Double Clustering as an Unsupervised Approach for Order Picking of Distributed Warehouses

Hsin-Yi Huang, Ming-Sheng Liu, Jiun-Yan Shiau

***Abstract*—**Planning the order picking lists for warehouses to achieve some operational performances is a significant challenge when the costs associated with logistics are relatively high, and it is especially important in e-commerce era. Nowadays, many order planning techniques employ supervised machine learning algorithms. However, to define features for supervised machine learning algorithms is not a simple task. Against this background, we consider whether unsupervised algorithms can enhance the planning of order-picking lists. A double zone picking approach, which is based on using clustering algorithms twice, is developed. A simplified example is given to demonstrate the merit of our approach.

***Keywords*—**Order picking, warehouse, clustering, unsupervised learning.

I. Introduction

A. Definition and Approaches of Order Picking

ORDER picking of a warehouse management system (WMS) is a planning process, that generates multiple order picking lists from multiple customer orders based on configuration of the physical warehouse, to optimize some operational performances. When doing order picking planning, the warehouse configurations normally take layout of the warehouse, picking equipment, storage strategies, and batching or splitting of customer orders into consideration. The operational performance indexes of a warehouse are total lengths of picking distances, number of picks per hour, etc. [1].

B. Definition and Advantages of Machine Learning

Nowadays, order picking planning techniques employ supervised algorithms (as illustrated in Fig. 1). However, the definition of which features should be processed by such algorithms is not a simple task, being crucial to the proposed technique's success.

Clustering is one of the most common data analysis methods that are considered as a method of unsupervised learning. Unsupervised learning is to use the features of the original data without labeling or grouping in advance (as illustrated in Fig. 2). Clustering analysis helps to divide data into several groups based on distance indexes among data. On the other hand, clustering analysis can directly utilize the observed data to analyze Clustering analysis helps to divide data into several groups based on distance indexes among data.

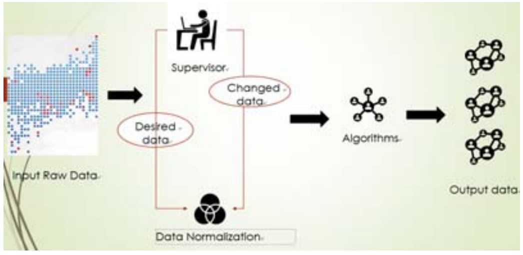

Fig. 1 Supervised Learning Approach

C. The Objective

This paper uses K-means clustering as the computing basis in assigning customer orders to trucks and zone pickings. We call the double clustering approach as Zone^2 picking. The concept of Zone^2 is to enable pickers in three distributed warehouses to pick up the customer orders at the same time. Then, according to the quantity of picking carts and stackers in each warehouse, the assigned customer goods are clustered into sub-groups again. The sub-groups are so called zone picking orders/lists.

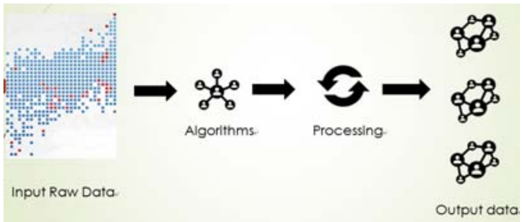

Fig. 2 Unsupervised Learning Approach

II. Literature Reviews

According to [2], the missions of a WMS could be (1) achieve transportation economies, (2) achieve production economies, (3) take advantage of quality purchase discounts and forward buys, (4) support the firm's customer service policies, (5) meet changing market conditions and uncertainties, (6) overcome the time and space differences that exist between producers and customers, (7) accomplish the least total cost logistics commensurate with a desired level of customer service, (8) support the just-in-time programs of suppliers and customers, (9) mix and repack products for each customer's order, (10) store disposed or recycled materials temporarily, (11) provide a buffer location for transshipment.

Zone picking policy divides the picking area into a few subzones; and a dedicated picker will pick items in that subzone

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only. Research of zone picking focuses on the number of subzones and pickers [3]. Some algorithms have been proposed for generating picking orders. Rim and Park [4] proposed a linear programming approach to assign the inventory to the orders to maximize the order fill rate. Lu et al. [5] developed an algorithm for dynamic order picking that allows for changes to pick-lists during a pick cycle. Füßle and Boysen [6] aimed at a synchronization between the batches of picking orders concurrently assembled and the sequence of Stock Keeping Units (SKUs) moved along the line, such that the number of lines passing to be accomplished by the picker is minimized. Giannikas et al. [7] improved the responsiveness of an order system with an interventionist order picking strategy. Ho and Lin [8] improved order-picking performance by converting a sequential zone-picking line into a zone-picking network. Schwerdfeger and Boysen [9] proposed a multi-objective approach to solve order picking along a crane-supplied pick face, etc. With all these algorithms, none of them considered truck loading due date into their models.

III. Double Clustering Approach

To assign customer orders to trucks, there are several steps to follow. First, we cluster the order picking area and coding the goods by their feature. Second, we normalize the latitude and longitude of customers. Third, we calculate the total volume of the goods that costumers order and cluster by latitude and longitude of costumers. Then, according to the quantity of trucks, we randomly select customers as the clustering center of gravity and calculate the optimal loading capacity of each truck and assigning the customer orders to each truck. Finally, according to the loading of each truck, we can plan and arrange the order picking operation.

A. Zone[1] Approach - Assigning the Trucks to Each Warehouse for Picking and Loading Goods

In order to assign the trucks to each warehouse for picking and loading orders, an opportunity cost function is developed and attached to each truck. Then we select the truck with lower opportunity cost to load the highest proportion. The assigned trucks will be removed from the list, and so on, until all the estimated quantity of trucks in each warehouse is assigned. If there is a truck that has not been assigned to a warehouse, the idle truck will be assigned to the warehouse, which has the highest loading proportion. The process of assigning the trucks to each warehouse for picking orders is thus completed.

The heuristic algorithm of Zone[1] Approach is summarized as following steps:

1) Calculate the total volume of original customer orders and the total volume of each truck.
2) Calculate the number of trucks required from the total volume of original customer order divided by the volume of each truck.
3) Cluster Costumer: According to the quantity of trucks then to cluster the costumers by their delivering area.
4) After clustering the customer orders, renumber the cluster according to the delivering area, so that there is the concept of distance between the numbers.
5) Calculate the total volume of costumer orders then divide by the volume of truck to derive the number of required trucks.
6) If the quantity of required truck is more than one, the volume of goods will be accumulated to each truck. If there are few goods in customer orders cluster, it can be considered to be combined with other close ones for deliver.
7) Estimate the quantity of trucks to pick the order in each warehouse.
8) Calculate the proportion of goods loaded by each truck in each warehouse.
9) Calculate the opportunity cost of each truck loading in each warehouse
10) Select the truck with the lowest opportunity cost as the first priority.
11) If the opportunity cost is the same, assign the truck to the warehouse which loading with the highest proportion.
12) Remove the trucks that have be assigned.
13) Repeat steps (10)-(12) until the estimated quantity of trucks to pick the order in each warehouse is reset to zero.
14) Assign the unallocated trucks to the warehouse which the loading with the highest proportion.
15) Assigning trucks to each warehouse for picking orders is completed.

B. Zone[2] Approach - Cluster the Area in the Warehouse for Order Picking

For generating picking orders, the storage location of the goods that is scheduled to be picked must be analyzed first. Those goods can be further clustered based on the similarities of storage locations in each warehouse. Clustered goods will be assigned to picking carts. The route of order picking can be scheduled in more detail for each picking cart. After finishing the order picking, pickers can place the picking cart in the temporary storage area and wait for the trucks to load the goods.

The algorithm of Zone[2] is as following steps:

1) Confirm the total amount of goods in the warehouse
2) Analyze the storage location of the goods
3) Cluster based on the quantity of picking carts
4) Generate picking orders based on the clustering results
5) Place the picked goods in the temporary storage area and wait for loading to trucks.

IV. A Simplified Example

There is large food mart with three different warehouses located at South Taiwan. The finance department receives the customer's orders the day before as the starting point. After receiving the orders, the finance department will first check the inventory stocks with the purchasing department. After confirming the available stocks, the estimated selling orders will be created, and then the quantity and items on the selling orders will be confirmed as the customer orders (as illustrated in Fig. 3). Once the customer orders are confirmed, the step of converting the customer orders into picking orders will be entered on the next day. Due to the large number of customer orders, the company's current practice is to arrange the customer orders according to the delivery area, and manually converting the customer orders into each warehouse picking order. Once the picking process is completed, the picking staff will confirm whether the item and quantity of the goods are correct. If it is correct, the order will be loaded onto trucks.

Longhua Technology Co., Ltd.

Domestic order

Company phone:07-8062211 company fox:07-8062212

Tabulation date:2021/3/1 page:1/1

Order number:20210302	Currency:NTD	Undertaker:Zhang Shizhe
Document date:2021/3/2	Exchange rate:0%	Employee number:36259
Dueday:2021/3/4	Payment method:cash	Unit:CUFT
Order category:Domestic	Taxable:duty free	
Delivery methods:Home Drlivery	Business Tax:0%	
Customer Phone Number:07-5553086	customer fax07-5553842	
Address:No.858,Dashun1stRoad,Gushan District,Kaohsiung City,804	price:2466	

Customer order number	Product name	Specification	Quantity
823	Book6	paperback / 184 pages / 12.8 x 18.8 x 0.92 cm / ordinary / Partial full color / First edition	1
361	Book12	paperback / 352 pages / 14.8 x 21 x 1.76 cm / ordinary / Single-Color Printing / First edition	5
513	Book17	paperback / 272 pages / 19 x 24 x 1.36 cm / ordinary / double-Color Printing / First edition	5
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Total:11	Order amount:2466	Tax:0
Gross weight:3(kg)	Total volume:1.5	CUFT

Manager:_______ Business People:_______ Lister:_______

Fig. 3 Customer Order

The concept of Zone[2] is to enable pickers in three distributed warehouses to pick up the customer orders at the same time. The proposed double clustering approach is implemented and validated by using PolyAnalyst 6.5 software.

A. Zone[1] Approach

In order to cluster the customer orders and assign customer orders to trucks (as shown in Fig. 4), there are several steps:

1) Calculate the total amount of customer orders and the total volume of each truck.
2) Cluster Costumer: According to the quantity of trucks then to cluster the costumers by latitude and longitude (as shown in Fig. 5).
3) After clustering the customer orders (as shown in Fig. 6), renumber the cluster according to the latitude and longitude, so that there is the concept of distance between the numbers.
4) Calculate the total volume of each costumer order then divide it by the volume of truck to get the number of required trucks.
5) Combine those customer order clusters with few goods with other customer order clusters for delivery.

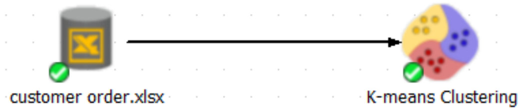

Fig. 4 Zone[1] Approach

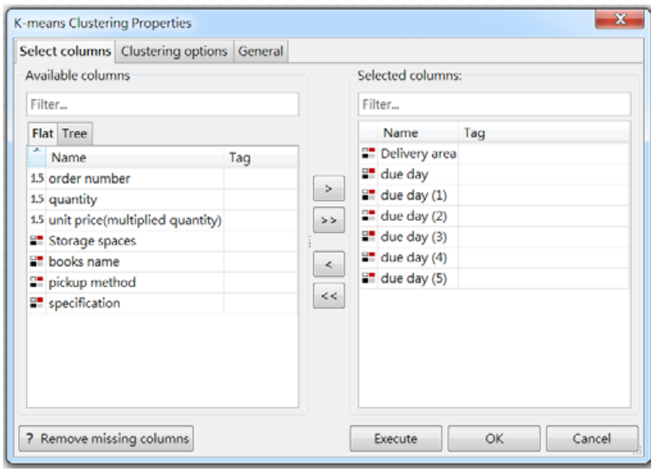

Fig. 5 Cluster costumer orders by delivery area (latitude and longitude)

To assign the trucks to each warehouse for picking orders, there are several steps as follows:

1) Estimate the quantity of trucks to pick the order in each warehouse.
2) Calculate the proportion of goods loaded to each truck in each warehouse.
3) Calculate the opportunity cost of each truck loading in each warehouse
4) Select the truck with the lowest opportunity cost as the first priority.
5) If the opportunity costs are the same, assign the truck to the warehouse with the highest proportion loading.
6) Remove the trucks that have been assigned. Subtract the estimated quantity of trucks by one.
7) Repeat steps (10)-(12) until the estimated quantity of trucks to pick the order in each warehouse is reset to zero
8) Assign the idle trucks to the warehouse that has the highest loading proportion.
9) Assigning the trucks to each warehouse till picking orders is completed.

B. Zone[2] Approach

To assign customer orders to each picking order/list (as shown in Fig. 7), there are several steps:

1) Confirm the total amount of goods in the warehouse
2) Analyze the storage location of the goods (as shown in Fig. 8)
3) Cluster orders based on the quantity of handcarts (as shown in Fig. 9)
4) Generate picking orders based on the clustering results (as illustrated in Fig. 10).
5) Place the picked goods in the temporary storage area and wait for loading.

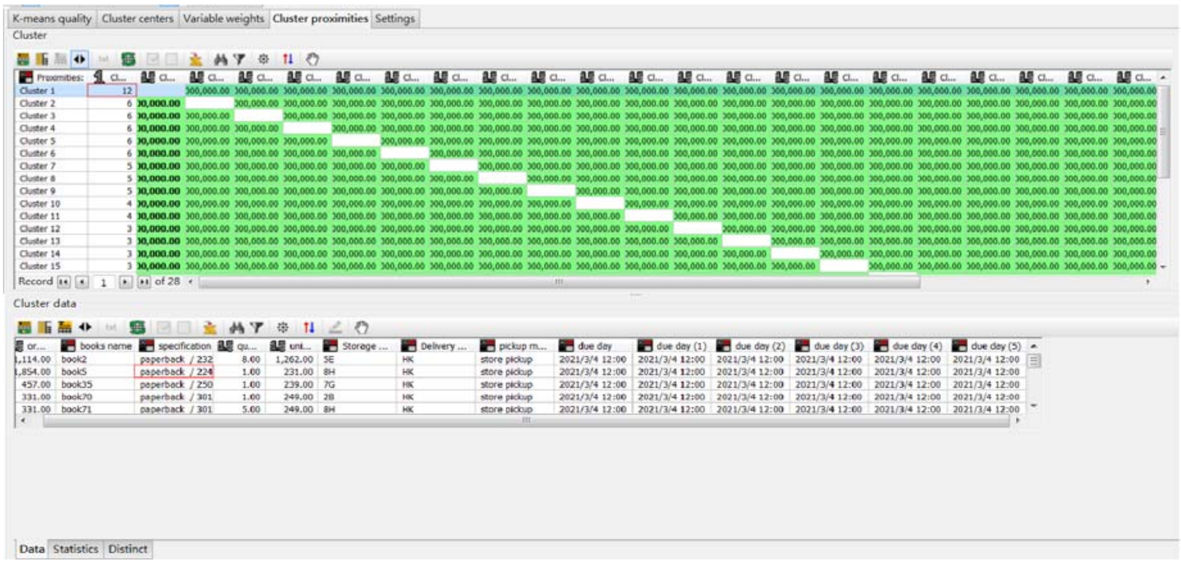

Fig. 6 Cluster costumer orders into trucks

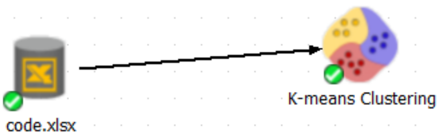

Fig. 7 Zone^2 Approach

V. Conclusion

Order picking policy is a case-oriented design and planning task. In this paper, we reviewed algorithms of zone picking, and concluded that there is a gap of applying unsupervised algorithm to order picking planning.

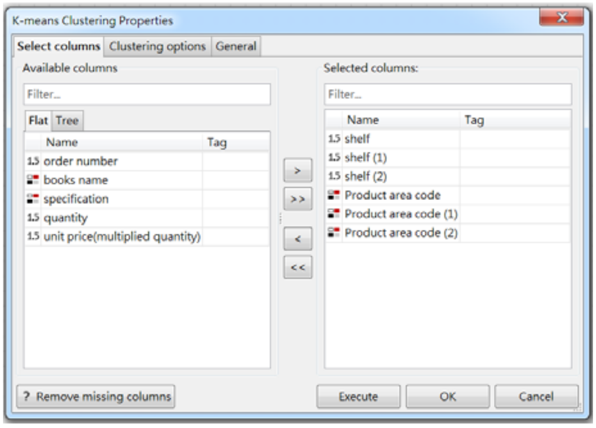

Fig. 8 Cluster costumer orders by SKU area

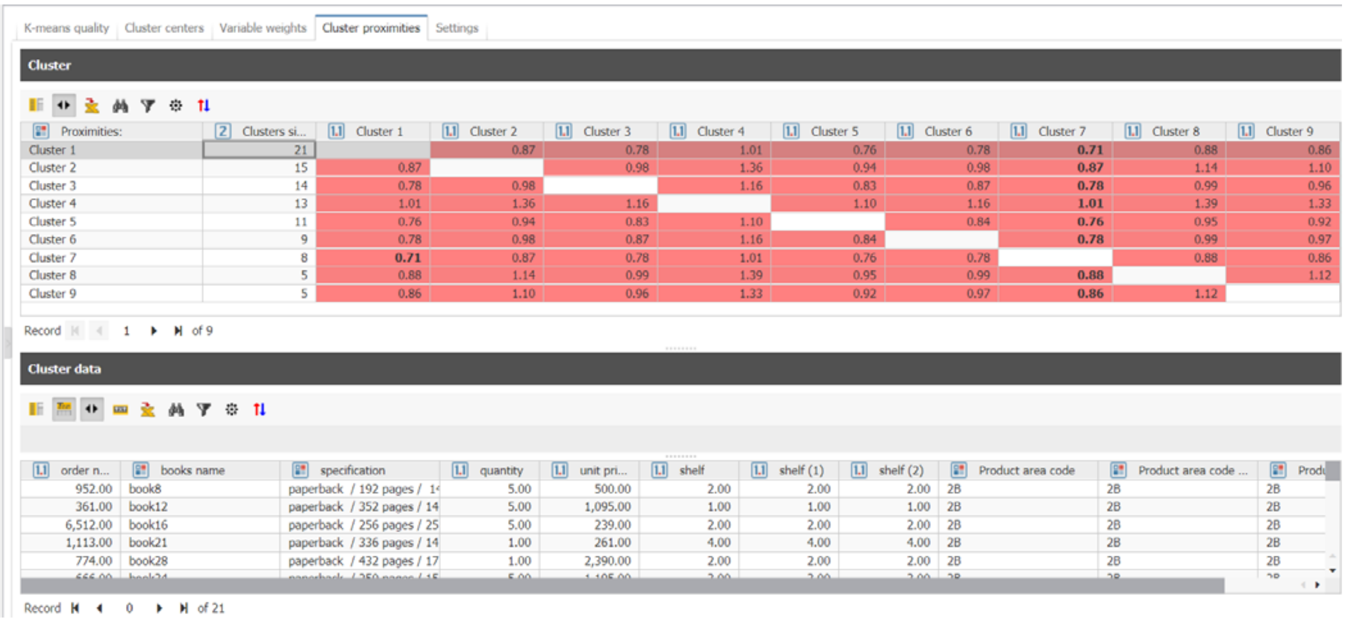

Fig. 9 Cluster costumer orders into picking orders

Longhua Technology Co., Ltd. Picking List

Order number:2021030301 Due Day:2021/3/4 Picking store:Sanmin0621
Picker number:42511 Price:2466 Item Status:Not loaded
Picker name:Wu Qin Han Total:
Picking floor:F1 Total boxes:

No.	Customer number	Product name	Specifcation	Area code	shelf	quantity
1	823	Book6	paperback / 184 pages / 12.8 x 18.8 x 0.92 cm / ordinary / Partial full color / First edition	9I	3	1
2	853	Book36	paperback / 384 pages / 26 x 24 x 4 cm / ordinary / full-color-printing / First edition	9I	2	1
3	92	Book39	paperback / 320 pages / 15 x 21 x 1.6 cm / ordinary / Single-Color Printing / First edition	9I	1	1
4	2114	Book1	paperback / 288 pages / 15 x 21 x 1.4 cm / ordinary / Single-Color Printing / First edition	9I	1	1
5	906	Book3	Hardback / 360 pages / 14.8 x 21 x 2.5 cm / ordinary / Single-Color Printing / First edition	9I	2	5
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Fig. 10 A Picking Order

The zone planning model we developed was based on double clustering algorithms. It takes multiple customer orders, locations of SKUs and warehouses, and planned delivering truck loading times as input parameters, then calculates the groups of picking SKUs (i.e., order batch problem) and the groups of pickers (i.e., batch assignment problem), and finally outputs a set of order picking lists with their associated warehouses.

To sum up, the object of the model is that distribution centers can not only achieve the goal of fast delivering but also increase the capacity utilization rate which can make distributions fulfill more orders within the same time and can completed orders before departure time.

ACKNOWLEDGMENT

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