AN IMPROVED LARGEST GAP ROUTING HEURISTIC FOR ORDER PICKING

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KEYWORDS
Improved Largest Gap Routing, Largest Gap Routing, Order Picking, Simulation.

ABSTRACT

The largest-gap policy is a routing heuristic for order picking systems. In this paper we develop an improved largest gap routing method. A simulation approach is used to demonstrate the superior performance of the improved largest gap routing over traditional largest gap. Moreover, this paper tests the performance impact of storage assignment rules on largest gap routings. Several scenarios with various order sizes and different item popularity proportions are tested. Monte-Carlo simulation is used to carry out the experiments. The numerical results from the computational analysis show that our improved largest gap routing always outperforms the traditional largest gap routing, i.e. for all order sizes. The effect is the most distinct when the order size is smaller. Finally the study demonstrates that the optimal storage assignment rule to be combined with largest gap routing is within-aisle storage.

INTRODUCTION

Order picking is a highly labour-intensive and costly operation. Of all warehouse operation costs, order picking costs account for 65% (Coyle et al. 2002). Order picking activities are diverse, ranging from administration activities to preparing, searching, extracting and packing goods and walking. In a manual order picking system, this latter activity – walking – amounts to 50% of the total order picking operation time (Tompkins et al., 2003). Thus, the reduction of walking times can help improve picking efficiency.

In order to reduce walking times, it is important to carefully select a good routing strategy. Routing strategies deal with the route of a picker for a picking tour. More specifically, through the use of well-defined rules, the exact sequence in which items are to be picked during a picking tour is determined (Petersen 1997). Although, for a rectangular warehouse, an optimal routing algorithm exists (Ratliff and Rosenthal 1983), in practice heuristic strategies are often applied because of their simple use. Largest gap routing is one type of heuristic strategy. Although largest gap routing is not as easy as “S” routing, which is based on a transversal strategy, it is still used in some warehouses due to the shorter walking distances that are often obtained.

A large number of studies exist that focus on order picking routing policies (Petersen1997, Petersen 1999, Petersen and Schmenner 1999, Petersen and Aase 2004, Petersen et al. 2005, Caron et al. 1998, Roodbergen and De Koster 2001).

Aside from routing, a good storage assignment is another aspect that has an influence on picking efficiency, put-away productivity and space utilization. Two main storage policies are available: random and class-based. By a class-based storage rule, items are classified into several groups based on a specific criteria – e.g. volume, popularity, product group, weight – and each group is then assigned to a dedicated area of the warehouse. Volume-based storage means that items are classified into several categories, according to expected cubic movement during a period (Petersen, 1999), and high-volume items are assigned to storage locations close to the I/O point in order to reduce pickers’ travel. Petersen (1999) and Petersen and Schmenner (1999) studied volume-based storage and showed significant savings over random storage. Edward (2001) indicates that the number of requests for an item during a period is the true measurement of popularity in a warehouse. Popularity can be translated into the number of times a picker must visit a storage location for a given item. Different from the volume-based criteria, this indicator counts how many times an item is requested by customers rather than the cubic volume or units of the item that are demanded during a period.

Petersen and Aase (2004) gave a deeper study on the interaction of routing methods and storage rules. However, largest gap routing was left out. Moreover, little research studies the combination of routing and class-based storage strategies (De Koster et al., 2007). Petersen (1999) studied the impact of routing and storage strategies on warehouse efficiency but without consideration of popularity-based storage. Petersen and Aase (2004) gave a deeper study on the interaction of routing methods and storage rules. They considered popularity-based storage rules but largest gap routing was left out. Petersen et al. (2005) also found that popularity-based storage performs better than volume-based storage, but this research again did not consider largest gap routing.

It is clear that largest gap routing as well as popularity-based storage should be studied more. In this research, an improved largest gap strategy (ILG) is developed. A simulation approach is applied to compare ILG routing and original largest gap routing, taking into consideration two different storages rules, i.e. random storage and popularity-based storage.

IMPROVED LARGEST GAP ROUTING

Under a largest gap routing strategy, the largest gap in a visited aisle is the distance between either any two adjacent picks, or between the first pick and the front cross-aisle, or between the last pick and the back cross-aisle. If the largest gap is the distance between two adjacent picks, the picker should perform a return as shown in Figure 1.

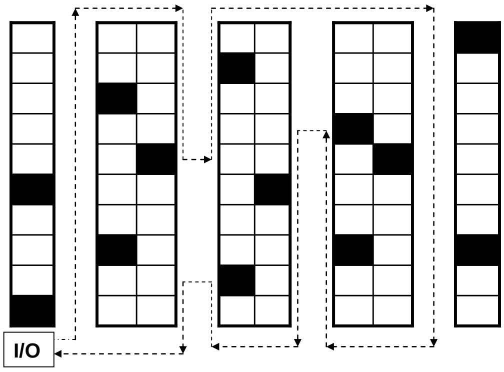


Figure 1: Largest Gap Routing

Under the principle of the largest gap strategy, when the quantity of visited aisles is one, a return is performed (return routing); when the quantity of visited aisles is two, a picker always traverses two aisles (also called "S" routing); when there are more than two aisles visited, the first and last aisle to be visited must be traversed as well, and the aisles in between will be entered as far as the largest gap within the aisle (largest gap rule).

This means that even when all the visited locations fall into the front half section of the warehouse, a picker should still traverse the first and last visited aisle. In this case, the walking distance could be reduced if the picker would perform return routes rather than traversing any aisles. Therefore, some modifications can be made to improve the performance of the largest gap strategy.

Figure 2 presents the logic of improved largest gap (ILG) routing. Each location is represented by a two-dimensional coordinate (x, y) and I/O is (0,0). The parameter $\max(y^i)$ is the vertical coordinate value of the furthest location visited from the front cross-aisle. The quantity of aisles visited during a pick tour is denoted by n. L^λ is the length of one picking aisle denoted by the number of stock locations, and $0.5L^\lambda$ is half of the length of the picking aisle. The function $\max(y^i) \le 0.5L^\lambda$ then means that all locations to be visited fall in the front half section of the picking area.

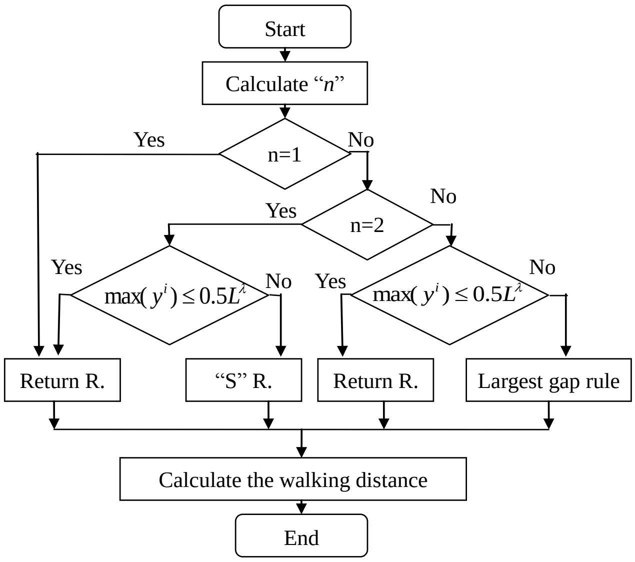
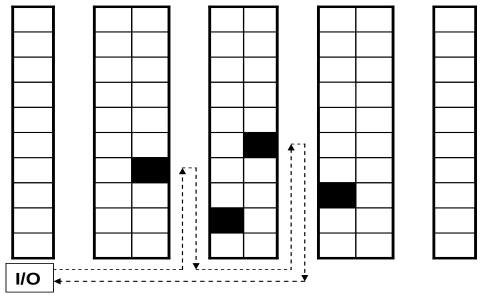
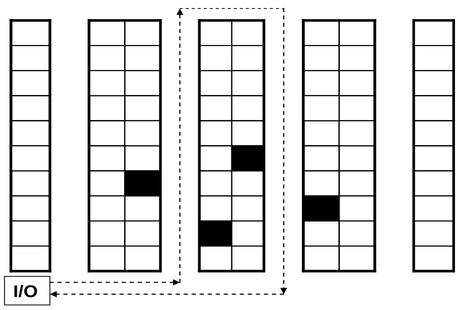


Figure 2: Decision Framework for ILG Routing

The improvements of ILG routing over largest gap routing stem from two aspects. The first aspect is illustrated in Figure 3, where there are two aisles visited during a pick tour. If the furthest location(s) visited from the front aisle fall in the front half section of the picking area, a return routing should be conducted under ILG routing as shown in Figure 3a; on the contrary, under traditional largest gap routing "S" routing would be performed as shown in Figure 3b.



a. ILG Routing



b. Largest Gap Routing

Figure 3: Difference of ILG and Largest Gap Routing

The second aspect of improvement is seen when there are more than two aisles visited during a picking tour. If all visited storage locations are distributed in the front half section, a return routing is applied again; on the contrary, under the traditional largest gap routing the first and last aisle would be traversed entirely.

CASE STUDY

This research is based on a broken-case cosmetics order picking system where single order picking, random storage and “S” routing are currently used. This scenario will be a base-case to discuss largest gap routing and ILG routing.

The warehouse layout has five picking aisles with front and back cross-aisles. The picking aisles are two-sided and wide enough for two-way travel. It is assumed that each item is assigned to one storage location and every location has the same size. An item is a single unique type of product; it is also called SKU (stock keeping unit) or product line.

Single order picking is applied. It is a manual picking environment where the picking cart is used to move the items picked back and forth to the I/O where each picking tour begins and ends. The I/O is located in the lower left corner of the warehouse. Bin-shelving is used and 800 items are stored. The height of the storage racks is four in terms of the number of stock locations. Each storage location is 1 meter by 0.3 meter. The width and length of the picking aisles are 2m and 6m respectively. The width of the cross-aisle is 3m.

EXPERIMENTAL DESIGN

This section presents the warehouse simulation model used for analysis and the experimental design. The purpose of this research is to identify the advantages of ILG routing in comparison to largest gap routing under several storages policies. The base-case is “S” routing and random storage. Two additional routing policies are examined: largest gap routing and ILG routing. The popularity-based storage policy is examined with four variations. This design of experiments results in 15 combinations.

Two proportions of popularity will be considered: on the one hand 20/80, which means that 20% of items contribute to 80% of all item requests, while the remaining 80% of items only provide 20% of all item requests; on the other hand 20/60 which indicates that 20% of the items provide 60% of all item requests and the remaining 80% of items provide 40% of all item requests. According to their popularity, all items will be classified into two groups: A and B.

The class-based storage rule also must consider the categorization of stock locations. Two principles are often used in practice to classify storage locations: within-aisle (W) and cross-aisle (C). Within-aisle storage means that the “A” items will be assigned to the aisle closest to the I/O point as shown in Figure 4a. According to a cross-aisle rule, the “A” items should be stored in the most accessible locations closest to the front cross-aisle, as shown in Figure 4b. In this study, storage assignment within each area is at random.

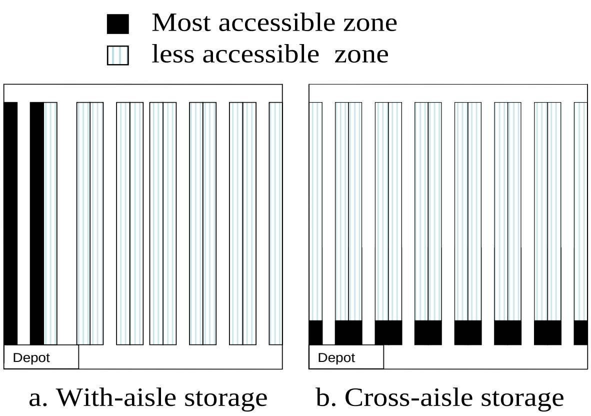


Figure 4: Location Categories

The 15 treatments from the 3×5 factorial design are evaluated using data sets generated by Monte Carlo simulation. A sensitivity analysis is conducted to evaluate different combinations of routing and storage rules. The analysis is carried out for different order sizes. More specifically, seven levels of order size are chosen: 3, 5, 10, 15, 20, 25 and 30 items. Among them, 3 and 5 items represent small orders; 10 and 15 items correspond to medium orders, and the rest are considered as large orders. Thus, for every given order size 15 combinations of routing and storages rules are tested. This results in 105 cells. Table 1 summarizes the design of experiment. Each cell is run for 1000 randomly generated orders and this results in a total of 105000 observations. The performance measurement for this experiment is the walking distance per picking tour.

Table 1: Experiment Factors

Factors	Explanation	Levels
Routing policies	“S” routing (S), largest gap routing (LG), improved largest gap routing (ILG)	3
Storage rules	Random(R), W(20/80), W(20/60), C(20/80), C(20/60)	5
Order size	3,5,10,15,20,25,30	7

RESULTS AND ANALYSIS

The analysis part has three sections. The first section explores the efficiency of ILG routing in comparison to LG routing. The second section examines the best performance of largest gap routings in combination with three types of storage policies. The final section investigates the effect of the popularity proportion on the performance of routing and storage policies.

Routing Performance

Figure 5 shows the savings percentage in average walking distance of a picking tour under random storage, for largest gap and ILG routings relative to "S" routing. The ILG routing is clearly a better heuristic than largest gap routing when the order size is smaller, for instance 3 items per order. Largest gap routing performs the same or sometimes even worse than "S" routing when the order size is three or less. This indicates that ILG routing can improve the performance of largest gap when order sizes are very small.

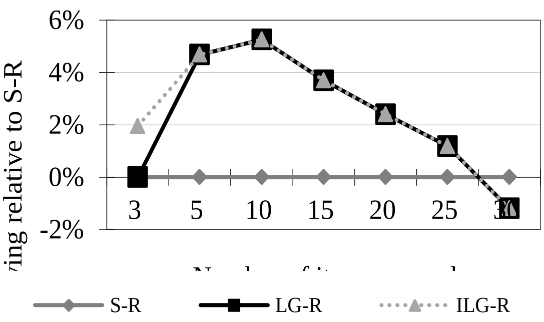


Figure 5: Percentage of Savings of ILG and Largest Gap Routing over Base-case under Random Storage

There is no significant difference between ILG and traditional largest gap routing when order sizes become larger than 3. Both largest gap routings achieve the biggest percentage of savings relative to "S" routing, 5.2%, when the order size is 10. As the order size increases, the advantages of largest gap routings are gradually lost. Both of the largest gap routings generate longer distance than "S" routing when the order size becomes 30. This indicates that largest gap routing is ineffective for large orders.

The Effect of the Storage Policy

Figure 6 compares the percentage of savings for different scenarios, i.e. different combinations of routing and storage policies, relatively to the base-case of "S" routing and random storage. Within-aisle and cross-aisle storage rules are applied under a 20/80 popularity distribution.

Firstly, we note that all three routing policies perform much better when they are operated with within-aisle storage, and the percentage of savings relative to the base case is between 13% and 35%. The ILG routing and traditional largest gap routing perform identically when order sizes ranges from 5 to 30 but when the order size is 3, ILG routing saves more than largest gap routing. Secondly, under the cross-aisle storage rule, ILG routing achieves savings relative to the base-case of nearly 5% more than largest gap routing, while both of them are becoming identical as order sizes increase to 15. Finally, in general, the scenario of ILG-W storage achieves the best performance for all order sizes in the experiment.

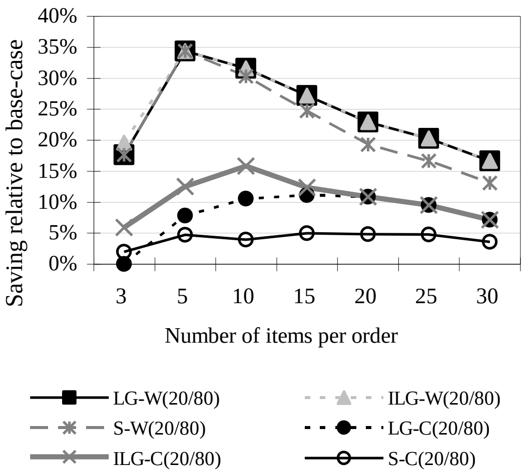


Figure 6: Effect of Storage Rules on Routings (20/80 Popularity Proportion)

The Effect of Popularity Proportion

The difference between the two types of popularity proportion can be found by comparing Figures 6 and 7. With an item popularity distribution of 20/80, the combinations of ILG-W and LG-W provide the largest savings (between 16% and 35% as order sizes vary) and S-W has an acceptable performance. Under a 20/60 proportion, the scenarios of ILG-W and LG-W still give the shortest distances. However, the savings percentage only ranges from 6% to 20%. Under both popularity proportions, ILG-W provides a little more savings than LG-W, when the order size is 3 items.

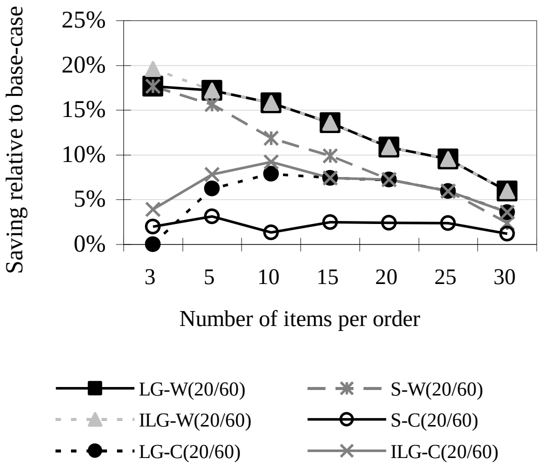


Figure 7: Effect of Storage Rules on Routings (20/60 Popularity Proportion)

In Figure 7, the relative savings achieved by S-W show a sharp decline as the order sizes increase. As a consequence, as long as the order sizes are smaller than 25 items, S-W is the third best policy, after ILG-W and LG-W; but when the order size is 30 items S-W is outperformed by LG-C. This is different to the scenario of 20/80 where S-W is always the third performer behind ILG-W and LG-W. ILG-C and LG-C acquire less than 10% savings for all order sizes.

In some circumstances, order sizes may vary. We now assume the situation where there is a balanced mix of orders, i.e. the proportion of small, medium and large orders are equal. The average percentage of savings for various order sizes is calculated for each combination of routing and storage rules. Figure 8 and 9 show the rankings of each combination for respectively the 20/80 and the 20/60 scenario.

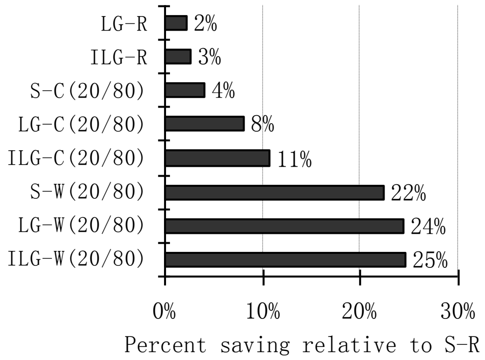


Figure 8: Ranking of Average Percentage of Savings under 20/80 Proportion

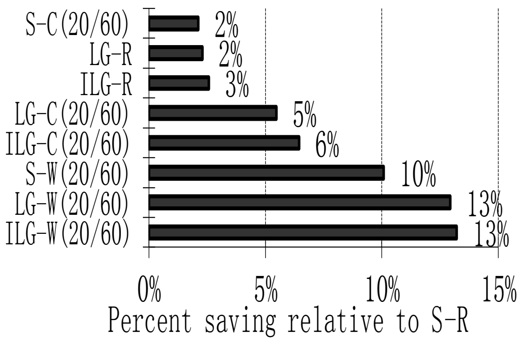


Figure 9: Ranking of Average Percentage of Savings under 20/60 Proportion

The change in popularity proportions has a negligible effect on the ranking of the heuristics combined with within-aisle storage. ILG-W, LG-W and S-W, are listed first, second and third respectively for both proportions. However, the change in popularity proportions has an effect on the ranking of S-C. The case of S-C (20/80) performs better than ILG-R and LG-R, while S-C is ranked behind ILG-R and LG-R with a 20/60 popularity.

CONCLUSION AND FUTHER RESEARCH

To achieve a more efficient order picking operation, it is necessary to reduce picking routes. Heuristics routings are commonly used due to their simplicity. A literature study has shown that little research focuses on largest gap routing and popularity-based storage. This paper evaluates an improved largest gap (ILG) routing policy in comparison with the original largest gap routing policy in a manual bin-shelving warehouse. It is concluded that the ILG routing policy can improve the performance of traditional largest gap, especially when the order size is smaller. Moreover, we investigated the effects of storage rules, order size and item popularity proportions on the performance of largest gap routings. When considering to switch from “S” routing to (improved) largest gap routing, an analysis by order size and by item demand popularity should be conducted. This is essential in order to gain insight in the potential returns of using largest gap routings. The results of this paper will provide decision-making support for order picking system designers and managers.

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ACKNOWLEDGEMENT

This research is funded by the Fundamental Research Funds for the Chinese Central Universities and while Dr. Jinping Liu is a visiting researcher at the Department of Industrial Management, Gent University.