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New batch construction heuristics to optimise the performance of order picking systems

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ABSTRACT

Two new batch construction heuristics called K-means Batching (KMB) and Self-organisation Map Batching (SOMB) are developed and verified by simulation experiments. Both KMB and SOMB have a preferment of superior performance in total travel distance and average picking vehicle utility, and even a conspicuous improvement in total CPU running time. Besides, this paper investigates the overall performance of order picking systems integrating storage assignment, order batching and picker routing to find the optimal policy combinations under different order types. The sensitivity analysis is performed to distinguish the relative importance of the various strategies to enhance the performance of operations management.

1. Introduction

In the current fluctuant market, how to use limited resources to satisfy the needs of customers has become the key to enterprises' success in sustainable operation. The development in information technology and the advancement of the Internet have not only speeded up the global competition for local industries, but also shortened the life cycle of products. The market became more fluctuant and difficult to predict. To quickly adjust to the needs of customer and adapt to the changes, enterprises must utilise their distribution centre to integrate and connect all the partners on the supply chain, allowing the products to be delivered to the customer even faster. Amongst the internal operation processes in the distribution centre, the order picking process is the core procedure, taking up over 55% of the storage operation cost (Bartholdi and Hackman, 2006). Recent trends show that customer orders changed from few kinds and large quantity orders to many kinds and small quantity ones, which need to be picked and distributed in short time. These changes require efficient and effective order picking systems in warehouses for companies to remain competitive. It was discovered that all the related strategies including storage assignment, order batching and the picker routing would affect the performance of order picking systems, and the order batching is a key strategy especially. Therefore, appropriate order batches can enhance the performance of order picking procedures to effectively reduce the cost of operations management, and then improve the quality of service.

It is believed that if focus on the layout design, storage assignment, order batching and picker routing strategies separately, and discuss the optimisation of either, it often causes local optimisation of the order picking system. De Koster et al. (2007) give a comprehensive literature review on these topics. They indicated the key factors affecting the performance of order picking systems include the layout of the warehouse, the storage strategy, the order picker routing policy, the zoning method and the order batching policy. Petersen and Aase (2004) pointed out, overly complicated picker routings or storage assignments would cause unnecessary waste of costs, their experiment also showed that order batching instead of picker routing planning and storage assigning, has the most prominent effects on decreasing the order picking time; however that research used a traditional warehousing environment as its simulation environment. Ruben and Jacobs (1999) indicated that the methods used for constructing batches of orders and for assigning storage space to individual items can significantly impact order retrieval efforts in warehouses. Thus, the objectives of this study are as follows:

(1) To develop two new batch construction heuristics called K-means Batching (KMB) and Self-organisation Map Batching (SOMB), since both the amount of stock keeping units (SKUs) in an order and the variation of the order size for an order picking system will affect the order batching procedure. This study contemplates the effects of KMB and SOMB by further comparisons amongst KMB, SOMB, Association rule and Particle Swarm Optimisation Batching Method (PSOBM)

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under different order types. The Association rule and PSOBM are suggested for order batching by the literature.
(2) To ensure the feasibility and preciseness of SOMB, the optimal weights for applying SOMB are found to further improve the solution quality of SOMB.
(3) To evaluate the performance of order picking systems integrating different policies for storage assignment, order batching and picker routing under small, medium, large and mixed order environments, respectively. The optimal policy combinations under different order types are found by the simulation experiment.
(4) Lastly, sensitivity analysis is performed on order type, storage assignment, order batching and picker routing. Based on the worst policy combination, this paper analyses the improvements made by varying one strategy at a time.

2. Literature review

Different distribution centres might adopt different order picking systems. Heiko and Darkow (2010) conducted a scenario development process to picture the most probable future of the logistics services industry 2025. The general notion towards strong social responsibility and ecological awareness; the intensifying pace of globalisation and its imperative for global networks; the shortage of young, qualified and mobile personnel; the change in customer demands towards more convenience, simplicity, promptness and flexibility; and the digitisation of business are five dominant themes that are likely to influence the macro-environment and industry structure in the future. Since the diversification of order picking systems, this paper focuses on picker-to-part systems to collect the data and literature review. The relevant literatures about order picking strategies and heuristic algorithms used in this study will be elaborated in the following sections.

2.1. Warehouse layout design

Facility layout of a warehouse has great influence on the order picking operations; a good layout design will enhance the performance of order picking operations quite substantially. How to maximise the effectiveness in a limited storage space is the key point to layout design of a warehouse. De Koster et al. (2007) indicated that on the theme of facility layout of a warehouse, the issues needed to address include the amount of storage zones to be set up, whether or not cross aisle should exist, how many cross aisles should be established, the locations of Pickup/Deposit (P/D) point and issues such as the total amount of the main aisles and the length and width of the aisles. In the aspect of establishing cross aisles, Vaughan and Petersen (1999) pointed out that the laying of cross aisles would help increasing the flexibility of picker routing and decreasing the total travel distance for order picking operations, but too many cross aisles would cause the space utility rate dropping off and increases the complexity of order picking operations. Hsieh and Tsai (2006) had experimented on the effects between 0 and 10 cross aisles under different picking densities within an aisle and various strategies, and justified that appropriate cross aisle quantity accompanied with storage assignment planning has a distinguished effect on reducing the overall picking distance. They showed that the addition of two or three appropriate cross aisles is the best design for enhancing the order picking efficiency and the space utilisation rate.

2.2. Storage assignment policy

In order to achieve better storage efficiency and access efficiency, storage assignment must ensure assigning different stock keeping units (SKUs) to suitable storage locations. The main consideration of storage efficiency is the efficiency of storage space utility, while access efficiency focuses on the efficiency of the procedure from storage to retrieval. There are numerous ways to assign SKUs to storage locations within the forward and reserve storage areas. Petersen and Schmenner (1999) examined the interaction of storage assignment and picker routing policies on order picking efficiency under different operating conditions of order size and demand skewness. The results showed that the within-aisle policy provides travel distance saving of 10–20% over the other volume-based storage assignment policies. De Koster et al. (2007) described five frequently used types of storage assignment: random storage, closest open location storage, dedicated storage, full turnover storage and class based storage. The random storage results in high space utilisation and at the expense of increased travel distance. Petersen et al. (2004) showed that with regards to the travel distance in a manual order picking system, full turnover storage outperforms class-based storage. This result depends on the class partition strategy and the picker routing policy used. However, they suggest using the class-based storage with 2–4 classes in practice. Chen et al. (2011) propose a dynamic operating policy to optimise the relocation problem in a warehouse. A two-stage heuristic method is developed to generate an initial solution, and tabu search algorithm is proposed to improve the solution.

2.3. Order picking policy

Order picking policies determine the picking sequence for all orders and subsequently retrieve from their storage locations by a single picker. Tompkins and Smith (1998) discussed the influence of order picking models, which are strict-order picking, batch picking, zone picking and wave picking. The benefit for these types of policies becomes apparent as the size of the warehouse increases. In application, more than one system may be employed in a single warehouse. Chen and Wu (2005) applied the Apriori algorithm to define the relativity between every two orders, prioritising the orders with a higher relation to the same batch. Since the order batching problem is regarded as a NP-Hard problem, the time complexity is exponential growth when the amount of orders increases. Hsu et al. (2005) applied Genetic Algorithm to solve the order batching problem, namely GABM, experimented on ten different environments including two-dimensional or three-dimensional storage spaces, as well as the amount of orders, and further compared the results with that of the Gibson and Sharp's batching method (GSBM) and first-come, first-served (FCFS). The result showed that GABM has an average of 15% improvement under a two-dimensional storage space, while under three-dimensional cases it has at most a 52% improvement from FCFS. Ho et al. (2008) continued the study of Ho and Tseng (2006) to investigate the mutual effects between route planning policies, aisle-picking-frequency distributions, seed-order selection rules and accompanying-order selection rules on their performance. It also showed that the performance rankings of seed-order selection rules and accompanying-order selection rules are affected by aisle-picking-frequency distributions, but not by route planning policies. Le-Duc and De Koster (2007) proposed a greedy heuristic to find the optimal picking batch size in a two-block rectangular warehouse to minimise the mean order throughput time. The results were verified to provide a good accuracy level.

2.4. Picker routing policy

The goal of picker routing is to plan the order pickers to complete the order picking operations in minimum travel