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An Application of Cluster Analysis to Midpoint Routing Policy in Order Batching Process

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Abstract

Order-picking process is one of the major operations in warehouses and distribution centers. In low-level picker-to-part system, picker usually combines orders (order batching) as much as possible so that he can pick a set of the combined orders at the same time. For midpoint routing policy, this paper develops an efficient order-batching algorithm based on cluster analysis. The algorithm is compared with a well known existing algorithm in terms of the total travel time and number of batches grouped. The test results show that the proposed heuristic performs better than the other.

1. Introduction

In low-level picker-to-part systems, picker performs the retrieval of items on the pick list from their storage locations to satisfy customer orders. This process is known as the order picking process and constitutes 65% of the total operating costs for a typical warehouse [1]. The efficiency of the order picking process is closely related with operating policies on batching (grouping of customer orders for pick lists), routing (sequencing the retrieval orders in a pick list), and storage (assignment of storage space to inventory items).

There exist three different principles with respect to the organization of the order-picking process, *i.e.*, order-picking by order, batch picking, and sort-while pick. In this paper, we focus on the last principle where the order-picker picks a number of orders simultaneously on a pick device (cart or pallet). Together with an efficient pick route, it can drastically reduce the picker's travel time compared with picking one order at a time (order-picking by order). For order batching, Elsayed and Unal [6], Pan and Liu [7], and Hwang and Lee [8] proposed various batching algorithms for the case of single-aisle situations. For warehouses with a similar layout as in Figure 1, Rosenwein [9] proposed several batching algorithms and then compared their performances. De Koster *et al.* [10] recently combined all known heuristics together with some new ones in an attempt to find good, fast and robust algorithms that are simple enough to be used in practice.

Routing policies deal with how to tour in the warehouse in order to pick up all the items on a pick list. Considerable effort has been paid to minimize the travel time, when the pick locations in a warehouse that have to be visited in one route are known beforehand. De Koster and van der Poort [2] developed an optimal routing algorithm based on dynamic programming approach. For practical applications, various heuristic routing policies appeared in the literature. They include midpoint policy, traversal policy, return policy, and largest gap return policy (Ratliff and Rosenthal [3], Goetschalckx and Ratliff [4], and Hall [5]). This study assumes that the picker follows midpoint policy. In a midpoint policy, the warehouse is divided equally and horizontally into two sections. A picker accesses as far as the midpoint in a picking aisle. He performs either a return route from the front aisle, a return route from the back aisle, or return routes from the front and back aisles in an aisle. He traverses the rightmost aisle containing picks to enter the back aisle and the leftmost aisle containing picks to exit the back aisle (see Figure 1).

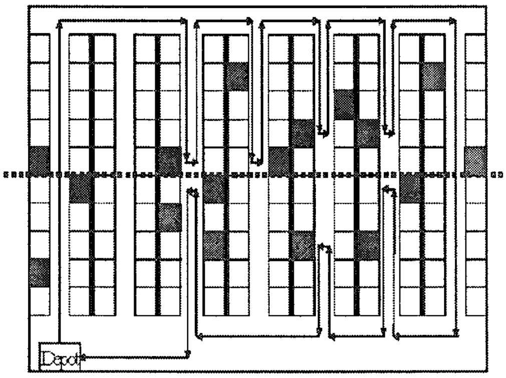

Figure 1. Midpoint routing policy

The objective of this paper is to develop a new batching procedure for the following problem situation: A set of orders is given where each order consists of several items to be retrieved from known locations in a storage region similar to Figure 1. Depot (input/output point) is located at the bottom left corner. Aisles are numbered *1, 2,…,K* from left to right in the lower section and *K+1, K+2,…,2K* from right to left in the upper section of the warehouse. We want to batch a set of given orders in a way to minimize the total travel distance of the order picker who leaves the depot to retrieve all the orders following the midpoint routing policy and then returns to the depot. Each order must be contained entirely in one batch and thus the maximum order size is at most equal to the picker's capacity. For the above problem we develop a new batching heuristic based on the similarity coefficient that utilizes the characteristics of the midpoint policy. This paper is organized as follows: In section 2, the similarity coefficient is defined for a pair of orders. Then we present a mathematical model from which a set of batches can be found. To evaluate the proposed heuristic and compare with an existing algorithm, simulation experiments are studied in Section 3. Finally, conclusions appear in section 4.

2. Development of batching algorithm

The term 'batching' means generating groups of similar items such that the items within a group are more strongly related to each other than those in different groups. In this study, batching is done on the basis of the similarity coefficient determined for a pair of orders. The similarity coefficient is a kind of surrogate measure to represent the similarity among objects. Since McAuley [11] who applied the Jaccard similarity coefficient to the cell formation problem, various types of similarity coefficients were proposed to find part families. For the midpoint routing policy, a new measure of similarity can be defined between pairs of orders. Let d_{ik} and d_{jk} be the normalized distance of the farthest item in aisle k on order i and j, respectively. Let K and s_{ij} be the number of aisles and similarity measure between order i and j, respectively. We define s_{ij} as

$$s_{ij} = \sum_{k=1}^{2K} d_{ik} * d_{jk}$$

The basic idea of the above similarity coefficient is as follow: Under the midpoint policy, the distance the order picker travels in a picking aisle is determined by the item whose storage location is farthest from the front/back aisle. Thus it is preferable to combine those orders when their items are located together in a given aisle far from the front/back aisle. It is known that the midpoint routing policy tends to be efficient when product is located close to the front aisle or the back aisle.

With the similarity coefficient determined for every pairs of orders, a mathematical model can be formulated to find order-batches. We define the binary variable x_{ij}= 1 if order i is assigned to cluster j, and 0, otherwise. Note that x_{jj} is the binary variable equal to 1 if the order j is chosen as a cluster median, and 0, otherwise.

$$\text{Maximize} \quad \sum_{i=1}^{P}\sum_{j=1}^{P} s_{ij}x_{ij} \quad (1)$$

$$\text{Subject to} \quad \sum_{j=1}^{P} x_{ij} = 1,\ i = 1,\ldots,P \quad (2)$$

$$x_{ij} \le x_{jj},\quad i,j = 1,\ldots,P \quad (3)$$

$$\sum_{i=1}^{P} n_i x_{ij} \le C,\ j = 1,\ldots,P \,(4)$$

$$x_{ij} = 0,1,\quad i,j = 1\ldots,P \quad (5)$$

where n_i is the number of items in order i, P is the number of orders, and C is the capacity of the order picker. The objective function (1) of the model enforces to cluster orders such that the sum of similarity measures is maximized. The constraint (2) serves to assign each order, but only to a cluster that has actually been designated. The constraint (3) ensures that order i belongs to cluster j only when this cluster j is formed. The constraint (4) is used to limit orders, which are clustered in one batch to the capacity of the order picker. And the constraint (5) restricts the variable values as zero or one.

3. The simulation experiments

To evaluate the performance of the proposed heuristic and compare with an existing algorithm, simulation experiments are made with the following assumptions and system parameter values.

Assumptions:

i. The depot is located at the front end of the most left aisle.

ii. Within an aisle, two-sided picking can be performed, that is, simultaneous picking from the right and left side within an aisle is possible.

iii. Order sizes are generated from a discrete uniform distribution.

iv. Item-locations are spread randomly over the warehouse.

v. The item is so light that we ignore weight of items.

System parameter values:

Number of orders: $P = 30$

Order size: U [2, 10]

Capacity of the order picker (items): 24

Number of aisles: 10

Number of storage locations per aisle: 2 * 20

Total number of storage locations: 400

Aisle length: 10 m

Center distance between two adjacent aisles: 2.4 m

Travel speed within each aisle: 0.6 m/s

Travel speed outside of the aisles: 0.6 m/s

Additional time to enter or leave an aisle: 0s

The saving algorithm from de Koster *et al.* [10] is selected for comparison purpose. In the algorithm, clustering is based on the time saving that can be obtained by combing two orders in one batch as compared to the situation where both orders are collected individually. As long as the picker's capacity permits, batch size is increased sequentially by adding an order with the highest savings. Twenty sets of data were generated and then solved by the two heuristics. For the proposed heuristic, CPLEX 7.0 was utilized. Table 1 shows the experimental results in terms of the total travel time and number of batches (in parenthesis) for each experiment.

	Proposed heuristic	Existing algorithm
1	1554.83 (9)	1711.83 (10)
2	1397.67 (8)	1486.83 (9)
3	1464.83 (9)	1545.83 (10)
4	1501.67 (8)	1723.83 (10)
5	1487.83 (8)	1522.17 (9)
6	1449.83 (8)	1615.67 (10)
7	1611.17 (9)	1666.5 (10)
8	1237.5 (7)	1323.67 (8)
9	1447.33 (9)	1570.17 (10)
10	1587.83 (9)	1593.5 (9)
11	1638.33 (9)	1768.17 (10)
12	1423.67 (8)	1599.83 (9)
13	1215.67 (7)	1333 (8)
14	1405.17 (8)	1498.67 (9)
15	1410.33 (8)	1463.33 (9)
16	1425 (8)	1499 (9)
17	1539.33 (9)	1471.17 (9)
18	1486.5 (9)	1516.5 (9)
19	1437.83 (8)	1520.17 (9)
20	1532.5 (9)	1637.5 (10)
Avg. of the total travel time	1462.74	1553.37
Avg. of the no. of batches	8.35	9.3

Table 1. Computational result.

4. Conclusions

This paper proposed a heuristic batching procedure for the order-batching problem with a midpoint routing policy. Through the numerical experiments, the proposed algorithm was shown to perform better than the best heuristic solution appeared in the literature. This research could be extended in a number of ways. Currently, we are applying a similar approach to other routing policies under various warehouse configurations.

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