Optimization of picking in the warehouse

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Abstract. This paper studies the shortest path that the pickers should follow to complete the picking task in the actual e-commerce warehouse. Firstly, the concept of relay point is introduced and the distance model of the pickers in the warehouse is established through multiple Manhattan distances, and the computer simulation method is used to obtain the precise distance of the pickers from the review station to the review station, from the stock keeping unit to the stock keeping unit and from the stock keeping unit to the review station. Then the picking problem of the picker is analogous to the TSP problem, and the shortest path that the picker walks is obtained by improving the results of the genetic algorithm. The sensitivity analysis results show that the model has good stability and prove the reliability of the model.

1. Introduction

The rapid development of e-commerce makes warehouse efficiency a focus. As one of the core operations of the warehouse, picking occupies an important position in the operations of the entire warehouse. Scholars pay more and more attention to how to quickly complete the picking in the warehouse according to order requirements. Paper[1] established a multi-objective mathematical model with the goal of minimizing order fulfilment costs and warehouse picking path length, which effectively improved the overall efficiency of order fulfilment. Paper[2] aims at the slow optimization speed and low execution efficiency caused by local changes in the regional environment in mobile robot target path planning and proposes a solution for mobile robot path planning. Paper[3] uses the idea of intelligent shelves to propose a distributed parallel sorting method for large-volume orders, which effectively solves the bottleneck problem of the number of packaging points in the overall order sorting problem. Paper[4] designed a multi-objective partition picking model with the smallest total service time, the best partition workload balance, and the highest secondary sorting efficiency, which improved the efficiency of picking. Paper[5] proposed a rolling time window scheduling strategy and a high-dimensional sparse dynamic clustering algorithm to improve the sorting efficiency and dynamic response capabilities of e-commerce logistics distribution centers.

In the above studies, most scholars have proposed new sorting methods to adapt to the various complex situations of picking in the warehouse, but they rarely consider calculating the precise distance between the review station and the review station, the stock keeping unit (SKU) and the stock keeping unit, and the stock keeping unit and the review station in the warehouse in order to give the picker's movement path planning method more scientifically. Based on previous studies, this article studies the shortest walking distance for picking in the warehouse. This paper combines the actual situation of picking in the picker's warehouse, first introduces a relay point in the warehouse, and uses the Manhattan
distance[6-7] to quantitatively indicate the distance of the pickers from the review station to the review station, from the stock keeping unit to the stock keeping unit and from the stock keeping unit to the review station, and solves the exact distance through computer simulation. We then approximate the problem to a TSP problem and use genetic algorithm to solve the shortest loop[8-10]. Finally, we improve the shortest loop, and the pickers start from a certain review station and return to a certain review station after completing the task list.

2. Problem description

This article considers the optimization of picking in the warehouse under normal circumstances, and takes a representative lower-left corner of a large warehouse for analysis, as shown in Fig.1:

![Fig.1 The bottom left corner of the warehouse](image)

The green square in Fig.1 represents the review station (numbered FH01-FH03, FH09-FH11), which is responsible for reviewing the goods in the order and then packing the goods according to the order. The black squares indicate the goods compartment, and the goods are placed in the goods compartment. Pickers start from a review station, pick the goods in a certain order according to the position of the goods in the order, and finally return to any review station. When a person walks around an obstacle, the horizontal and vertical offset are both $d=750$ mm. For the convenience of the following description, the coordinates of the review station mentioned later refer to the coordinates of the lower-left corner of the review station, and the coordinates of the stock keeping unit refer to the midpoint of the side of the stock keeping unit reached by the picker. We know the coordinates of the check station and the stock keeping unit compartment in the picture. The distance between each group of shelves in the horizontal direction is 1500 mm, the length and width of each stock keeping unit compartment are $\delta=800$ mm, and the length and width of each check station is $l=1000$ mm. When the picker is walking in the warehouse, the distance from the stock keeping unit to the review station is simplified as the distance from the midpoint of the stock keeping unit to the midpoint of the nearest side of the review station, such as $L4$; the distance from the review station to the review station is simplified as the sum of the absolute value of the coordinate difference between the two review stations; the distance from one stock keeping unit to another is recorded as the distance between the midpoints of each side of the two stock keeping units, such as $L1$, $L2$ and $L3$. 

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3. Model establishment and solution

We define the distance of the picker from the review station to the review station, from the stock keeping unit to the stock keeping unit, and from the stock keeping unit to the review station according to the actual walking situation of the picker during picking.

3.1. Distance from review station to review station

The distance between the two review stations can be simplified as the sum of the absolute values of the two coordinate differences, that is, the Manhattan distance. Therefore, for the two review stations numbered \( i \) and \( j \), their coordinates \((x_i, y_i), (x_j, y_j)\), define the distance between them as:

\[
d_{ij} = |x_i - x_j| + |y_i - y_j|
\]  

(1)

3.2. The distance from the stock keeping unit to the stock keeping unit

After analysis, there are the following three situations.

Case 1, as shown by \( L_1 \) in Fig.1, when the two stock keeping unit compartments face each other, the result obtained by the above formula (1) is consistent with the actual situation.

Case 2, as shown in \( L_3 \) in Fig.1, when two stock keeping unit compartments are on the same shelf, the Manhattan distance between the two coordinates and the actual distance always differ by 2 offsets, that is, \( 2d \). Therefore, we can use:

\[
d_{ij} = |x_i - x_j| + |y_i - y_j| + 2d
\]  

(2)

to represent the distance between the two compartments in this case.

Case 3, as shown in \( L_2 \) and \( L_5 \) in Fig.1, the distance travelled by the picker from S00914 to S01713 according to \( L_2 \) and \( L_5 \) is recorded as \( d_{ij} \), and the shortest distance traveled by the picker is recorded as \( d_{ij} \). For the convenience of the following description, we need to introduce four relay points.

Suppose stock keeping unit S01015 (the red square framed in Fig.1.) is stock keeping unit A, and its coordinates are \((x_\alpha, y_\alpha)\), and stock keeping unit S01713 (the orange square boxed in Fig.1) is stock keeping unit B.

Take the coordinates of the relay point \( s' \) as an example to illustrate how to find the coordinates of each relay point. The coordinate formula of the relay point \( s' \) is:

\[
x_{s'} = x_\alpha + d
\]

(3)

\[
y_{s'} = y_\alpha + d + \frac{\delta}{2}
\]

(4)

Where \( x_{s'}, y_{s'} \) are the abscissa and ordinate of the relay point \( s' \), \( d \) is the offset, and \( \delta \) is the side length of the stock keeping unit.

The precise distance \( d_{i'p'} \) between S00914 and the relay point \( r' \) can be obtained by formula (1). The precise distance between the relay point \( r' \) and the relay point \( s' \) is \( d_{r' s'} \), the precise distance between the relay point \( s' \) and the stock keeping unit B is \( d_{s' j} \). Therefore, the precise distance \( d'_{ij} \) of \( L_2 \) is expressed as:

\[
d'_{ij} = d_{i'p'} + d_{r' s'} + d_{s' j}
\]

(5)

In the same way, find the distance \( d''_{ij} \) between S00914 and S01713 with \( r'' \) and \( s'' \) as the relay point. Finally, the distance between the two stock keeping unit compartments is:

\[
d_{ij} = \min(d'_{ij}, d''_{ij})
\]

(6)

3.3. The distance between the stock keeping unit compartment and the review station

Take the review station FH10 as an example to illustrate the solution method. For the convenience of description, first, define the following:

1. The midpoints of the three sides of the review station are marked as A, B, and C respectively.
2. We define two relay points \( p, q \) and take relay point \( p \) as an example to illustrate the coordinate formula:

\[
x_p = x_t + l + d
\]

(7)
\[ y_p = y_t + l + d \]  \hspace{1cm} (8)

As shown in Fig.1, where \( x_t \) and \( y_t \) are the abscissa and ordinate of the review station FH10, respectively. We found that the distance from the relay point \( p \) to the midpoints A and B of the review station is equal to the distance from the relay point \( q \) to the midpoints A and C of the review station, both of which are \( 2d + \frac{l}{2} \). Therefore, the distance from the request grid to the midpoint of the three sides of the review station can be simplified to the distance to the two relay points.

3. We define the shaded area in Fig.1 as the direct access area of the review station. If the stock keeping unit is close to the direct zone and the ordinate of the stock keeping unit is within the direct zone, it is said that the stock keeping unit is in the direct zone of the review station. For example, in this example, the stock keeping unit S00106, S00107, and S00108 are in the direct area of the review station FH10.

The distance from the stock keeping unit compartment to the review station can be considered in two cases. For the stock keeping unit compartment in the direct area, we choose the nearest point among A, B, and C to directly calculate the Manhattan distance. For the stock keeping unit outside the direct area, calculate the distances \( d_p \) and \( d_q \) from the relay points \( p \) and \( q \) to the stock keeping unit respectively. The distance from the stock keeping unit \( i \) to the review station FH10 is:

\[ d_{it} = \min\left(d_p + d_q\right) + \frac{l}{2} + 2d \]  \hspace{1cm} (9)

Where \( t \) is the number of the review station FH10 in this example.

3.4. Model solving

The distance between any two in the warehouse system can be classified as the situation in the above model. We can obtain the precise distances between all review stations and review stations, stock keeping unit spaces and stock keeping unit spaces, and stock keeping unit spaces and review stations through computer simulation. The distance between some nodes is shown in Table 1.

|                | SH00101 | SH00102 | SH00103 | FH01   | FH03   |
|----------------|---------|---------|---------|--------|--------|
| SH00101        | 0       | 2300    | 3100    | 5400   | 14400  |
| SH00102        | 2300    | 0       | 2300    | 6200   | 15200  |
| SH00103        | 3100    | 2300    | 0       | 130600 | 16000  |
| FH01           | 5400    | 6200    | 130600  | 0      | 9000   |
| FH03           | 14400   | 15200   | 16000   | 9000   | 0      |
The above calculation results are basically consistent with the actual situation in the warehouse, indicating the reliability of the model. After obtaining the above-mentioned precise distance, the picking problem of the picker can be analogous to the TSP problem first. But the picker does not need to return to the departure review station in the end. Only after finishing the picking, the picker arrives at a review station closest to the last visited stock keeping unit box. Therefore, we consider solving the TSP problem first and using the genetic algorithm to find the shortest path sequence \( i_1j_1j_2 \ldots j_n i_1 \) starting from the review station FH10 to traverse all the stock keeping unit spaces in the task list and then back to the review station FH10, where \( i_1 \) represents the starting review station, \( j_1, j_2, \ldots, j_n \) represent \( n \) SKU. Then we find the nearest review station to the last stock keeping unit box \( j_n \) in the path, record it as \( i_2 \), then the final sequence \( i_1j_1j_2 \ldots j_n i_2 \) is what we want.

4. Model results

The results of the genetic algorithm solution are shown in Fig.3.
After running the above genetic algorithm many times, the convergence is similar to that in Fig.3. It converges to a stable value of 26700 around the 60th generation. We have four optimal paths to complete the task list T0001. We take path 1 as an example to show:

Path 1 is: FH10, S00107, S01713, S01308, S07515, S08502, S06213, S07212, S10115, S11106, S11205, S12608, S13509, S15911, S14401, S14908, S13812, S14510, S13809, S13004, S12103, S10508, S10501, S07305, FH07.

5. Model checking
When using the genetic algorithm to solve the TSP problem, we set the population size $M=100$ by ourselves. Next, we will analyze the sensitivity of the shortest loop distance to the population size $M$. We keep the values of other parameters unchanged, change the value of $M$ per 20, observe the change of the shortest distance, and get the result as shown in Fig.5.

![Fig.5 Sensitivity analysis result graph](image)

It can be seen from Fig.5 that when $M<100$, the shortest distance of the loop decreases with the increase of $M$, indicating that the system at this time is not stable and the result obtained is unreliable. But when $M>100$, the shortest distance remains almost constant and the system result is stable, which proves that it is reasonable to choose $M=100$ in the genetic algorithm and the result obtained is stable.

6. Conclusion
Based on the above results and discussion, the following conclusions can be drawn: In the actual e-commerce warehouse, we can quantitatively characterize the precise distances between the review station and the review station, the stock keeping unit and the stock keeping unit, and the stock keeping unit and the review station by introducing relay points and based on multiple Manhattan distances. The precise distance can be solved by computer simulation. On the basis of obtaining the above-mentioned
precise distance, through the analogy of TSP problem and the improvement of the genetic algorithm result, we can better obtain the shortest distance the picker takes to complete a task list. The sensitivity analysis results show that the model has good stability and is more reasonable.

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