The 2nd International Conference on Applied Mathematics, Modeling and Computer Simulation (AMMCS 2022)

Paper ID: CS403

A Solution of Freshness Constraint Order Batching Problem for Fresh Food E-commerce

Wenjing Yan, Zesheng Zhang, Min Zuo, Qingchuan Zhang

National Engineering Research Centre for Agri-product Quality Traceability, Beijing Technology and Business University, Beijing, 100048, China.

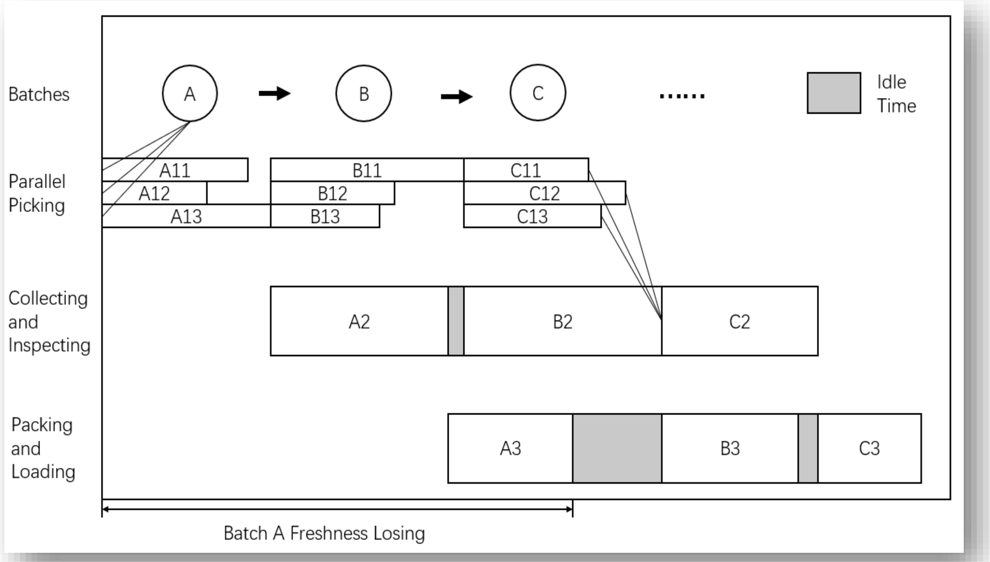
Supported by National Key Technology R&D Program of China (No.2021YFD2100605)

Introduction

Influenced by the Covid-19 pandemic, fresh food e-commerce market in China developed quickly. Efficient solution for Order Batch Problem (OBP) could achieve efficient batching operation and then reduce costs and control risks. However, the OBP model proposed by the previous researches did not consider the characteristics of fresh food products such as the less demand of orders, the large variety of products, perishability of products and etc. Therefore, this paper proposed a model of OBP with freshness constraint of perishable food products, and proposed a two-stage heuristic algorithm to solve the target problem of the model. Our solution could improve the efficiency of the sorting process while ensuring the freshness of food products.

Model of sorting

(1) The probability distribution of demand for all goods is in accordance;
(2) Any order is not allowed to be split into different batches;
(3) Picking for the next batch can only begin after the picking for current batch in all regions has been finished;
(4) After the order set is determined, new orders are not allowed to be inserted (Urgent orders are not considered);
(5) The freshness of the goods decays constantly from the beginning of sorting, and the minimum freshness must be met at the time of loading;
(6) The shelf lives of products in different storage areas are different, but in same area are the same.



The flows of batches A, B, and C during sorting process under parallel partition mode

For large storage center with a great many of product categories, a parallel partition mode could improve the efficiency of sorting, which includes parallel picking, collecting and inspecting, packing and loading.

Upper model:

$$\min \sum_{j}\sum_{d}\left|\sum_{i} x_{ij}\cdot Q_{id} - \frac{1}{m}\sum_{i} Q_{id}\right|$$

$$s.t.\ \sum_{j} x_{ij} = 1, \quad \forall i$$

$$\sum_{i} x_{ij} \le S, \quad \forall j$$

$$1 - \frac{t_j^1 + t_j^2 + t_j^3}{T_d} \ge g_d, \quad \forall j, d$$

$$x_{ij} \in \{0,1\}, \quad \forall i, j$$

Lower model:

$$\min \sum_{p=1}^{3}\sum_{k=1}^{m} I_k^p - F_{k-1}^p$$

$$s.t.\ \sum_{k} y_{jk} = 1, \quad \forall j$$

$$\sum_{j} y_{jk} = 1, \quad \forall k$$

$$1 - \frac{F_k^3 - I_k^1}{T_d} \ge g_d \cdot A_{jd}, \quad \forall k, d$$

$$y_{jk} \in \{0,1\}, \quad \forall j, k$$

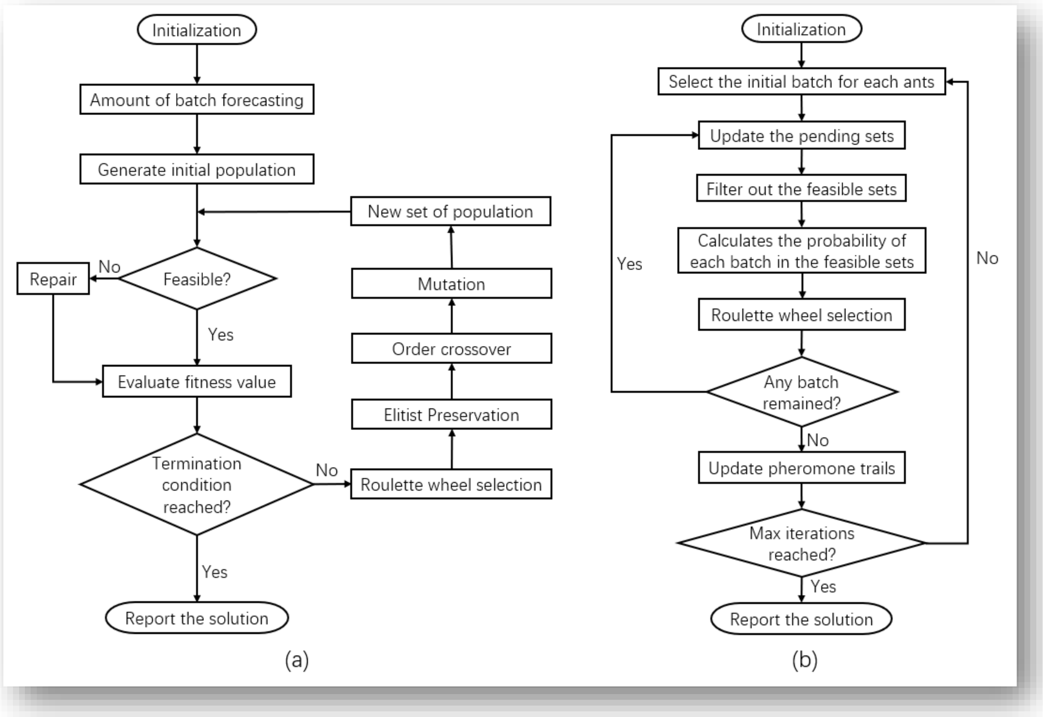
The objective function of the upper model try to keep balance of the load of each picking area in each batch to ensure the balance of scale between each batch, thereby reducing the idle time caused by excessive load differences;

In the objective function of the lower model, the total idle time of the sorting process of all batches is minimized.

The third constraints of the upper and the lower model mean that the minimum freshness must be met when goods leave the warehouse;

Algorithm of solution

In the two-stage heuristic algorithm proposed in this study, the e-GA is used to solve the OBP for the upper model, the improved ACO is used to solve the batch sorting problem for the lower model.



(a) The e-GA for the upper model (b) The improved ACO for the lower model

Results

Table 4 Comparison of results for the proposed method and FCFS

n	The proposed method	FCFS	Reduction (%)
100	250.04	269.58	7.25%
300	878.20	1268.60	30.77%
500	1648.48	1959.08	15.85%
750	2806.16	3122.69	10.14%
1000	3688.98	3852.14	4.24%

This study set a horizontal and vertical comparison between the sorting mode based on the two-stage heuristic algorithm and the traditional first come first serve (FCFS) rule at different scales, as shown in Table 4. The analysis shows that the proposed method can reduce the idle time by 4.245% to 30.77%, which proves that the proposed model has certain feasibility and superiority. As the number of orders increasing from 100 to 1000, the improvement shows a trend of rising first and then decreasing, indicating that there is an optimal number of orders to make the effect of the proposed method reach the best.