to Part” systems for which the picker has to move throughout the warehouse to collect products.

The most used technology of AS/RS systems is the carousel, which is a device using a set shelves mounted on a closed loop rail where products are stored on (see Fig.1 for an illustration). As soon as a product is requested, the carousel rotates to reach the desired shelf and then waits until the product is retrieved by the picker and another product is requested. In practice, the carousels are located in the picking area, also called pod, where one or several pickers have to collect products from one or several carousels. In this paper, we focus on the vertical carousel, which consists of shelves connected to each other’s with chains rotating on the horizontal axis. On each shelf, there are some boxes where products are stored.

In this article, we focus on the order picking activity, which is the operation of retrieving products from their storage location to fulfil customers’ orders. Each order contains a set of orders lines, also called lines, representing a given quantity of a given product. This product is stored on a given shelf of a given carousel. The picking activity is a critical operation with a high impact on warehouses’ performances, it is also the most labor intensive activity. It counts for about 55% of all operating costs for manual warehouses according to Tompkins et al. (2003) and according to De Koster et al. (2007) it is a primordial activity in warehouses using AS/RS.

In practice, in order to achieve a higher throughput, warehouse managers regroup orders into batches and retrieve the orders belonging to the same batch together. A batch is composed by a set of orders. Note that an order cannot be split into several batches. For a better efficiency, it is essential to collect together products from different orders located on the same shelf instead of retrieving them one order at the time (Yu and De Koster (2010) and Pazour and Meller (2013)).

The order picking process on a pod composed by carousels can be described as follows:

For each batch, the picker receives a number of bins equal to the number of orders in the considered batch. Each bin corresponds to only one order (see Fig 2). All the products (of a given order) that are being retrieved from a given shelf of a given carousel have to be placed into their corresponding order’s bin. The picker proceeds by retrieving all the order lines that have to be collected on the first shelf of the first carousel that has to be visited. Then, the picker moves to the next carousel. Meanwhile, the first carousel rotates to present the next shelf. The picker continues by collecting all required lines from the first shelf of the second carousel. He continues by moving from one carousel to another until all products from the first shelf of all carousels are retrieved. Then, the picker comes back to the first carousel in order to collect the required
products from the second shelf of this carousel. Similarly, to the first collecting round, he moves from one carousel to another until he finishes collecting all the required items from the second shelf of these carousels. He repeats this process until all the required order lines are collected from all the shelves of all carousels that have to be visited. The batch is now collected and the bins leave the pod while new bins come to the picker. These new bins correspond to the next batch of orders and the picker repeats the process described above until all batches are collected.

Although many companies using carousel systems proceed by regrouping orders into batches before collecting them, the literature did not give adequate attention to the batching decision in AS/RS systems with carousels. Note, however, that the order batching problem in case of classical picker to part systems is well studied. Reviews of the solution approaches related to the order batching problem in manual warehouses are provided by De Koster et al. (2007) and Henn et al. (2012).

The literature relative to carousels systems can be split into two main categories. The first category of papers focus on the pick sequence of an order (or a sequence of orders) while the main purpose of the second category is to determine the best storage location of products in the carousel.

The problem of determining the pick sequence on a carousel, for a set of products of a given order, in order to optimize the travelled distance is well studied since 1980 (Weiss (1980)). Bartholdi and Platzman (1986) considered a single order sequencing problem. They developed a discrete model and studied the computational performance to find the near-optimal pick sequence of products to retrieve from the carousel. Wang et al. (2013) proposed an analytical model with a set of heuristics considering multiple carousels in order to find the near optimal picking sequence. Another picking strategy studied in the literature is the m-step strategy, consisting in taking the route that changes direction at maximum once after collecting m products (a review for this problem is given by Litvak and Vlasiou (2010)).

The literature relative to the second category, i.e. the storage location of products within the carousel, is also widely studied since the 90’s. Several storage policies have been studied and savings of travel time have been evaluated. The first studied strategy is the Randomised policy (Hwang and Ha. (1991) and Litvak. (2001)). Ha and Hwang (1994) proposed the two-class based storage policy, which splits the products into two class according to their demand frequency and the storage is based on the class of these products. A random location was decided for the high turnover class and the items having the lowest demands are located as far as possible from this location. A valuable review providing good insights on the literature relative to the storage location of products within a carousel is given by Litvak and Vlasiou (2010).

In our case, the pick sequence is given and the storage location of the product is imposed. To our knowledge, papers on the batching decision in case of carousels systems are missing in the literature. In practice, basic tools for the batching decision are used, such as the first come first served, which are generally far from optimality.

Two situations may arise concerning the order batching: “Offline” and “Online” batching. For Offline batching, all information about the orders is available before deciding how to batch these orders. For Online batching, the arrival time of orders is considered and therefore the information regarding each given order can be known only after this time. This paper focuses on Offline batching, which is the most common situation in practice.

This paper aims to provide a batching optimization model for an AS/RS warehouse with carousels. The objective of our model is to minimize the total completion time required to collect a given set of customers’ orders. We first consider the case of one carousel and then study the more complex situation with multiple carousels. We consider real data of two companies to conduct experiments on our model and to compare its performance with the actual batching strategy of these companies.

This paper is organized as follows: In section 2, we evaluate the completion time and provide the optimization model and experiments in the case of one carousel. Section 3 is dedicated to the case of several carousels. We finally conclude in section 4 and give future work directions.

2. ORDER BATCHING WITH ONE CAROUSEL

In this case, the picker has to retrieve a given number of batches from one carousel. First, we present the model notations and assumptions. Then, we explain how we obtain the completion time required to retrieve a given set of batches. Based on the completion time, we develop the batching model and conduct experiments.

2.1 Notations and assumptions

The number of shelves of the carousel is denoted by $S$. We let $s$ denote the set of all shelves, indexed by $s (s=1, ..., S)$. We let $O$ refer to the number of considered orders and $\Theta$ its associated set, indexed by $o (o=1, ..., O)$. The set of batches is denoted by $B$ and is indexed by $b (b=1, ..., B)$ where $B$ is the number of batches to be collected. The batch size is $B_{max}$.

Thus, the number of batches to build is given by $B = \left\lfloor \frac{O}{B_{max}} \right\rfloor$ with $\lfloor . \rfloor$ the ceiling function.

For batch $h$, the number of shelves to visit is denoted by $S^b$ and we let $s^b$ denote the vector representing the shelves that
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