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To cite this article: Jian-Chang Lu and Xu-Yuan Nie 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **237** 052068

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Logistics distribution path optimization research based on adaptive chaotic disturbance flies optimization algorithm

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Abstract. With the economic globalization and fast-changing of information technology, the logistics industry and production efficiency have greatly improved, and the logistics distribution have become an important part of the modern logistics industry. The selection of the distribution path in the logistics is the key issue because the choice of reasonable distribution route have great significance on increasing delivery speed, improving service quality, reducing distribution cost and increasing economic benefit. Aiming at this characteristic in the process of logistics distribution, this paper presents an adaptive chaotic disturbance flies optimization algorithm (ACD-FOA), which can optimize fruit flies algorithm in a state of convergence for global optimization. It also can overcome the shortcoming of flies optimization algorithm which is easy to fall into local faults in the solving process to some extent. Based on this advantage, the convergence speed, reliability and optimization on the accuracy of optimization algorithm are much better than the pure flies. Finally the instance simulation test have been carried out, which proved that the adaptive chaotic flies optimization algorithm has better ability of global optimization. In order to prove that the proposed adaptive chaotic disturbance fly optimization algorithm has higher optimization accuracy in logistics distribution, the results were compared with three other models, which indicates that the ACD-FOA established in this paper is more applicable to the current Logistics distribution path optimization. It also can find the optimal logistics distribution path quickly and reduce the logistics distribution cost effectively at the same time.

1. Introduction

With the rapid development of market economy, the logistics industry has served as the leading industry in the production and consumption from the end of the original industry in the last few years. High level of logistics skills has been generally used at home and abroad. Logistics distribution path optimization is one of the traditional vehicle distribution routing optimization, which is an indispensable part in the process of logistics and the minimum necessary step of logistics cost. In the logistics distribution path optimization, how to select the vehicle and the path correctly, deliver the goods to the customer timely and formulate a feasible distribution plan have become an important part of the group, which are the Vehicle Routing Problem (VRP)[1]. That is to say, logistics company will complete the target of the delivery of the goods with the minimum of vehicles and total travel time. In general, the comprehensive domestic and foreign research on optimization of logistics distribution path optimization algorithm based on pure research path optimization method is relatively



more. However, a simple optimization algorithm often has a variety of defects, such as the lower optimization accuracy. So this article puts forward a method that introduce adaptive and chaos disturbance into fruit fly optimization algorithm. It can overcome the pure fruit fly the shortcoming of easy to fall into local optimum effectively, and improve the precision of algorithm optimization greatly. It will shorten the logistics distribution path and saves the logistics distribution cost effectively.

2. Mathematical model

2.1. Logistics distribution problem description

The essence of the logistics distribution path optimization is the problem of the route of the logistics vehicles. From the distribution center, multiple vehicles are used to deliver goods to multiple demand points (customer points). Assuming that there is C customer point, given each customer point location and demand for a certain, each delivery vehicles load constant, point to send the goods to the customer delivery task after return to distribution center. In order to minimize the total cost of distribution, arrange the distribution route reasonably, make the delivery route and delivery time shortest. The following conditions will be meet: ① The total quantity of customer points on each logistics distribution path shall not exceed the maximum capacity of the delivery vehicles; ② The maximum length of each distribution path shall not exceed the maximum driving distance of the delivery vehicles; ③ The needs of each customer point must be met, only one delivery vehicle is allowed to be delivered.

2.2 Mathematical modeling

From the above about the description of the logistics distribution routing problem, the following analysis can be known:

① The total quantity of customer points on each logistics distribution path shall not exceed the maximum capacity of the delivery vehicle:

$$\sum_{i=1}^{n_k} r_k^i \leq Q_k, \quad n_k = 1, 2, \dots, K \quad (1)$$

Where K represents the total number of vehicles in the distribution center. The maximum load weight of each delivery vehicle is Q_k , The demand for customer points is expressed as q_i ($i = 1, 2, \dots, C$), n_k represents the total number of customers for vehicle k. d_{ij} and R_k represents the distance from customer I to customer j and a collection of customer points for delivery vehicle k respectively. r_k^i represents the customer order I that distribution path of delivery vehicle k in the collection. The order of the customer in the delivery vehicle k is j.

② The maximum length of each distribution path shall not exceed the maximum driving distance of the delivery vehicle:

$$\sum_{i=1}^{n_k} d_{r_k^{i-1} r_k^i} + d_{r_k^{n_k} 0} \leq D_k, \quad n_k = 1, 2, \dots, K \quad (2)$$

③ The needs of each customer point must be met and only one delivery vehicle is allowed to be delivered:

$$R_k = \{r_k^i | r_k^i \in \{1, 2, \dots, n\}, i = 1, 2, 3 \dots n_k\} \quad R_{k_1} \cap R_{k_2} = \emptyset, \quad \forall k_1 \neq k_2 \quad (3)$$

According to the description of the above logistics distribution path optimization problem, the mathematical model to achieve the optimization goal can be expressed as follows:

$$\min Z \sum_{k=1}^K \left[\sum_{i=1}^{n_k} d_{r_k^{i-1} r_k^i} + d_{r_k^{n_k} 0} \text{sng}(n_k) \right] \quad (4)$$

In the formula:

$$\text{sng}(n_k) = \begin{cases} 1, & n_k \geq 1 \\ 0, & n_k < 1 \end{cases} \quad (5)$$

3. Mathematical model

3.1. Basic fruit fly optimization algorithm

Fruit Fly Optimization Algorithm (FOA) was put forward by scholar Wen chao Pan [2] in 2011 as a new intelligent algorithm based on the basic fruit fly foraging behavior to find the global optimal solution. The algorithm has the advantages of simple structure, less data and strong operability. Flies can smell 40 km outside of the food source with a sense of smell. According to the search for floating in a variety of smell in the air, it can find food and place of other companions gathered and fly to the direction rely on the acute sense of smell and visual. The steps to iterate the fruit fly population in search of food are summarized as follows:

Step1 Group size is defined as $Size_{pop}$, Maximum iteration number Max_{gen} , initialize the position of flies population randomly as X_{axis} , Y_{axis} .

Step2 According to the location of the flies population, the individual fruit flies was given a random distance and direction and initialized the flies population randomly. The formula is as follows.

$$\begin{cases} x_i = x_{axis} + RandomValue \\ y_i = y_{axis} + RandomValue \end{cases} \quad (6)$$

Where the $RandomValue$ represents the search distance.

Step3 Due to the position of the food can not be acquired, the distance between the individual and the origin $Dist_i$ is estimated. Then calculate the corresponding taste concentration determination value S_i , which is the reciprocal of the value of distance. The taste concentration for smell is $smell_i$. The formula is as follows.

$$\begin{cases} Dist_i = \sqrt{x_i^2 + y_i^2} \\ S_i = 1/Dist_i \end{cases} \quad (7)$$

Step4 The taste concentration determined value of the individual position of the fruit fly $smell_i$ can be determined by bring the taste concentration S_i into the taste concentration decision function (or fitness function). The formula is as follows.

$$smell_i = f(S_i) \quad (8)$$

Step5 To obtain the fruit fly individual that has the optimal flavor concentration in the fruit fly group. The formula is as follows.

$$[bestsmell, bestindex] = \max(smell) \quad (9)$$

Step6 Determine whether $bestsmell$ is superior to the previous iteration value, otherwise (6) is executed continually.

Step7 The optimal flavor concentration and the coordinates were preserved as x and y , so that the fruit flies population will fly to the corresponding position using their vision.

$$smell_{best} = bestsmell \quad (10)$$

$$\begin{cases} x_{axis} = x(bestindex) \\ y_{axis} = y(bestindex) \end{cases} \quad (11)$$

Step8 Iterative optimization was carried out in this step, repeat the step2 to step5, and then determine whether the flavor concentration is better than the previous one. If not, repeat step7.

3.2. Adaptive chaotic disturbance flies optimization algorithm (ACD-FOA)

3.2.1 Adaptive fly optimization algorithm

Based on the operation steps of FOA and Matlab program operation, the convergence speed and convergence accuracy of FOA algorithm are lower. The main factors affecting this two are the initial location and the size of the population. The initial position is determined by the function independent variable, and the population size also affects the running time. Therefore, the selection of the appropriate evolution iteration step is significant to improve the convergence speed and convergence

accuracy. A kind of Self-adaptive flies optimization algorithm (SA-FOA) is presented in view of this, and its evolution step is no longer fixed, which can be adjusted according to the optimal taste concentration and current iteration number of the previous generation[3]. After initializing the position coordinates of the drosophila (x, y) in the drosophila group randomly, the olfaction was then used by individual fruit flies to search for food and find the individual flies that had the highest concentration of the fruit flies in the iteration ($\max(\text{Smell})$). If the concentration of taste is superior to that of the previous iteration flavor concentration, the coordinates of the individual's position x_k, y_k were record. In the next iteration, the individual fruit flies in the group were solved by formula (14) for the step value of the olfactory search.

$$L' = \frac{|x-x_k|+|y-y_k|}{2} \quad (12)$$

Then, using the formula (13), the individual flies in the group are assigned the location coordinates after the search, so that the individual flies in the group can search for food by smell.

$$\begin{cases} x_i = x + L' \times \text{rands}(1,1) \\ y_i = y + L' \times \text{rands}(1,1) \end{cases} \quad (13)$$

3.2.2 chaotic disturbance

Due to the initial pheromones of each path in the fruit fly optimization algorithm are equal, and the flies are equally likely to choose each path, the fruit fly search for the best path through the smell of air. So it is difficult for fruit flies to find the optimal solution in a short time, reducing the convergence speed of the fruit fly optimization algorithm. In order to deal with the contradiction of optimization fruit flies in time and space better and guarantee the diversity of initial pheromone, the convergence accuracy and speed of convergence should be improved when the fruit fly select the path. This paper introduces chaos system on the basis of the basic fly optimization algorithm. The improvement of fly optimization algorithm in chaotic system mainly includes chaos initialization and chaos disturbance. The latter was used in this article. Chaotic state is a nonlinear phenomenon widespread in nature and society, which has the characteristics of regularity, ergodicity and randomness. The biologist's study has found that the behavior of individual fruit flies is chaotic, so chaos disturbance can be introduced to avoid the optimization algorithm of fruit flies to solve the local optimal and improve global optimization performance. In this paper, a well-behaved good Tent map is used for the ergodic and fast speed[4]. The model equation is as follows:

$$z_{k+1} = \begin{cases} 2z_k & 0 \leq z_k \leq 0.5 \\ 2(1 - z_k) & 0.5 < z_k \leq 1 \end{cases} \quad (14)$$

Where z_k represents Chaotic variables.

When the optimal fruit fly individual was obtained from the adaptive fly optimization algorithm, chaos optimization search was conducted in the neighborhood of the solution. The formula was as follows:

$$x_{i,j}^{(k)} = x_{1,j}^* + \varphi x_{i,j} \times z x_{i,j}^{(k)} \quad (15)$$

$$y_{i,j}^{(k)} = y_{1,j}^* + \varphi y_{i,j} \times z y_{i,j}^{(k)} \quad (16)$$

Where (x^*, y^*) , $\varphi x(y)_{i,j}$ is the optimal location and regulation coefficient of fruit flies, $z x(y)_{i,j}^{(k)}$ represent the chaos variable in the $[0,1]$ interval. The $x_{1,j}^*$, $y_{1,j}^*$ is the current position of the fruit fly.

4. Case analysis

In order to prove the feasibility and effectiveness of the adaptive chaotic optimization based on the fly algorithm for the selection of logistics distribution path, the 52 points coordinates were randomly generated by MATLAB as the customer coordinates of 52 logistics distribution. The 35th coordinate was used as the logistics distribution center and the other 51 points coordinates were standardized, so as to simulate the logistics distribution environment in real life. Logistics distribution center and customer location data were shown in table 1.

Table1.Information of customer location coordinate.

Customer number	Coordinate (km, km)	Customer number	Coordinate (km, km)
1	(88,98)	27	(163.5,72)
2	(34,59)	28	(156.5,80.5)
3	(66,115.5)	29	(97.5,58.5)
4	(126,109)	30	(72.5,65.5)
5	(116,106)	31	(73.5,96)
6	(119.5,106.5)	32	(89,107)
7	(34,63.5)	33	(146.5,156.5)
8	(84,140.5)	34	(101.5,98.5)
9	(89.5,158)	35	(100,100)
10	(96.5,153.5)	36	(100,101.5)
11	(192,102.5)	37	(108.5,101.5)
12	(153.5,98.5)	38	(111,105)
13	(178,60.5)	39	(103.5,104)
14	(184.5,41)	40	(107.5,105.5)
15	(114.5,89)	41	(79,136.5)
16	(104,77.5)	42	(41,66.5)
17	(46,107)	43	(119,132.5)
18	(73,104)	44	(101.5,90.5)
19	(82.5,128)	45	(87,122)
20	(87.5,77)	46	(114.5,89)
21	(61.5,87)	47	(148.5,47)
22	(83.5,99)	48	(114.5,101.5)
23	(79.5,82)	49	(92,103)
24	(115,103)	50	(91,76.5)
25	(129,98.5)	51	(165.5,113)
26	(153,65)	52	(205.5,65)

Optimization algorithm established in this paper mainly combined the basic fruit fly optimization algorithm and chaotic disturbance to find the optimal solution at the fastest rate without overloading, and adjust the distribution route in time to get the optimal path optimization. The parameters are set as: The distribution center coordinates are set as (100,100), and the number of customers need to be shipped is set as 52 totally. The maximum weight of the vehicle is 8t. The distance between customers and distribution centers and customers and customers are calculated by distance formula, which is as follows:

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (17)$$

5.Application of ACD-FOA

5.1 The steps of ACD-FOA

Step1 Initialization parameters including population size, maximum number of iterations, initial position of the flies population, fitness variance threshold and the number of chaotic times. Which are shown in table 2.

Step2 The average flavor concentration of the fruit flies was calculated.

Step3 Get the optimal position of the individual.

Step4 Adjust step length of the individual, and get the optimal location of the fruit fly and update

the fly speed and position.

Step5 Chaos optimization search was conducted to obtain the optimal location of fruit flies and update the fly speed and location.

Step6 Iterative optimization, repeat step 2 - step 7 until the current iteration number is equal to the maximum iteration number maxgen or has reached the precision target requirement.

Step7 Output the optimal path.

5.2. Model simulation result analysis

This paper adopts Matlab 2016a in Windows 10 system to run the above program, Initialization parameters: population size Sizepop = 200, Max iteration number Maxgen = 50, drosophila population position (X_axis,Y_axis) = (100,100), fitness (flavor concentration) variance threshold $\vartheta = 0.00001$, chaos iteration number M = 5. Then the results of flies optimization algorithm, adaptive chaotic disturbance flies optimization algorithm, chaotic disturbance flies optimization algorithm and Self-adaptive flies optimization algorithm were obtained. The results are shown in figure 1,2,3,4.

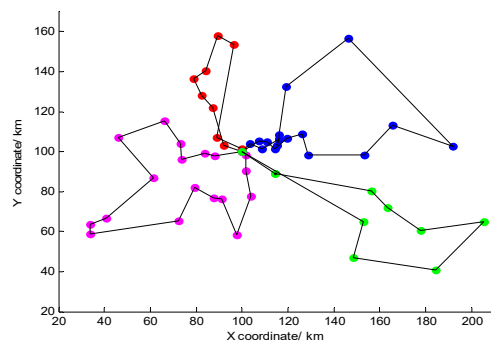


Figure.1 The optimization results of FOA.

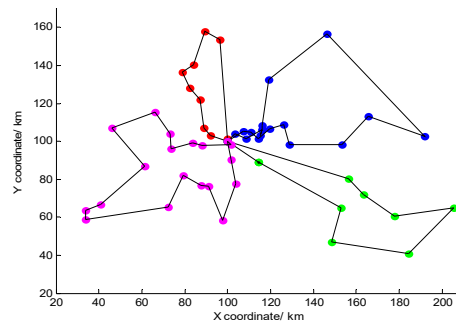


Figure.2 The optimization results of SA-FOA.

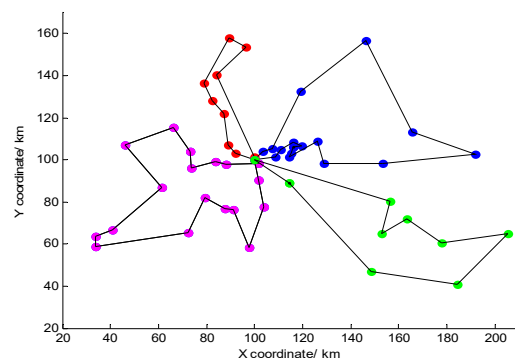


Figure.3 The optimization results of CD-FOA.

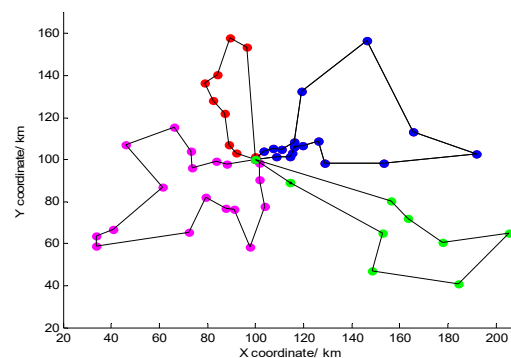


Figure.4 The optimization results of ACD-FOA.

The distribution routes and total path length of four model optimize dare shown in table 2. From the table, it can be seen that the total length of optimal distribution path obtained by the pure fruit fly optimization algorithm is 1164.6907. While the total path of the SA-FOA and CD-FOA is 967.9765 and 969.0679 respectively. The distribution path has been shortened. Meanwhile, the total path of the flies algorithm optimized by adaptive and chaotic disturbances is 741.763. Compared with the other three algorithms, the optimization precision of the algorithm established in this paper is improved to a certain extent.

Table2. Comparison of Four algorithms optimized distribution route.

Distribution route	FOA	CD-FOA	SA-FOA	ACD-ACFOA
Vehicle 1	35-49-32-45-19-41-9-10-8-36-35	35-49-32-45-19-41-8-9-10-36-35	35-36-32-10-9-8-41-19-45-49-35	35-49-32-45-19-41-8-9-10-36-35
Vehicle 2	35-39-40-43-33-51-11-12-25-4-6-5-24-5-48-15-38-37-35	35-39-40-43-33-51-11-12-25-4-48-24-5-5-6-15-38-37-35	35-39-37-5-24-5-15-43-33-11-51-12-25-4-6-48-38-40-35	35-37-48-24-5-5-6-4-25-12-11-51-33-43-15-38-40-39-35
Vehicle 3	35-1-22-31-21-42-7-2-17-3-18-23-30-20-20-29-16-44-34-35	35-34-1-22-31-18-3-17-21-42-7-2-30-23-20-50-29-16-44-35	35-1-22-31-21-42-7-2-17-3-18-23-30-20-50-29-16-44-34-35	35-34-44-16-29-50-20-23-30-2-7-42-21-17-3-18-31-22-1-35
Vehicle 4	35-15-46-47-14-52-13-27-26-28-35	35-46-15-28-27-13-52-14-47-26-35	35-46-15-28-27-13-52-14-47-23-35	35-28-27-13-52-14-47-26-46-15-35
Total length	1164.6907	967.9765	969.0679	741.763

In order to further verify the effectiveness of adaptive chaotic fly optimization algorithm, the optimization results are simulated by standard test function. The standard test function is defined as follows:

$$y = -\frac{30 \times \sin(0.5 \times x - 10)}{(0.5 \times x - 10)} - 100 \quad (21)$$

This function has many minimum values, but the minimum value is only one, so that the algorithm can be assisted to verify the existence of local optimal defects. Its test function curve is shown in figure 5.

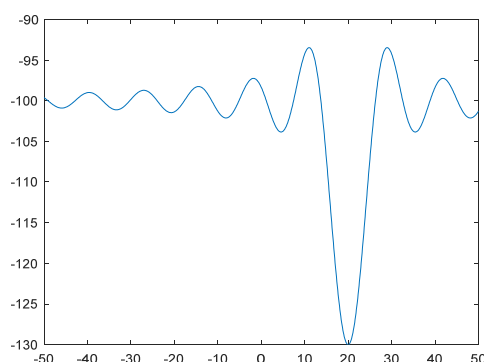


Figure.5 Function curve.

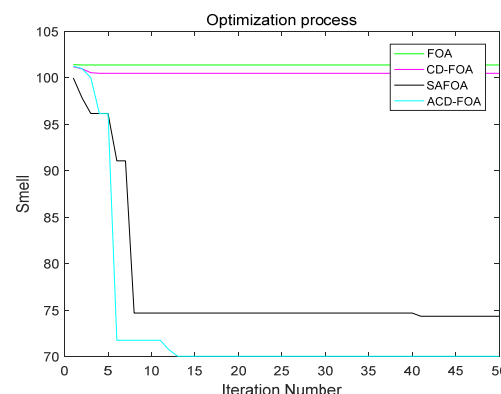


Figure.6 The comparison of optimization curves.

The numerical evolution curves of the four algorithms after 50 independent operation were performed, and the optimization curve of the shortest path of the four algorithms is shown in figure 8. (note: in order to facilitate the display and observation of the evolutionary curve, the fitness of the function is taken as the logarithm of base 10). In the figure 6, FOA, ACD-FOA, CD-FOA and SA-FOA represent flies optimization algorithm, adaptive chaotic disturbance flies optimization algorithm, chaotic disturbance flies optimization algorithm and self-adaptive flies optimization algorithm separately. It can be seen from the figure that, whether the convergence speed or the final result is compared, the basic fruit fly optimization algorithm is directly involved in the local optimization in the previous section. The improved chaotic fruit fly optimization algorithm is also involved in the local optimization in the early stage of the optimization, while adaptive fly optimization algorithm can jump out of local optimal and achieve optimal iteration 20 times. As a contrast, adaptive chaotic disturbance flies optimization algorithm is optimized to achieve optimal iteration 13 times. It can be seen that the self-adaptive flies optimization algorithm can quickly jump out of local optimal and avoid precocious phenomenon, but it has the characteristics of slower convergence speed. However, chaos perturbation

and adaptive fusion are combined to optimize the fly optimization algorithm for adaptive chaotic disturbance, thus speeding up the convergence speed, avoiding the precocious phenomenon and improving the optimization precision. Therefore, the AC-FOA algorithm constructed in this paper presents better optimization performance than the other three optimization algorithms.

6. Conclusion

In order to improve the distribution efficiency of logistics, save transportation costs of logistics distribution and solve the problems existing in the logistics distribution path, this paper proposed the adaptive chaotic disturbance flies optimization algorithm (ACD-FOA) from the perspective of combinatorial optimization. The optimal logistics distribution path of 51 customers in China were selected by the optimized algorithm in this paper. The results showed that the improved algorithm will improve the global optimization precision and reduce the search time. It also had better efficiency in the choice of the optimal path. In solving the problem of logistics distribution path optimization, it presented the obvious advantages of optimizing the logistics distribution path and reduced the total transportation distance of the logistics distribution. Thus this algorithm can prove that the optimization strategy is effective and feasible, it can speed up the delivery, improve service efficiency and save distribution cost. Finally, the optimization model constructed in this paper was compared with the other three models, which proved that the model has better optimization precision and has certain practical significance.

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