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Application of metaheuristics-based clustering algorithm to item assignment in a synchronized zone order picking system

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ABSTRACT

Warehousing management policy is a crucial issue in logistic management. It must be managed effectively and efficiently to reduce the production cost as well as the customer satisfaction. Synchronized zoning system is a warehousing management policy which aims to increase the warehouse utilization and customer satisfaction by reducing the customer waiting time. This policy divides a warehouse into several zones where each zone has its own picker who can work simultaneously. Herein, item assignment plays an important role since it influences the order processing performance. This study proposes an application of metaheuristic algorithms, namely particle swarm optimization (PSO) and genetic algorithm (GA), for item assignment in synchronized zoning system. The original PSO and GA algorithms are modified so that it is suitable for solving item assignment problem. The datasets with different sizes are used for method validation. Results obtained by PSO and GA are then compared with the result of an existing algorithm. The experimental results showed that PSO and GA can perform better than the existing algorithm. These results also show that PSO has better performance than GA, especially for bigger problems. It proves that item assignment policy obtained by PSO and GA has higher utilization rates than the existing algorithm.

1. Introduction

Logistic plays an important role in the supply chain. It relates to many aspects including information system, inventory, warehousing, customer satisfaction and etc. An efficient logistic management allows productivity improvement as well as cost reduction. Warehousing as one of an important part in logistic has to be managed well since the inefficient warehousing system may require high management cost. Aware of this issue, many companies focus on designing warehousing system which has high productivity and low cost. In the warehouse, order picking is a major operation which may give significant influences to the productivity rate. There are many systems which can be applied to improve the order picking operation such as order batching, routing and storage policies. This paper focuses on item assignment since assigning an item to the right location may optimize labor efficiency, including order picking, put away, and replenishment labor functions.

A traditional storage policy focuses on differentiating items based on the order frequency and then assigning the fast-moving items and slow-moving items to two different locations. Practically, a customer order may consist of both fast-moving and slow-moving items. Thus, locating both of them in two different locations causes the order picker has to take far distance in completing the order. As the consequence, the customer waiting time becomes longer. A synchronized zone is one of order picking system that can reduce the customer waiting time [1]. In this system, items which most likely appear in the same order are stored in different zones. Herein, each zone has its own picker. When an order comes, items which are stored in different zones can be taken at the same time. Hence, the customer waiting time can be reduced. Different with other assignment policies which only consider relative distance between storage location and input/output point, the synchronized zoning system considers the similarity between items based on the historical data of the coming orders. The advantage of this policy is in reducing order processing time as well as increasing warehouse utilization. Dividing order picking area into zones makes the order pickers only travel within a small area and more familiar with their zone [2]. It therefore helps the order pickers work faster. Hence,

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Nomenclature

a	The index of item, $a = 1,2,\ldots,q$
b	The index of item, $b = 1,2,\ldots,q$, $b > a$
m	The number of zones
n	The number of orders
N_{ab}	The similarity between two items, a and b
q	The number of items

this paper focuses on studying the synchronized zoning system. However, improper design may lead to workload-imbalance [3] and low utilization [4]. Thus, designing zoning system is very crucial in synchronized zoning system.

In order to design the synchronized zoning system, Jane and Laih [1] proposed a heuristic method. In general, designing synchronized system can be defined as finding the best combination of each item's location so that it minimizes the picking time or maximizes the picker efficiency. It also aims to balance the workload of each picker. Therefore, the item assignment becomes an important task in designing synchronized zoning system. This paper aims to solve this problem by proposing two algorithms which can cluster the items as well as determine the storage location of each item. Based on its objectives, this paper views this problem as a NP-hard combinatorial optimization problem. In many previous studies, metaheuristic methods have been proven can solve the NP-hard problems [5–7]. However, since the synchronized zoning system is a new proposed assignment policy, metaheuristic method has not been applied to solve this problem. Therefore, this study proposes an application of metaheuristic method to solve the synchronized zoning system. There are many metaheuristic methods have been introduced such as genetic algorithm (GA), particle swarm optimization (PSO), tabu search (TS), bee colony optimization (BCO), simulated annealing (SA) and etc. However, this study only utilizes GA and PSO to solve the synchronized zoning system. GA is a very well-known optimization method. Its application in discrete combinatorial optimization problem has been well proven [8–12]. Therefore, it is chosen to be applied in this study. On the other hand, PSO was originally proposed for continuous problem [13]. It has been applied in many applications [14–16]. Later, its applications for binary and discrete problem were proposed [17] in many different ways. Since the problem discussed in this study is a discrete problem, applying PSO to solve this problem is feasible. Hence, this paper proposes an improvement of GA and PSO to solve the synchronized zoning system. The proposed algorithms intend to cluster the items and determine the item locations simultaneously. Through a relatively simple algorithm, the warehouse management can apply the proposed algorithms to optimize the warehouse operational cost.

The remainder of this paper is organized as follows. Section 2 presents the literature survey related to current study. Section 3 proposes the developed model, while the evaluation results are discussed in Section 4. Finally, the concluding remarks are made in Section 5.

2. Literature review

This section briefly discusses basic theories about warehouse design and metaheuristic algorithms applied in this paper.

2.1. Warehouse design

Warehouse design is an important issue in warehouse management. An inefficient warehouse management may result in a huge loss. There are many issues which should be considered in designing a warehouse including warehouse capacity, structure, sizing and dimensioning, department layout, equipment selection, operation strategy, equipment determination, the material handling systems' design, and the layout development [18–20]. Therefore, many previous studies concern about this problem. Apple [21] brought up a twenty-step procedures for facility design in warehousing. In 1994, Oxley provided a more complete list of steps about combining the previous key features [22]. He mentioned that the key of the warehouse design is the storage and the handing equipment. Rouwenhorst et al. [18] organized a recent survey on the overall warehouse design and warehouse operation problems, and showed three levels, strategic level, tactical level, and operational level in warehouse design. The cost is also a key issue in warehouse management. Many proposed methods in warehouse design very concern about the cost. Their objective functions can be a minimizing distance, time or space utilization.

Warehouse design procedure consists of many steps. Baker and Canessa [23] classify the steps into two major categories: (1) addressing the overall steps used in warehousing and (2) examining particular tools and techniques. Furthermore, Heskett et al. [20] described three general steps in warehouse design, namely: (1) determining warehouse requirement, (2) designing material handling system and facility design, and (3) developing the facility layout. More detail steps introduced by Oxley [22] concern with alternating operation methods, equipment types and layout. This method stress that the warehouse design should be centered on the storage and handling requirements, so the building should be designed based on this center.

Furthermore, warehouse design is also related to the order picking operation. Koster et al. [2] divided warehouse layout design into two sub-problems: (1) facility layout design including the order picking system and (2) the layout design of the order picking system. The first sub-problem aims to minimize the cost arising from any activities related to department's layout such as receiving, picking, storage, sorting, shipping, etc. On the other hand, second sub-problems consider the number of the storage blocks, and the number, length and width of aisles in each storage blocks in the order picking area. Many researches optimize the order picking operations by managing the storage policies, picking styles, etc. Roodbergen [24] proposed a nonlinear objective function for deciding the aisles disposition of random storage warehouse. Later, Roodbergen et al. [25] presented a model that can minimize the travel distances by recognizing suitable number of aisles. Kovács [26] used an MIP model to find a class-based storage policy for each zone in a warehouse. This model can minimize he order cycle time, the average picking effort, or the linear combination of these two criteria served by milk run logistics.

2.2. Warehouse operation

In general, warehouse operation can be divided into four major activities: receiving, storage, order picking and shipping [19]. All of them have to be managed well to increase efficiency of the warehouse.

2.2.1. Storage assignment

Storage assignment policy is an important factor in order picking operation. According to the availability of the information about arrival and departure product stored in the warehouse, storage assignment problem can be divided into three different cases: (1) complete information, (2) only information about the items stored and (3) no available information [19]. Frazelle [27] stated that the storage assignment is generally made based on the product's popularity, maximum inventory and cube-per-order-index (COI). In the case where there is no available information about item arrival, only simple storage policies can be applied such as closest-open-