Model research on route optimization of fourth party logistics based on uncertainty theory and genetic algorithm

LIMENG LIU[1]

Abstract. Based on the uncertainty theory, this paper analyzes and establishes the model of route optimization of fourth-party logistics. Based on the traditional genetic algorithm, an improved genetic algorithm based on simple graph is designed from the point of view of the prohibition of infeasible solution. The improved genetic algorithm is used to solve the fourth-party logistics path optimization model, which not only improves the search efficiency of the algorithm, but also solves the problem of solving large-scale problems. Finally, the proposed model and algorithm are validated by case study. The results show that the proposed algorithm is effective and analyzes the performance, convergence and robustness of the proposed algorithm.

Key words. Fourth-party logistics, uncertainty theory, route optimization.

1. Introduction

The main advantage of genetic algorithm[1] is to automatically obtain the search space, automatically adjust the search direction, and has been one of the most successful and most widely used algorithms in the field of evolutionary computing.Braysy et al. Proposed an improved genetic algorithm based on local search and constructive heuristic algorithms. Compared with the traditional standard genetic algorithm, the improved genetic algorithm uses the maximum neighbor search algorithm in the cross operation, which effectively solves the local convergence problem of genetic algorithm.

In the third party logistics, although the third parties and customers are a long-term strategic alliance, there is a possibility that the goal is not uniform and the performance of cooperation is decreasing. In this case, logistics outsourcing perfor-

[1]Acknowledgment - We acknowledge the foundation of Scientific Research Fund of Hunan Provincial Education Department (Grant No.15C1101).

[2]School of Business, Huaihua University, Huaihua 418000, China

mance will tend to decline gradually, and then hinder the overall development of supply chain logistics. Taking into account the shortcomings of the traditional third party logistics, a new form of organization, the fourth party logistics (4PL) [2], has gradually developed. It overcomes the shortcomings of the third party logistics, and makes the entire logistics supply chain improved and optimized, and then maximize the customer demand and obtain higher income.

Based on the uncertainty theory, this paper first analyzes and establishes the model of route optimization of fourth-party logistics. Based on the traditional genetic algorithm, an improved genetic algorithm based on simple graph is designed from the point of view of the prohibition of infeasible solution. Finally, the proposed model and algorithm are validated by case study. The results show that the proposed algorithm is effective and analyzes the performance, convergence and robustness of the proposed algorithm.

2. Establishment of the fourth party logistics path optimization model

As shown in Figure 1, X and Y represent node set and edge set respectively.$X_S$indicates the start node and $X_e$represents the destination node, and the other nodes represent the transit nodes. $|X|=n$ shows that there are n nodes in each graph, and each node represents the time and cost needed for the transport task to pass through the node. Each edge represents one supplier that could undertake the task of transportation in the graph, also having the time and cost property, which expresses the time and cost needed by the supplier performing the task in the segment between the two nodes.

For a given transport task from the start node X_S to the destination node X_e, a path consisting of nodes and edges is the solution of the problem, as shown in the red line in Figure 1.

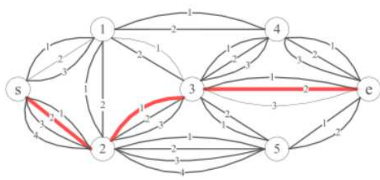

Fig. 1. Multiple graph of route optimization of fourth party logistics

For ease of description, suppose that $t_{ijk}\left(i,j=1,2,\cdots,n,k=1,2,\cdots,r_{ij}\right)$ are subject to normal uncertain distributions $\phi_{ijk}\left(t\right)$ and are independent of each other. That is$t_{ijk}??N\left(\mu_{ijk},\sigma_{ijk}\right)$, Where μ_{ijk} indicates its mean, σ_{ijk} represents its standard deviation, and its variance isσ^2_{ijk}. In addition, the transportation time of the supplier is composed of $T_{ijk}$and t_{ijk}, and T_{ijk} is a deterministic quantity, t_{ijk} is an uncertain variable, and $T_{ijk}+t_{ijk}$,is still an uncertain variable. And, in order to not lose the generality, set the letter level$\alpha\in[0.5,1)$.The problem presented in this paper is based on the assumption that the total transport time of the customer is satisfied at a certain confidence level, to select a connection path that transports the transport task from the originating node to the destination node, in order to minimize total transit costs. Therefore, the uncertain planning model (UPM) is as follows

$$Min\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{r_{ij}}C_{ijk}x_{ijk}\left(R\right)+\sum_{j=1}^{n}C_{i}y_{i}\left(R\right) \tag{1}$$

$$s.t.\ \mathrm{M}\left\{\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{r_{ij}}\left(T_{ijk}+t_{ijk}\right)x_{ijk}\left(R\right)+\sum_{j=1}^{n}T_{i}y_{i}\left(R\right)\leq T_{0}\right\}\geq\alpha \tag{2}$$

$$x_{ijk}\left(R\right)=\begin{cases}1, e_{ijk}\in R\\ 0, \quad \text{else}\end{cases} \tag{3}$$

$$y_{i}\left(R\right)=\begin{cases}1, x_{i}\in R\\ 0, \quad \text{else}\end{cases} \tag{4}$$

$$R=\left(x_{s},\cdots,x_{i},k,x_{j},\cdots,x_{e}\right)\in D \tag{5}$$

The formula (1) is the objective function, which means minimizing the total transportation cost. Formula (2) indicates that the confidence level that the total transport time of path R does not exceed the customer's expectation T_0 is equal to or greater than the specified confidence level α, in which M is an uncertainty measure. X_{ijk}(R) and y_j(R) in formula (3) and (4) are 0-1 variables, which indicate whether the edge e_{ijk} and the node X_S are on the path R or not. Equation (5) requires that the selected path R starts at the start node X_S, and ends at the destination node X_e, and the nodes and edges are communicated with each other. In addition, it can be seen that there should be no loops on path R when the total cost of the objective function is guaranteed to be minimal.

Transform UPM into a deterministic model, that is, to transform formula (2) as follows:

$$\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{r_{ij}}x_{ijk}\left(R\right)\phi_{ijk}^{-1}\left(\alpha\right)+\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{r_{ij}}T_{ijk}x_{ijk}\left(R\right)+\sum_{j=1}^{n}T_{i}^{'}y_{i}\left(R\right)\leq T_{0} \tag{6}$$

3. Solution of the path optimization model of fourth party logistics

For 4PLRP[3], a key problem in the search process of genetic algorithm (GA) is to deal with an infeasible solution that is not a path from the start node and terminates at the destination node. To avoid the generation of such infeasible solutions or to design effective repair strategies will directly affect the efficiency of the algorithm. Therefore, from the angle of avoiding such infeasible solutions, an improved genetic algorithm (SDGA) based on simple graphs is designed, and the multiple graphs are transformed into simple graphs. Based on the characteristics of undirected multiple

graphs, the 4PLRP is encoded by the upper triangular matrix, and GA[4] is designed to solve the proposed problem, as follows:
(1) Encoding multiple graphs according to the upper triangular matrix;
(2) Initialize the population;
(3) Perform crossover, mutation, and selection operation on populations.
(4) Repeat procedure (3), complete the required iteration number, and output the current optimal individual as the solution of the problem.

4. Case analysis

To test the performance of the proposed algorithm and the effectiveness of the proposed model, three kinds of numerical examples are generated randomly, and the performance of the proposed algorithm and the impact of convergence on the algorithm performance are analyzed according to an example. Furthermore, the robustness of the proposed model is analyzed by comparing it with the expected value model[5].

Assume$\mu = 0, \sigma = 1.40, \alpha = 0.93$ and the results of each node example are shown in table 3. Among them, "Algorithm" represents the proposed algorithm, and the "Node" and "LCode" represent the nods number of computation example and the length of the code, which reflects the size of the example. The algorithm runs 100 times and the parameters are population size "NP", the number of iterations "NG", the crossover rate "Pc", the mutation rate "Pm", the best solution "Best", the worst case "Bad", the mean "Avg", the standard deviation "Msd" And the average time required for the algorithm to run once "Time". Where the standard deviation "Msd" is as shown in equation (7).

$$Msd\,(S) = \sqrt{\frac{\sum_{i=1}^{n}\left(S_i - \overline{S}\right)^2}{n-1}} \tag{7}$$

In order to explain the searching process of the algorithm more clearly, the convergence of the algorithm is analyzed and compared by numerical examples. The formula (7) and the formula (8) respectively represent the average value and the good rate of the solution of the current population in the algorithm iteration. C_i represents the cost of the i-th individuals in the current population, and m is the number of better solutions in the current population, that is, the number of individuals whose cost is equal to the cost of the final better solution of the algorithm.

$$Mean\,(c) = \frac{1}{NP}\sum_{i=1}^{NP} c_i \tag{8}$$

$$Rate\,(c) = \frac{m}{NP} \tag{9}$$

Fig. 2 shows the change of the average of the two GA solutions with the number of iterations in the 15 node example. To make a clearer comparison, the population sizes of the two GA are set to 200. Because the Dijkstra algorithm and the K short-circuit algorithm are considered respectively, advantage of SDGA on initial population is obvious. SDGA converges faster than GA.

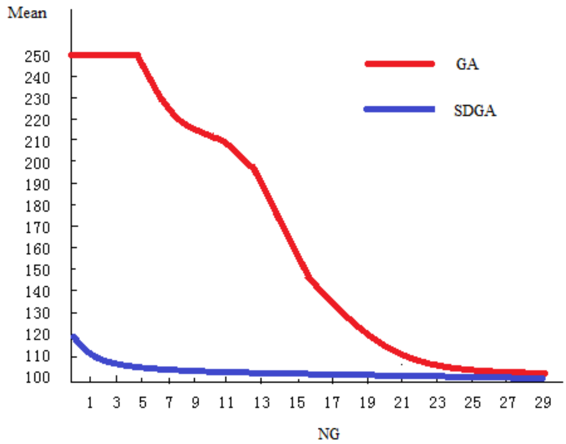

Fig. 2. Change of cost average in a 15 node example

Figure 3 shows the change of the average of the two GA solutions with the number of iterations in the 30 node example. For genetic algorithm, it is difficult to solve large-scale problems. When the population size is small, the algorithm is difficult to converge to a better solution. Thus, the population size of the two algorithms in Figure 3 is not equal, and the population sizes of GA and SDGA are set at 2000 and 100 respectively. It can be seen from Figure 3 that the improved strategy of the improved algorithm is effective.

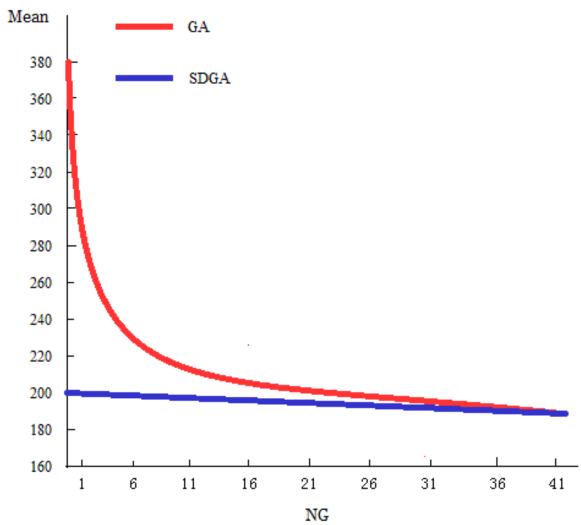

Fig. 3. Change of cost average in a 30 node example

5. Conclusion

Based on the uncertainty theory, this paper analyzes and establishes the model of route optimization of fourth-party logistics under uncertain environment. Based on the traditional genetic algorithm, an improved genetic algorithm based on simple graph is designed from the point of view of the prohibition of infeasible solution. The improved genetic algorithm based on simple graph is used to solve the fourth-party logistics path optimization model. Finally, a numerical example is given to compare the established model and the proposed algorithm. The results show that the proposed algorithm can effectively solve small scale problems, and with the increasing size of the problem, the improved genetic algorithm is gradually showing advantages.

References

[1] A. Aguezzoul: *Third-party logistics selection problem: A literature review on criteria and methods.* Omega *49* (2014), No. 12, 69–78.

[2] J. Li, Y. Q. Liu: *A Research on Routing Optimization of Fourth Party Logistics with Time Reliability Constraint Considered.* Industrial Engineering Journal (2014).

[3] B. Wu, H. Shen: *Analyzing and Predicting News Popularity on Twitter.* International Journal of Information Management Corresponding *35* (2015), No. 6, 702–711.

[4] M. Huang, Y. Cui,S. Yang: *Fourth party logistics routing problem with fuzzy duration time.* International Journal of Production Economics *145* (2013), No. 1, 107–116.

[5] M. Huang, L. Ren,L. H. Lee: *Model and algorithm for 4PLRP with uncertain delivery time.* Information Sciences *330* (2016), No. C, 211–225.

[6] L. Jia, Y. Liu,Z. Hu: *Routing optimization of fourth party logistics with reliability constraints based on Messy GA.* Journal of Industrial Engineering and Management *7* (2014), No. 5, 1097–1111.

[7] B. Wu, H. Shen,K. Chen: *Exploiting Active Sub-areas for Multi-copy Routing in VDTNs.* Proc. of the 24th International Conference on Computer Communications and Networks (ICCCN) (2015).

[8] B. Wu, H. Shen: *Discovering the Densest Subgraph in MapReduce for Assortative Big Natural Graphs.* Proc. of the 24th International Conference on Computer Communications and Networks (ICCCN) Workshop on Big Data and e-Health (BDeHS) (2015).

Received November 16, 2016