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E-Commerce Logistics System Based on Discrete Dynamic Modeling Analysis

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The development of green logistics in a low-carbon environment is an important way for logistics companies to reduce operating costs, and it is also a strategic measure to strengthen the construction of ecological civilization. This study improves the bat algorithm for single-delivery express delivery and multi-delivery, determines the optimal target and seeks the optimal solution, establishes the optimal logistics distribution scheme combined with corporate profits, and finally, compares it with other algorithms to verify the feasibility of the model. In the same experimental environment, it is proven that the performance of the built model is about 20% higher than that of other methods, and the planned path is the most reasonable. In the future application of e-commerce logistics system, it is a more efficient, reasonable, and perfect discrete logistics model.

Keywords: low-carbon environment, energy conservation and emission reduction, e-commerce, logistics system, discrete dynamic modeling, bat algorithm

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INTRODUCTION

Under the influence of "Internet thinking," many industries have begun to establish connections with the Internet (Yong et al., 2019), of which the retail industry has the highest proportion of online sales. According to the statistics of the China Internet Network Information Center (CNNIC), by June 2019, the total number of online shopping users in China was 639 million, accounting for 74.82% in China, an increase of 2,870 compared with 2018 (Hafiz et al., 2020). Among them, the total number of mobile online shopping users was 622 million, accounting for 78.93% of China's mobile Internet users, an increase of 29.88 million from the end of 2018 (Wang et al., 2020). A large number of online purchases have generated a large number of express orders. According to the development data of China's express delivery industry during the "13th Five-Year Plan," the total order volume of China's express delivery industry will reach 70 billion person-times in 2020, and the per capita express delivery volume will rapidly increase from 0.01 person-time in 2,000 to about 50 person-time in 2020 (Asokan et al., 2020). In recent years, the profits of China's traditional manufacturing and offline retail industries have been greatly compressed by market competition. The first profit source theory expands profits by reducing labor costs and raw material costs that have achieved maximum profit growth, and the second profit source theory gradually narrows the gap between firms by increasing workers' labor productivity (Suganthi and Malathi, 2017).

Literature (Dantzig and Ramser, 2021) shows that online e-commerce reduces a large number of offline site, labor, maintenance and other costs, and is more competitive than offline site. Therefore, many enterprises choose to develop online business in order to reduce costs and obtain more profits. Among them, effective logistics services can ensure user experience while reducing costs. Therefore, driven by online business, logistics has gradually become closely related to people's lives. People can shop online through logistics and exchange goods through logistics. To a certain extent, the development of the logistics industry can reflect a country's modern technological level and economic globalization. The work of Chen et al. (2019) analyzes that the development speed of China's e-commerce logistics system has accelerated sharply in recent years. With the advent of the 5G era, major upstream companies have proposed the concept of "metaverse," which has stimulated the development of online e-commerce, and put forward views on the huge potential of China's logistics and express delivery industry in the future (Stodola, 2018). The work of Atefi et al. (2018) proposes that the logistics operation cost will not only affect the profits of e-commerce enterprises but also directly affect the user's purchasing experience, and then fundamentally affect the development of affiliated enterprises. Zhang and Chai (2010) pointed out that the market has gradually higher requirements for express delivery, and the transformation of the logistics system to fast, accurate, and low-cost distribution is an important issue that express delivery practitioners continue to solve.

Since most of the aforementioned studies are theoretical studies and no practical solutions have been proposed, this study, based on the development status of e-commerce logistics systems and combined with previous research results, aims at the unreasonable distribution routes and backward logistics and transportation system equipment in my country's e-commerce logistics systems. The lack of physical infrastructure construction and other issues, using mathematical models and big data computing methods conducted in-depth research. By establishing a fast logistics transportation scheduling model based on the discrete dynamic algorithm and optimizing it, the logistics system scheduling problem is optimized, and through simulation verification, the performance of the constructed e-commerce logistics system based on discrete dynamic modeling analysis is better than other methods, the planned path is the most reasonable, and the distribution route uses less resources.

RELATED RESEARCH

According to the relevant survey data in the past two years, the damage or loss of express packages has the greatest impact on users' logistics experience. Almost all respondents said that these are intolerable express problems. In addition, for some users who value the timeliness of distribution (accounting for about 90% of e-commerce logistics express users), the problem of untimely distribution is also one of the important problems affecting the experience (Cai et al., 2014). Therefore, the direction of enterprise express transformation is to ensure that the express can reach users safely under the condition of timeliness and control the corresponding cost to maximize profits. Through the unremitting efforts of relevant scientific researchers, at present, it is mainly through rational planning of express logistics and transportation scheduling scheme as an important way of transformation in this direction (Fachini and Armentano, 2020).

Express logistics transportation scheduling is mainly composed of path planning and vehicle scheduling. Therefore, researchers generally attribute the express logistics transportation scheduling problem to vehicle-routing problem (VRP) or vehicle-scheduling problem (VSP). In 1959, Dantzig and others proposed the vehicle-routing problem for the first time. Among them, the travel agency problem has attracted extensive attention of scholars, which is known as the most classic vehicle-routing problem. Subsequently, Christophe et al. proposed a tabu search algorithm to solve the vehicle path planning problem with Backhaul and time window. Petr et al. improved the ant colony algorithm for multi-site vehicle-routing problem and got a good application. Inspired by the genetic algorithm, atefi et al. applied an iterative local search algorithm to the tabu search algorithm, and proposed an improved genetic algorithm to solve vehicle-routing problem with a time window (Zheng et al., 2020). Li Yang and others put forward a two-stage mixed variable neighborhood search algorithm, which mainly solved the random demand vehicle routing problem based on the idea of optimizing and scheduling first, and proved the validity of the algorithm (Zhang et al., 2019) in the experimental simulation. On the whole, through the strategy of reducing the cost of labor and vehicles, scholars at home and abroad have paid high attention to the field of vehicle routing and planning (Bayzid and Warnow, 2018).

MATERIALS AND METHODS

Research on Discrete Bat Algorithm for Single Distribution Express Logistics Transportation Scheduling Problem

The single-delivery express logistics transportation scheduling problem is the most simplified case in the express logistics transportation scheduling problem. Under the premise that the number of warehouses is unique, the courier completes the distribution task of the corresponding user through the shortest distance, and finally returns to the path planning problem of Knight cargo hold (Wang, 2016). On the whole, the single-delivery express logistics transportation scheduling problem is basically similar to the classical traveling salesman problem. As for the traveling salesman problem, in the express logistics transportation scheduling problem, it has been studied for a long time and in great depth. The overall solution algorithms roughly fall into the following two categories: one is to design an optimized local heuristic search algorithm based on the characteristics of the traveling salesman problem. The other is the heuristic intelligent algorithm designed according to the penalty of the problem-type. The advantage of the local heuristic algorithm is that it can quickly solve the traveling salesman problem with a large number of cities. However, because its starting point is the characteristics of traveling salesman problem, its algorithm design accounts for a large proportion in solving the problem (Fan, 2019). Therefore, it has few applicable problem types, and it is easy to fall into local optimization in the calculation process, so it is unable to find the optimal value of the overall problem, Representative algorithms include 2-OPT and 3-OPT. Heuristic intelligent algorithms are more combined with big data technology and corresponding computing thinking of other disciplines, such as fireworks algorithm, genetic algorithm, immune algorithm, particle swarm optimization algorithm, and ant colony algorithm (Pan, 2018). These algorithms play an important role in heuristic intelligent algorithms and solving traveling salesman problems. For example, others solved the classical traveling salesman problem by improving the clustering and group algorithm, which effectively solved the hierarchical and progressive system scheduling of the product line assembly process based on division of labor and cooperation (Jin, 2017). The operation flow of complex mutation operator number evolution was effectively optimized by solving the classical suitcase problem combined with the multi-chromosome genetic algorithm (Guo and Lv, 2015). It has been found that the fireworks algorithm has better convergence and stability (Chen, 2019). Therefore, according to the characteristics of the fireworks algorithm, the chaotic strategy in the classical traveling salesman problem is optimized to solve the classical traveling salesman problem. However, to sum up, there is still little research and application of the bat algorithm in solving classical traveling salesman problem. Therefore, based on the bat algorithm, this article puts forward the optimization method of single distribution express logistics transportation scheduling problem, and carries out discrete dynamic modeling and analysis combined with e-commerce logistics system in the era of big data (Li et al., 2021a; Li et al., 2021b; Le et al., 2021; Toyoda and Wu, 2021; Wu et al., 2021; Zhang et al., 2022).

The bat algorithm (He et al., 2020; Li et al., 2021c; Eligüzel et al., 2022) is mainly abstractly expressed according to bat echolocation. Its specific principle is to map bat individuals into points in space, the process of finding the optimal solution by the algorithm, and simulate the process of bat searching prey. The optimal solution simulated by the final function is the optimal solution of the bat position. At the same time, the survival of the fittest of the bat population represents the situation of different solution replacement effects. It is our default that the bats that are more suitable for the environment will win, and the casual clothes that are not suitable for mitigation will be eliminated. This process is the feasible solution behavior with poor replacement effect of the central solution of the bionic principle. Based on the aforementioned principles, we make three basic assumptions for the idealized bat algorithm: first, it is assumed that all bats recognize the direction and position using echolocation, and the distance from obstacles or food to themselves. The feedback signals of obstacles and food through echolocation are different, and bats can perceive this difference. Second, in the process of flying at a fixed speed, bats can emit wavelengths of fixed frequency and certain loudness for the search and pursuit of prey, and their pulse emission frequency is always maintained between zero and one. Third, the maximum and minimum loudness of sound waves emitted by bats is fixed. According to the earlier mentioned assumptions, when a bat searches for a target normally, its position and speed are calculated as follows:

$$F_i = F_{\min} + (F_{\max} - F_{\min})\beta, \tag{1}$$

$$V_i^{i+1} = V_i^t + (X_i^t - X_*)F_i, \tag{2}$$

$$X_i^{i+1} = X_i^t + V_i^{i+1}. \tag{3}$$

Here, F_i is the sound frequency emitted by the ith bat, $F_{\max}$ is the maximum value of the sound wave, and $F_{\min}$ is the minimum value of the sound wave. β is a uniform random number, ranging from zero to one. V_i^t and V_i^{i+1} represent the velocity of the ith bat at t time and T + 1 time, respectively. X_i^t represents the position of the ith bat at time t, and X_i^{i+1} represents the specific position of the ith bat at time t + 1.

Finding a target is the first step to the success of bat hunting. Therefore, when bats find a target in biology, it means that it is close to the global optimal solution in mathematical formula. So usually we have found that the target is the node. At this time, we adopt the local search strategy to solve the optimal value on the optimal bat individual. At this time, the location update formula of local search is

$$X_{new} = X_{old} + \varepsilon A^t. \tag{4}$$

At this time, the formula of loudness and frequency of sound waves emitted by bats is updated as follows:

$$A_t^{t+1} = \alpha A_i^t, \tag{5}$$

$$r_i^t = r_i^0 [1 - \exp(-\gamma t)]. \tag{6}$$

The single distribution logistics transportation scheduling model is essentially similar to the bat algorithm, which can be described as the bat finding the target location and evaluating the optimal solution in the local area algorithm. The former problem can be described as knowing the location of N recipients and targets, requiring couriers and bats to start from any point, continuously reach or pass through (n-1) pickup points, and finally return to the starting point, with the shortest total route distance. This problem is brought into the bat model to obtain the mathematical model of single distribution express logistics transportation, scheduling problem as follows:

$$MinD = \sum_{i=1}^{N-1} (d(S_i, S_{i+1})) + d(S_N, S_1), \tag{7}$$

where $d(S_i, S_j)$ represents the distance between the ith receiving point and the jth receiving point, and the values of i and j range from zero to n. The coordinate position of receiving point I can be expressed as (X_i, Y_i) and the coordinate position of receiving point J can be expressed as (X_j, Y_j). When the coordinate positions of receiving points S_i and S_j are known, the distance formula between receiving point I and receiving point J is

$$d(S_i, S_j) = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}. \tag{8}$$

According to the common sense, the distance from receiving point I to receiving point J is equal to the distance from receiving point J to receiving point I, so there are:

$$d(S_i, S_j) = d(S_j, S_i). \tag{9}$$

Discrete Bat Algorithm for the Rapid Logistics Transportation Scheduling Problem

The previously mentioned discusses the distribution scheduling of a distribution station with only one distributor and one distribution vehicle. However, in fact, multiple distributors in the same distribution center can mobilize multiple distribution vehicles to carry out the distribution tasks of multiple stations at the same time. Considering this situation, the single distribution logistics transportation scheduling problem model cannot solve.

Tion-scheduling problem is established based on the sub scenario. The ultimate purpose of this situation is to meet the needs of the receiving point and relevant requirements, and all distribution vehicles have the shortest driving path. At this time, all distribution points are called set $V = \{0, 1, 2, \cdots, N\}$, where zero represents the distribution center and the other points represent the distribution points. Call the collection of all delivery vehicles $K = \{0, 1, 2, \cdots, M\}$, and record the delivery package at the receiving point $d_i\,(i = 1, 2, 3, \cdots, N)$. The maximum load of each distribution vehicle is Q. The distance from receiving point I to receiving point J is recorded as c_{ij}. In order to ensure the accuracy of the results, this experiment verifies the solution ability of the optimized algorithm through three computational forces. Among them, C1 case is a single car express logistics transportation scheduling problem with 15 pickup points. C2 case is a single car express logistics transportation scheduling problem with 30 pickup points. C3 case is a single-vehicle logistics transportation scheduling problem with 50 pickup points. Then, there are

$$y_{is} = \begin{cases} 1, \text{Vehicle s} \\ 0, \text{other} \end{cases}, \tag{10}$$

$$x_{ijs} = \begin{cases} 1, \text{Travel from s to j} \\ 0, \text{other} \end{cases}. \tag{11}$$

Thus, the mathematical model of single-vehicle express logistics transportation scheduling problem can be obtained as follows:

$$Z_{\min} = \sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{s=1}^{M} c_{ij}x_{ijs}, \tag{12}$$

$$\sum_{i=0}^{N} d_i y_{is} \le Q, \tag{13}$$

$$\sum_{s=0}^{M} y_{is} = \begin{cases} 1, i = 1, 2, \cdots N \\ M, i = 0 \end{cases}, \tag{14}$$

$$\sum_{i=0}^{N} x_{ijs=} y_{is}, j = 1, 2, \cdots N; s = 1, 2, \cdots, M, \tag{15}$$

$$\sum_{j=0}^{N} x_{ijs=} y_{is}, i = 1, 2, \cdots N; s = 1, 2, \cdots, M, \tag{16}$$

where $Z_{\min}$ represents the minimum length of single-vehicle express logistics transportation general scheduling route, and **Eq. 12** represents the minimization of single-vehicle express logistics transportation general scheduling route. **Eq. 13** indicates that the weight of the package at all distribution points in charge of each distribution vehicle does not exceed the maximum load value Q of the distribution vehicle. **Eqs. 14–16** represents that all tasks of the distribution center are jointly completed by m-quantity distribution vehicles, and it is necessary to ensure that the package distribution at each receiving point is completed by only one distribution vehicle. The aforementioned formula simulates the most common scenario of the logistics distribution center, and perfectly fits the process of formulating the scheduling scheme of the logistics distribution center through the common sense constraints (**Eq. 13**) and the theoretical constraints (**Eqs. 14–16**) considering the basic principle of maximizing enterprise profits. Therefore, the optimal solution in line with the aforementioned formula should also be the best scheduling scheme in practical problems.

DISCRETE DYNAMIC MODEL SIMULATION VERIFICATION

Simulation Preparation

In the past two years, the price war between express enterprises has become more and more intense, which also means that the development of the traditional profit theory by reducing labor cost and raw material cost is gradually narrow. More and more enterprises transfer the cost compression path to logistics transportation. According to the data of China Federation of Logistics and Purchasing, in 2018, the total consumption cost of Chinese citizens in the logistics industry reached 13.3 trillion yuan, accounting for 14.7% of the gross national product of that year, an increase of 9.8% compared with the total social logistics cost of 1.21 trillion yuan in 2018. In addition, the proportion of China's total logistics expenses in the gross national product in 2018 has decreased by three percentage points compared with six years ago, and its trend has shown a downward trend. However, the decline is slow, and the proportion is still three times higher than that in the United States. Figure 6 shows the volume of express business in China from 2010 to 2019. It can be seen that in 2019, the volume of express business in China has reached 63,520,000,000, representing an increase of twenty-five point three percent compared with 50,710,000,000 in 2018. The total amount of express business was 749.7 billion yuan, a year-on-year increase of 24.4%.

Previously, chaotic sequences were used to adjust heuristic optimization algorithms, such as genetic algorithm parameters, particle swarm optimization algorithms, harmony search, ant and bee swarm optimization, imperialist competitive algorithms, Firefly algorithm, simulated annealing. Such a combination of chaos and hyperheuristics has been shown. Some promise the correct use of a set of chaotic maps. It is not clear why an algorithm chaos replaces something. The use of parameters may change performance; however, empirical studies do show that chaos also has a high level of mixing. Therefore, it is to be expected that when a fixed parameter of the chaotic map is replaced, the resulting solution is possible. There will be high mobility and diversity. For this reason, it may have to be studied more by introduction chaos to other useful, especially new, heuristic algorithms.

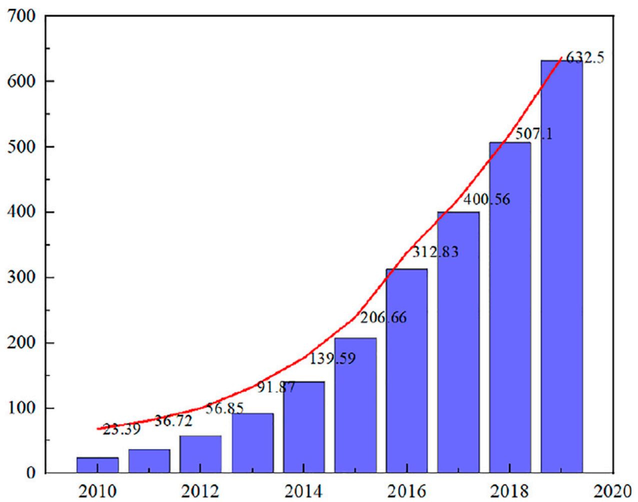

FIGURE 1 | Statistics of China's express business volume from 2010 to 2019.

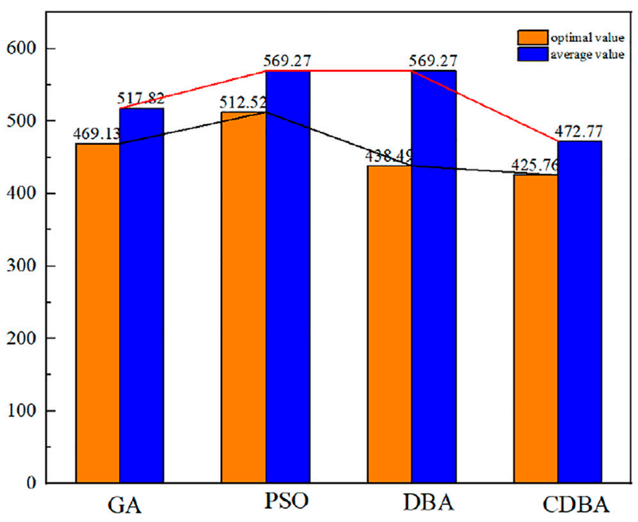

FIGURE 2 | Algorithm performance comparison experiments.

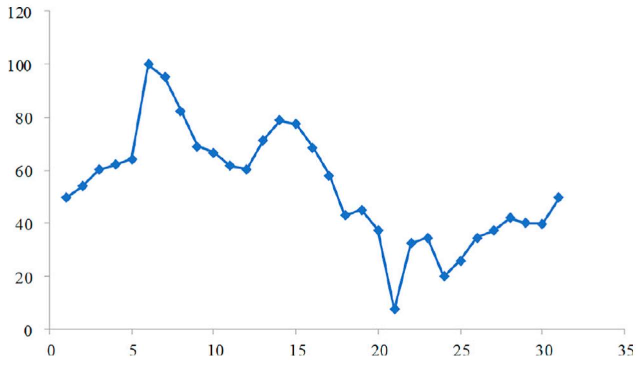

FIGURE 3 | CDBA solution for Oliver30.

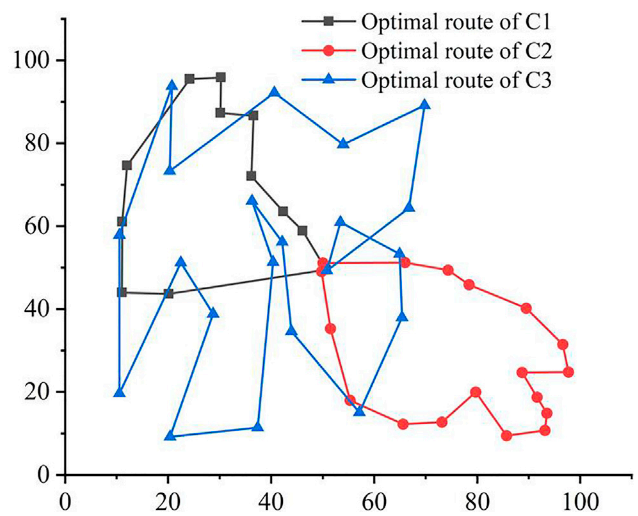

FIGURE 4 | Optimal route of C1~C3

Algorithm Performance Comparison

According to the aforementioned information, the optimized discrete dynamic algorithm is compared with the previous algorithm, and the results are shown in **Figure 1**.

As can be seen from **Figure 2**, the results of the discrete bat algorithm (DBA) in solving the logistics system scheduling problem with small data scale are due to genetic algorithm (GA) and particle swarm optimization (PSO) algorithm. However, with the gradual increase of solving data scale, its convergence decreases, and it is often unable to receive the same better value, which is more of the local optimal solution. The algorithm that adds the discrete dynamic algorithm to the previous algorithm and then carries out modeling analysis performs best in the process of solving the optimal solution, and it has a high improvement in the solution of the optimal value and the average value. It shows that adding the discrete dynamic algorithm to the original bat algorithm can effectively improve its convergence and global search ability. The specific path diagram is shown in **Figure 3**, it can be seen that as the number of abscissas increases, the solution process of the multi-model is more stable.

In order to ensure the accuracy of the solution ability of the optimized algorithm Vnqba, we use the optimized QBA algorithm and the optimized Vnqba algorithm for experimental comparison. The default initial bat population G is equal to 20; loudness attenuation coefficient of sound waves emitted by bats α is equal to 0.9, acoustic emission frequency enhancement coefficient γ equal to 0.9; the maximum number of iterations of bat population is 300. In order to control a single variable, the calculation CPU used in this experiment is Intel Core i5-3230 2.6GHz, the operating system is windows 10, the fixed running memory is 4GB, and the calculation software is MALTLAB 2014a. The results show that the optimized algorithm has the optimal solution of average timeout time in both BS and as situations, and FV is the fitness value of the optimal solution in both situations. In order to ensure the validity of the data, we take the measured values of 20 times in each group to calculate the average value. It can be concluded that both the Vnqba algorithm and QBA algorithm can obtain the optimal feasible solution under the load capacity of distribution vehicles not exceeding C1, C2, and C3. The optimized Vnqba algorithm based on the discrete dynamic analysis algorithm has obvious advantages in solving the large-scale single-vehicle express logistics transportation scheduling problem. The optimal solution obtained by the local search algorithm is obviously less than the QBA algorithm, which means that the path is the smallest when the Vnqba algorithm is used for logistics system transportation scheduling, and the quantum bat algorithm (QBA) will lead to distribution timeout when the data scale increases greatly. It can be concluded that the addition of discrete dynamic modeling analysis significantly improves the solvency of the bat algorithm. The optimal routes of C1, C2, and C3 are shown in **Figure 4**.

Result Discussion

Based on the aforementioned e-commerce industry needs, e-commerce logistics enterprises began to seek more efficient, fast, and low-cost logistics transportation operation methods on the premise of ensuring user service experience. First, this study decomposes the operation problem of e-commerce logistics system into a single distribution express logistics transportation scheduling problem. Based on the previous research on the bat algorithm, the bat algorithm is discretized and dynamically modeled and analyzed according to the full permutation theory and chaotic optimization strategy. Through the introduction of chaotic optimization and local segment counterclockwise search strategy, the bat algorithm based on discrete dynamic modeling analysis effectively improves the global search ability and the solution ability of local optimal solution. Finally, this optimized bat algorithm is called the chaotic discrete bat algorithm (CDBA). Experiments show that the chaotic discrete bat algorithm is more effective than the existing common algorithms in the single distribution express logistics transportation scheduling problem.

Second, this article continues to study the single-vehicle express logistics transportation scheduling problem. Compared with the single distribution express logistics transportation scheduling problem, the single-vehicle express logistics transportation problem has one more condition of distribution vehicles, which is more in line with the actual distribution situation in the logistics distribution of modern e-commerce enterprises. In this article, the local search ability is significantly improved by adding 2-opt strategy to the original bat algorithm. 2-opt strategy means that the bat algorithm changes the local search range by changing the neighborhood interval in the process of local search, so as to find the local optimal solution. Finally, in order to ensure the accuracy of the data, the experiment uses three cases with different distribution locations to simulate the pre optimization algorithm and the post optimization algorithm. The results show that the optimized Vnqba algorithm has stronger convergence ability than the optimized QBA algorithm, and performs better in local search.

CONCLUSION

Based on the application of the bat algorithm in the logistics and transportation scheduling of the e-commerce logistics system, this article optimizes the bat algorithm that has been less studied in the past, so as to be better applied to the operation of the e-commerce logistics system. By analyzing the actual demand of express logistics, a single-delivery express logistics transportation scheduling model is established. Based on chaotic optimization strategy and the discrete bat algorithm, a discrete dynamic chaotic bat algorithm is proposed. The experimental results show that the model algorithm can solve the optimal scheduling path more accurately than the commonly used intelligent algorithms, which proves that the algorithm is effective. At the same time, in view of the current situation of multi-vehicle distribution at the same time, a single-vehicle express logistics transportation scheduling model is established. Experimental results show that:

1) The algorithm has the highest accuracy in solving the optimal path scheduling scheme, which proves the effectiveness and feasibility of the algorithm
2) In this article, by adding the 2-opt strategy to the original bat algorithm, with the gradual increase of the scale of the data to be solved, the built model can effectively improve its convergence and global search ability
3) The optimized discrete dynamic algorithm is compared with the previous algorithm, and the performance is improved by about 20%

To sum up, this article has achieved some research results in the scheduling scheme of e-commerce logistics system, but the following improvements can be made in future research. For example, if the actual traffic conditions do not conform to straight-line transportation, traffic congestion may occur during peak hours. These important factors should be used as parameters affecting the discrete dynamic model, and we hope to continue to improve them in the future research process.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the author, without undue reservation.

AUTHOR CONTRIBUTIONS

GM independently completed all the content of the article.

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