OPTIMAL VEHICLE DISTRIBUTION ROUTE PLANNING BASED ON INTELLIGENT LOGISTICS SYSTEM

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ABSTRACT: The solution efficiency and accuracy of traditional vehicle route planning algorithm will decrease greatly in face of a large-scale logistics distribution. This study proposes an intelligent solution system for vehicle distribution route planning. Taking the optimal intelligent search algorithm as the core, this study explores the optimal route planning of logistics distribution vehicles by integrating the basic theories, such as fuzzy clustering and operations research. This study first carries out fuzzy clustering of distribution areas and customers according to geographical environment, urban layout and customer attribute so as to provide data pre-processing for subsequent vehicle distribution route planning. Considering the factors, such as the number of regional customers and the quantity of distribution goods, an optimal intelligent search algorithm for the distribution vehicle route planning is designed by taking the accumulated travelling distance, running time and total logistics cost of distribution vehicles as the optimization objective. The calculation results show that this method can effectively reduce the calculation time and the number of distribution vehicles, and the solution efficiency of the algorithm doesn’t reduce after the increase of the overall size of the logistics, which proves the feasibility of this method and provides a new idea for the research of intelligent logistics.

KEYWORDS: intelligent logistics, route planning of vehicles, optimization scheme, vehicle scheduling.

1 INTRODUCTION

Along with the development of e-commerce and the expansion of trade at home and abroad, the scale of logistics industry also shows explosive growth. With the rapid increase of logistics distribution points, distribution vehicles and distribution orders, the traditional logistics distribution mode has no longer been suitable for the development of modern logistics industry (Jiao, 2014; Meidutė et al., 2012; Sheng, 2014; Shi et al., 2014). It is the research focus and difficulty to construct an intelligent logistics system by considering multiple constraints such as order state, traffic situation, and optimal route planning so as to realize intelligent scheduling decision of logistics (Lau et al., 2010; Adamski, 2011; Yang, 2012; Ma & Zhang, 2006).

The route planning of logistics distribution vehicles is the core content of the whole logistics link (Su & Xue, 2014; Lin & Zhang, 2012; Gao et al., 2012; Harmati, 2007), which is a typical NP-hard problem. At present, researches on logistics vehicle distribution route planning have mainly focused on the following aspects: (1) route planning considering vehicle capacity; (2) vehicle route planning considering multiple distribution points; (3) vehicle route planning for distribution in batches; (4) roundtrip route planning for the integration of goods gathering and supply; (5) distribution route planning for random demand (Wu, 2014; Chai, 2017).

For the above-mentioned contents, the mathematical model based on traffic flow, the mathematical model based on logistics and the mathematical model based on set segmentation are constructed to simulate the optimal allocation and transportation process of logistics vehicles (Wu, 2011; Wang, 2013). The core solution algorithm of the model can be summarized as accurate solution algorithm and heuristic solution algorithm. The accurate solution algorithm mainly aims at accurately obtaining optimal analytical solutions and analog solutions for integer programming and graph theory (Zhou et al., 2013; Qureshi et al., 2009; Abdallah & Jang, 2014), including K-degree center tree method, dynamic programming method, branch pruning method and gradient optimization method (Qureshi et al., 2012; Chen, 2012; Qureshi, 2012; Qureshi, 2010). The heuristic solution algorithm can be regarded as a semi-empirical algorithm, which obtains satisfactory solutions according to a large number of historical data and other constraints (distribution time and space usage) (Scheuerer, 2006; Batsyn & Ponomarenko, 2014).
For example, C-W saving algorithm, two-stage algorithm and bionic algorithm are all heuristic solution algorithms (Zhang, 2014; Qi, 2011; Qi, 2010; John & Stanley, 2011). The models and algorithms mentioned above can solve some scheduling problems of logistics distribution. However, when the overall logistics distribution scale is large, the solution state space of the algorithms expands sharply, which will lead to the reduction of the solution efficiency and accuracy of the algorithms.

In order to solve the problem that the solution efficiency and accuracy of the traditional scheduling algorithms decrease when the logistics distribution scale is large, this study puts forward an intelligent solution system for the distribution vehicle route planning. Taking the optimal intelligent search algorithm as the core, this study explores the optimal route planning of logistics distribution vehicles by integrating the basic theories, such as fuzzy clustering and operations research.

2 INTELLIGENT ROUTE PLANNING ALGORITHM AND SOLUTION FOR LOGISTICS DISTRIBUTION VEHICLES

2.1 Cluster classification of distribution areas and customers

The overall optimization objective of logistics distribution is to take into account the constraints such as the distribution time of vehicles, the maximum cargo capacity of vehicles, the number of vehicles, the distribution of customers in the distribution areas, and the distribution route, as well as to control the minimum cost. Then the mathematical models established in this study are:

$$\sum_{i=1}^{n} (c_{ij}z_{ij})$$

(1)

Formula 1 is an objective function indicating that the total cost of single logistics is the lowest; Formula 2 is constraint conditions, which limits and constrains the maximum loading amount, the number of vehicles, and the running time respectively. Fig. 1 is statistics of influence factors of logistics distribution, including customer information, traffic environment and geographical environment information.

2.2 Relevant processing flow for the factors influencing logistics distribution

According to the influence factors of logistics distribution, this study designs the corresponding processing flow, as shown in Fig. 2. This flow focuses on the knowledge representation of influence factors, knowledge base of influence factors and inference engine in the process of distribution.
Fig. 3 further summarizes the factors that affect the cluster of distribution areas and customers in the areas. The cluster of distribution areas mainly considers the geographic environment and urban layout of distribution areas. The cluster of customers mainly takes into account customer attribute, geographical location and importance of distribution. At the same time, the traffic route, distribution cost and other constraints between different areas and customers should be considered.

In megacities and large cities, there is annular rapid transit where traffic lights are set and the speed is relatively fast. If the route planning of logistics distribution vehicles is on the annular rapid transit, the distribution efficiency will be greatly improved. Fig. 4 is a schematic diagram of vehicle route planning for annular logistics distribution. The customers to be distributed can be named as Class-A customers, Class-B customers, Class-C customers and Class-D customers in proper order by the area where the customers are from inside to outside. In the figure, there are two traditional distribution schemes, 1 and 2, but in the annular route, the vehicle take priority over the use of the annular road.
2.2 Optimal intelligent search algorithm of route planning for distribution vehicles

Vehicle route planning and design mainly consider three factors, namely, the number of customers in distribution areas, the accumulated travelling distance and time of distribution vehicles, and the accumulated quantity of distribution goods.

The accumulated supply quantity of logistics can be expressed as:

\[ Q_{jk} = Q \sum_{m=1}^{j} a_{mjk} \]  

(3)

Where, \( a_{mjk} \) indicates the number of \( m \)-th class of customers to be distributed by the \( k \)-th vehicle in the \( j \)-th vehicle planning scheme. Formula 4 and Formula 5 are recursion formulas of the accumulated distribution time.

\[
T_{i,j} = \begin{cases} 
0, & (a_{ij} = 0) \\
D_{ij} + a_{ij}U + (a_{ij} - 1)H_i, & (a_{ij} > 0) 
\end{cases} \quad j = 1, 2, ..., m_i 
\]  

(4)

\[
T_{i,j} = \begin{cases} 
T_{i-1,j} + (a_{ij} = 0) \\
T_{i-1,j} + E_{i-1,j} + a_{ij}U + (a_{ij} - 1)H_i, & (a_{ij} > 0), \quad i = 2, ..., C; j = 1, 2, ..., m_i 
\end{cases}
\]  

(5)

Fig. 5 Tree search schematic diagram of route planning for distribution vehicles

Fig. 6 Flow chart of route planning scheme for distribution vehicles based on search algorithm
In order to facilitate the planning, the vehicle route planning scheme is generally expressed in the form of tree diagram, as shown in Fig. 5. The number of layers of the tree diagram can be determined by Formula 6.

\[
\begin{align*}
    n &= \max\{W_1, W_2, \ldots, W_k\} \\
    a &= \min\{\frac{n}{d}, m\} \\
\end{align*}
\]

(6)

where, \(W_k\) is the cargo capacity of a vehicle; \(n\) is the maximum cargo capacity; \(d\) is the average quantity demanded; \(m\) is the number of customers in the vehicle distribution route.

The flow chart of route planning scheme for distribution vehicles based on search algorithm is shown in Fig. 5, and the working flow steps are as follows:

1. The initial state of the logistics distribution is described by the customer location, travelling time and supply quantity, namely \((C_i, T_n, Q_n)\). Enter the starting distribution point \(S\) into the open table, \(T_n=0, Q_n=0\).

2. Determine whether open is empty or not. If yes, exit the calculation, and if no, calculate the travelling time of the vehicle from \(S\) to the nearest node.

3. Determine whether the \(n_{th}\) node of the parent node of the \(n_{th}\) node is a distribution center based on a search algorithm. Then calculate the values of \(C_n, T_n\) and \(Q_n\) according to the corresponding calculation method.

4. When the vehicle completes a task dispatched by a customer, the action set for selecting the next distribution customer is \(\{G(C_1), G(C_2), \ldots, G(C_M)\}\).

5. The calculation threshold is set. When \(T_n > T\) or \(Q_n > c_n\), it is considered that the distribution vehicle has reached the maximum limit condition and the distribution task comes to an end, and the vehicle no longer continues the distribution task.

3 INTELLIGENT SOLUTION SYSTEM OF ROUTING PLANNING FOR DISTRIBUTION VEHICLES

Based on the optimal search algorithm of vehicle route planning, an intelligent solution system of vehicle distribution route scheme is designed, and its overall structure is shown in Fig. 7. The system contains three processing modules (distribution area processor, route scheme generator and solver), three subsystems (distribution contour line system, vehicle scheduling system and order real-time processing system) and a central visual information processing platform.

The system mainly includes the following functions:

1. Order information processing. The processing contents include customer information, distribution vehicle information and goods information. At the same time, the total distribution time, the maximum cargo capacity and the total cost of the vehicles also need to be estimated.

2. Cluster of distribution location and customers. According to the research contents mentioned above, the distribution area and the location and distribution importance level of customers in the area are clustered.

3. Planning and solving of vehicle distribution route scheme. The optimal distribution route is generated according to the set constraints and optimization objective, and the process of solving the model is completed according to the search algorithm in the system.

The specific flow of solving the distribution vehicle route planning is shown in Fig. 8. After receiving the distribution order information, the intelligent system imports it into cluster database of distribution areas and customers, and the database preliminarily divides the order based on the intelligent clustering method. After being divided, data is exported and standardized. The order-vehicle matching strategy is automatically generated according to the intelligent system. Initially, there are several schemes that are compared with the historical data in the knowledge base, and the optimal travelling scheme is selected according to other constraints and distribution conditions. Finally, the scheme is transmitted to the visual information platform for task allocation.
In order to facilitate the data reading and the analysis result export of the intelligent solution system and to improve the applicability of the system, this study innovatively designs the universal conversion interface of the system solution software, as shown in Fig. 9. This interface can be used to transfer the core data such as order information processing, cluster of distribution location and customers, planning and solution of vehicle distribution route scheme into txt text file and mdf data file so that the data can be processed later.
4 EXAMPLE VERIFICATION AND ANALYSIS

Taking the vehicle route planning problem in a distribution area of a logistics company as an example, the effectiveness of the proposed algorithm is verified. The logistics company is responsible for food distribution of a food factory. The customers are 105 retail stores in the urban area. Because of the different quantity of goods required by each retail store and the huge traffic jam in the urban area, the distribution route planned by experience and traditional optimization method can’t guarantee the normal delivery of goods. In addition, the distribution cost is high.

The three areas A, B, and C are further subdivided into four sub-areas (A₁-A₄, B₁-B₄, C₁-C₄).

Fig. 10 Division of distribution area and customer route

According to the circular logistics distribution planning shown in Fig. 4, retail stores to be distributed are divided into three areas A, B and C, as shown in Fig. 10. Retail stores in Area A account for 47.6% of the total number of stores, in Area B account for 34.3%, and in Area C make up 18.1%.

After comparing this algorithm with the route planning method based on ant colony algorithm, this study analyzes the number of vehicles, travelling distance and calculation time under 8 distribution scales, and the statistical results are shown in Table 1. The figures in brackets S1-S8 represent the total number of customers in the area and the maximum cargo capacity. From the table, it can be seen that the number of vehicles and the calculation time of this method are far smaller than those of ant colony algorithm, and the total travelling distance is increased to some extent. However, the total cost by reducing the number of vehicles is significantly reduced, and the less calculation time makes the algorithm of this study more rapid in logistic vehicle arrangement. At the same time, with the increase of logistics scale, the efficiency of this algorithm isn’t decreased, which proves the superiority of this algorithm.
5 CONCLUSIONS

For the defect that the solution efficiency and accuracy of the traditional scheduling algorithms decrease when the logistics distribution scale is large, this study puts forward an intelligent solution system for the distribution vehicle route planning. Taking the optimal intelligent search algorithm as the core, this study explores the optimal route planning of logistics distribution vehicles by integrating the basic theories, such as fuzzy clustering and operations research. The conclusions are as follows:

(1) According to the factors such as geographical environment, urban layout and customer attribute, the fuzzy cluster of distribution areas and customers is carried out. The cluster of areas and customers with the same attribute is divided in the way of tree diagram, which provides data pre-processing for the subsequent vehicle distribution route planning.

(2) Considering the factors, such as the number of regional customers and the quantity of distribution goods, an optimal intelligent search algorithm for the distribution vehicle route planning is designed by taking the accumulated travelling distance, running time and total logistics cost of distribution vehicles as the optimization objective.

(3) The comparison results show that the proposed method can effectively reduce the calculation time and the number of distribution vehicles, and the efficiency of the proposed algorithm isn’t decreased after the increase of the overall logistics scale, which proves the feasibility of this method and provides a new idea for the research of intelligent logistics.

Conflicts of Interest: The authors declare no conflict of interest.

6 REFERENCES


