Conservation Genetic Algorithm to Solve the E-commerce Environment Logistics Distribution Path Optimization Problem

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***Abstract*—E-commerce is a business activity that uses modern information technology to process cash flow and logistics to achieve transactions. With the increase of evolutionary algebra, saving genetic algorithm and genetic algorithm all tend to be more optimal. The evolutionary starting point of saving genetic algorithm is much lower than the evolutionary starting point of genetic algorithm. The evolutionary algebra and the population size in the conservation genetic algorithm also have certain influence on the performance of the algorithm. The maximum running distance of the vehicle is different when the trucks have distance limitation and have no-distance limitation. This paper can improve the efficiency of logistics distribution and shorten the distribution distance, which is of great significance for saving logistics costs and improving customer service level.**

***Keywords*— logistics and distribution, vehicle routing problem, saving algorithm, logistics costs**

I. INTRODUCTION

In the traditional logistics distribution, there are unreasonable factors such as low automation, untimely information reception, and low network level, which hinder the efficiency of logistics distribution. The logistics distribution under e-commerce is a new logistics distribution mode that can shorten the distribution cycle, optimize the service quality and improve the competitiveness of enterprises by combining information network technology and logistics distribution in an open network environment.

This kind of distribution mode is conducive to the improvement of logistics distribution efficiency. Logistics distribution under the e-commerce environment has many characteristics such as a large number of customers, relatively small customer demand, obvious customer respectability, and time requirements.

E-commerce logistics and distribution is to meet the customer's satisfaction, and it is the basic goal of the enterprise to find ways to minimize the transportation cost during the operation [1], [2].

Characteristics of E-commerce logistics distribution are a large number of customers, size of each customer's demand is relatively small, dispersion of customers is obvious, customer has high requirements for the timeliness of arrival of the goods, high customer service needs, and suppliers strive to save costs as showing in the Fig. 1.

The Vehicle Routing Problem (VRP) [3] is a typical NP-hard problem. It has a wide range of applications in computer science, operations research and engineering optimization. The algorithms of solving VRP problems mainly include precise algorithms, traditional heuristic algorithms, simulation algorithms and artificial intelligence algorithms. The exact algorithm [4] uses the mathematical programming method to obtain the optimal path solution. The exact algorithm is suitable for solving small-scale VRP problems. The traditional heuristic algorithm [5] refers to a feasible solution to the combinatorial optimization problem to be solved under the premise of acceptable computation time and space. The simulation method [6] obtains the optimized solution of the vehicle route through computer simulation experiments. The artificial intelligence optimization algorithm [7] finds the optimal solution of the problem by revealing and simulating

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natural phenomena. It is global optimization performance, strong robustness, and strong versatility and is suitable for parallel processing. It is widely used to solve large-scale VRP problems. [8] E-commerce is a business activity that uses modern information technology to process cash flow and logistics to achieve transactions. Under the e-commerce environment, whether an item can reach to the customer accurately is a key factor to enhance the company's image. Therefore, how to efficiently select the algorithm to solve the vehicle routing problem is an urgent problem to be solved. In this paper, the genetic algorithm and the conservation algorithm [9], [10]-[11] are combined to construct the conservation genetic algorithm to study the logistics distribution path optimization problem under the e-commerce environment and the experimental results are verified in the simulation environment.

This paper consists of six sessions. Session 1 is introduction. It introduce the problems of logistics distribution under the background of e-commerce and the current algorithm to solve the vehicle routing problem(VRP).Session 2 is e-commerce environment logistics distribution. In this session mainly introduce four basic streams and the characteristics of e-commerce environment logistics distribution. Session 3 is problem description. In the session it establishes a mathematical model to solve the NP hard problem. Session 4 is Saving Genetic Algorithm. Describing about saving algorithm and genetic algorithm respectively and combing the two methods to saving genetic algorithm. Session 5 is simulation. Get the result of using saving genetic algorithm and compare with genetic algorithm. Session 6 is conclusion as well as acknowledgement and references.

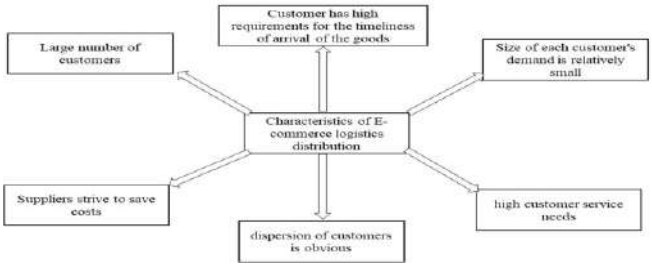

Fig. 1. Characteristics of E-commerce logistics distribution

II. E-COMMERCE ENVIRONMENT LOGISTICS DISTRIBUTION

E-commerce environment logistics distribution process includes procurement operation process, warehousing operation process, delivery operation process, return and follow-op operation process.

Any transaction in e-commerce contains four basic streams. That is logistics, business flow, capital flow and information flow.

- Information flow refers to the dissemination and flow of information.
- Business flow refers to the process of transferring the ownership of the transaction object, the ownership of the goods in the trade and the change of ownership between the purchase and sale. Including the payment process, the transfer process.
- Capital flow refers to the transfer of funds in the course of trade with the transfer of ownership of goods. The capital expenditure and income process including per-sales, prepayments, and advance receipts.
- Logistics is the final link in the completion of commodity goods transactions, and is also an important link in the realization of e-commerce. Companies need to choose the right logistics method based on the different nature of the traded goods.

E-commerce logistics and distribution is to meet the customer's satisfaction. During the operation, the basic goal is to find a minimize cost transportation way during the whole process-commerce environment logistics distribution have the following characteristics:

- A large number of customers;
- The size of each customer's demand is relatively small;
- The dispersion of customers is obvious;
- The customer has high requirements for the timeliness of arrival of the goods;
- High customer service needs;
- Suppliers strive to save costs.

How to quickly and efficiently deliver goods to customers in B2C mode and how to minimize transportation costs is essential to improve the overall competitiveness of enterprises. By studying the vehicle routing problem, it is possible to rationally use the transportation tools, optimize the transportation route and reduce the transportation cost of the enterprise.

III. PROBLEM DESCRIPTION

In the e-commerce environment, the logistics distribution path optimization problem can be described as follows: According to the customer's order status of the e-commerce enterprise, obtain the demand quantity of each customer's goods, determine the actual distribution network of the time period, and optimize the design of a vehicle. The delivery route completes the delivery tasks required by the customer under various constraints, so that the total cost of delivery is minimized.

In this paper, the maximum distance traveled by the vehicle is used as a limiting condition, and the saving algorithm and the genetic algorithm are combined to solve the optimal path. The delivery personnel take the list from the distribution center and deliver the goods to the customer points of known coordinates. When the total distance exceeds the maximum distance traveled by the truck, return to the distribution center to refuel, and then continue from the distribution center to the next waiting. The customer service department delivers the

goods until all the customers are served, and finally the vehicle travels back to the distribution center and can quickly effectively meet customer needs.

A) Model hypothesis

- There is only one central site that provides delivery services and provides fueling services;
- The location coordinates of the central site and each customer are known;
- The demand for each customer point is known;
- Only one truck is available in the entire area;
- The sum of the distance traveled by the vehicle during the delivery process shall not exceed its maximum travelable distance;
- Each customer has one and only one visit;
- Each customer's distribution needs must be met.

B) Model establishment

Each customer's representation is

$$p_i = p(x_i, y_i), i = 1, 2, ..., N$$

In the formula, x_i is the abscissa of the point where the customer is located; y_i is the ordinate of the point where the customer is located; N is the number of customers in the area who need the service. The coordinate point of each customer is known, so the distance between any two customers is known.

Define the decision variable as

$$X_{ij} = \begin{cases} 1, & Passing\ the\ vehicle\ on\ the\ line(i,j) \\ 0, & Otherwise \end{cases}$$

In the formula, (i, j) shows the car travelling from i to j.

1. The objective function for calculating the shortest path to travel is

$$D = \min \sum_{i=1}^{N} \sum_{j=1}^{N} d_{ij} \times x_{ij} + d_{1o} + s_o + d_{no} \quad (1)$$

In the formula, d_{ij} is the straight line distance between adjacent customers i and j; d_{1o} is the distance from the distribution center to the first customer point; s_o indicating that when the vehicle travel route is limited by the maximum travel distance, the extra travel time is added back and forth; d_{no} is the distance from a customer to the distribution center.

2. Each customer is visited once.

$$s.t. \sum_{i=1}^{N} x_{ij} = 1, \quad (i \neq j; j = 1, 2, ...N) \quad (2)$$

$$\sum_{j=1}^{N} x_{ij} = 1, \quad (i \neq j; i = 1, 2, ..N) \quad (3)$$

In the formula, $\sum_{j=1}^{N} x_{ij}$ represents the total number of times from the customer i to the customer j (the value ranges from 1 to N); $\sum_{i=1}^{N} x_{ij}$ shows the total number of times from the customer i to the customer j (the value ranges from 1 to N). The combination of formula (2) and formula (3) means that each customer can only be served once, and the service cannot be repeated.

3. The maximum distance that a truck can travel at one time during the delivery process and cannot exceed the maximum distance that can be traveled that L is

$$\sum_{i=1}^{k} x_{ik} + x_{k0} \leq L \quad (4)$$

In the formula, x_{ik} means that the vehicle travels from the customer i to the customer k; $\sum_{i=1}^{k} x_{ik}$ indicates the total distance that the vehicle has traveled to the point of k; x_{k0} indicates the distance from the point k to the origin.

IV. SAVING GENETIC ALGORITHM

A) Conservation algorithm

Conservation algorithm, also known as the C-W, which was proposed by Clarke and Wright [12] in 1964. Its basic idea is to first connect each point to the origin separately, c_{ij} the distance between the point i and the point j, from 1 to the total distance is

$$z = \sum_{i=1}^{l} c_{oi} + \sum_{i=1}^{l} c_{io} \quad (5)$$

Then define the savings of the distance between the points of i and j

$$s(i, j) = c_{oi} + c_{io} + c_{oj} + c_{jo} - (c_{oi} + c_{ij} + c_{jo}) = c_{io} + c_{oj} - c_{ij} \quad (6)$$

$$s(j,i) = c_{jo} + c_{oi} - c_{ji} \quad (7)$$

In the formula, the distance between the point and the point; for the path saving value, the steps of the saving algorithm are as follows:

1. Calculate the savings value of the route, arranged in a tabular form according to the value of the savings. And choose the maximum savings.

2. Check whether the two points corresponding to the saved value satisfy the following points:

- If the corresponding two points in the saved value are not on the already constructed line, get the line segment and turn to step 3.
- If the corresponding two points in the saved value are on the formed line and not the inner point of the line (i.e., not directly connected to the origin), the connection is obtained or the line is turned to step 3.
- If the corresponding two points in the saved value are on the different lines that have been constructed, and they are not internal points, the line is obtained and turned to step 3.
- If the corresponding two points in the saved value are on the formed line, then the connection cannot be made again, and turn to step 3.

3. If the row or column is removed, the point can no longer be connected to other points, and the point cannot be reached by other points.

4. After all elements are crossed, a qualifying line is obtained and the algorithm terminates. Otherwise, select the largest element from the elements that are not crossed, and turn to step 3.

B) Genetic algorithm

The genetic algorithm draws on the natural selection process of the survival of the fittest in the biological world and shows the excellent selection process in nature. Darwin kept the outstanding individuals in the selection process, and the process of bad individuals being eliminated was called survival of the fittest [13]. The robustness of genetic algorithm is relatively strong, simple and universal, and has strong advantages in parallel processing, and the application of genetic algorithm is wide. Therefore, genetic algorithm is listed as one of the important intelligent computing methods. Similarly, genetic methods are also one of the computational mathematics to solve the optimal search method. Evolutionary algorithms include genetics, natural selection, crossover, and mutation [14].

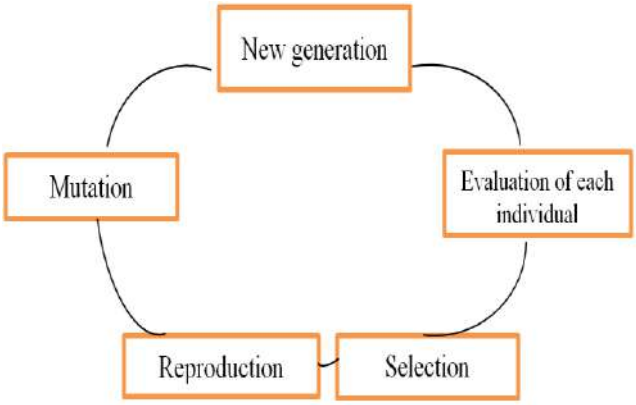

Fig. 2. The process of Genetic Algorithm

The genetic algorithm begins with a feasible solution set that represents a problem, and the population consists of a certain number of individuals genetically encoded [15]. As a chromosome carrying a gene, it also determines the external appearance of the individual's shape and characteristics. For example, genes in a chromosome determine the characteristics of a person's hair color and height. Therefore, the primary task of the algorithm is to perform the mapping from the external phenotype to the intrinsic genotype, which can also be understood as the coding work. Genetic algorithms basically use binary encoding for encoding work. After the initial population is generated, the genetic operators of natural genetics are used for cross-combination and mutation, and the evolutionary inferior principle is used to evolve more and more optimal solutions. The best individuals in the last generation population can be decoded the optimal solution to the problem.

The basic idea of genetic algorithm can be described from the above terms: starting from a population of optimization problems (a set of feasible solutions), according to the principle of survival of the fittest and the principle of survival of the fittest, evolved one by one to produce a better and better one (a set of feasible solution). In each generation, according to the fitness of the individual (feasible solution) (the objective function value), select some excellent individuals to copy (reproduce) to the next generation, and cross and mutate them to produce a new solution set population. This process will result in the population being like natural evolution. The progeny population is more adaptive to the environment than the parent (the new feasible solution is closer to the optimal solution of the problem than the old feasible solution), and the optimal individual in the whole evolution process is the final problem.

Genetic concepts in genetic algorithms and their effects are as follows [16][17]:

- Individual (individual) : Refers to an entity with a characteristic chromosome
- Chromosome: Encoding of the solution represented by a string or vector

- Gene: Elements in the chromosome
- Fitness: Individual fitness for the environment
- Population: The selected number is a set of solutions for the group size
- Reproduction: A set of solutions selected based on fitness function values
- Choose: Eliminate inferior individuals and choose excellent individuals
- Crossover: Gene interaction in chromosome
- Mutation: Genetic changes in chromosome

The genetic algorithm has a good global search ability, which can quickly search out the whole solution in the solution space without falling into the fast falling trap of the local optimal solution; and with its inherent parallelism, it can be easily distributed computing, speed up the solution. However, the local search ability of the genetic algorithm is poor, which makes the simple genetic algorithm more time-consuming, and the search efficiency is lower in the late evolution. In practical applications, genetic algorithms are prone to the problem of premature convergence. The choice of methods to maintain good individuals and maintain group diversity has always plays an important role in genetic algorithms. In the process of using the algorithm, we must develop strengths and avoid weaknesses, combined with other algorithms to avoid the shortcomings of the algorithm.

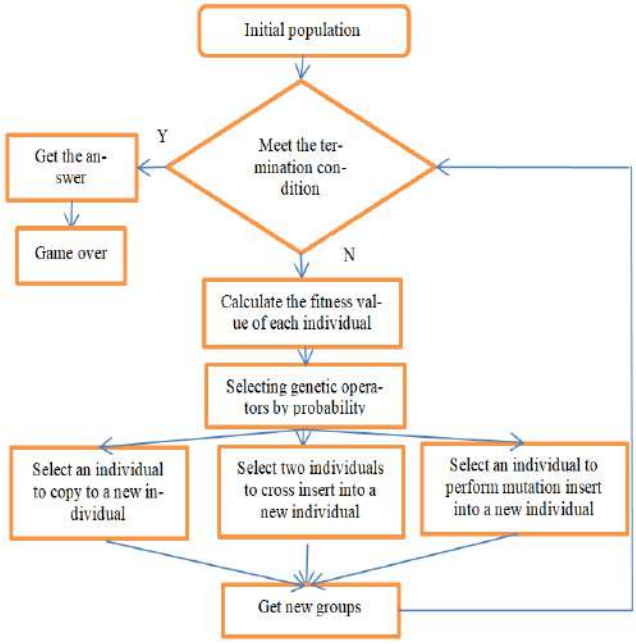

Fig. 3. The operational steps of the genetic algorithm

C) *Conservation genetic algorithm*

The combination of the conservation algorithm and the genetic algorithm [18] can improve the efficiency of the genetic algorithm. The specific steps of the algorithm are as follows:

- Required information.
- Initial population
- Fitness function.
- Select.
- Cross.
- Variation.
- control parameter

V. SIMULATION

It is assumed that within a certain period of time, a distribution demand order issued by 30 customers randomly selected in a region is received, and the maximum number of iterations is 200. Each order is analyzed by a conservation genetic algorithm, and the distribution center performs the vehicle on the vehicle loading to achieve logistics and distribution.

Each customer is numbered starting with 0 in decimal. And the demand for each customer is known.

Set the $N=200$ $p_c=0.9$ $p_m=0.1$ $p_s=0.6$ maximum evolution algebra $gen\max$ to increase with the number of customers, assuming that the maximum driving distance of the vehicle is 30km. In order to verify the validity of the algorithm and obtain the optimal path, the results obtained by the two algorithms of genetic algorithm and conservation genetic algorithm are compared respectively. The results are shown in Table I.

TABLE I
SIMULATION CALCULATION RESULTS

Method	Customer	Average Best Value	Best Result	Relative Deviation /%	Average Iterations
GA	30	427.7	412.7	3.6	162
CWGA	30	410.4	401.3	2.2	72

Note: Relative deviation= [(Single measurement-Measurement average)/Measurement average]*100% It can be seen from Table 1 that the average optimal value and the best result of the GA algorithm are larger than the CWGA algorithm when the number of customers is 30, which shows that the CWGA obtains the optimal path better; The relative error of CWGA is smaller than the relative error of GA, which indicates that the fluctuation of the CWGA result is smaller and more stable. The comparison of the average number of iterations shows that the convergence speed of the CWGA algorithm is much faster than that of GA. In summary, under a limited number of iterations, the algorithm CWGA as a new type of optimization algorithm is easier and faster to determine an optimized distribution path and reduce the delivery distance. The optimization process when the number of customers N=30 is as shown in Fig. 4.

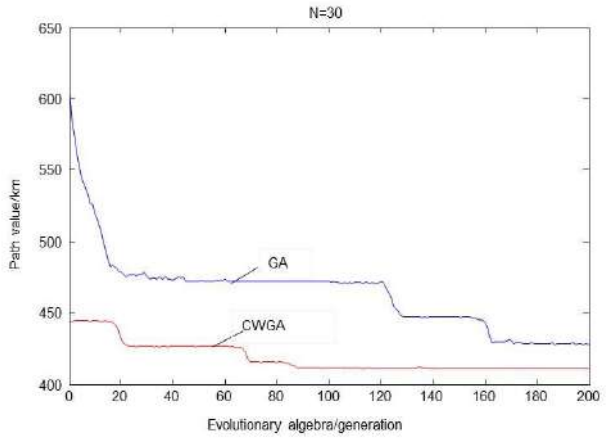

Fig. 4. Optimization process when the number of customers is N=30

Fig. 4 reflects the convergence of the path lengths of the two algorithms in the iterative process. The graph trends are gradually convergent. The CWGA algorithm requires less convergence than the GA algorithm, and runs to 200 generations. The shortest path finally obtained by CWGA is significantly improved compared to the shortest path obtained by the GA algorithm. Therefore, using the conservation algorithm to generate the initial population combined with the genetic algorithm makes the CWGA evolutionary starting point high and easy to find the optimal solution. 30 customer points are randomly selected. When considering the distance limit and not considering the distance limit, the route of the optimal path is obtained. One unit in the table indicates 1 km. The results are shown in Table II.

TABLE II
SIMULATION CALCULATION RESULTS

Customer	$N=30$
Consider the distance limit	Order：2 12 7 0 23 4 18 19 17 24 20 11 25 29 6 3 13 22 9 10 14 27 28 5 1 26 15 8 21 16 Distance：413.7km
No distance limit	Order：2 12 7 0 23 4 17 18 19 5 24 20 6 11 25 16 29 3 13 9 10 14 27 28 22 1 26 15 8 21 Distance：76.7km

In the conservation genetic algorithm, the population size (PS) is fixed, and this process does not conform to the actual biological evolution in the process of biological evolution. The population size cannot be constant in the process of human and biological evolution. Only one fixed population size in an algorithm cannot visually compare the results of the comparison. Poor population size will affect the quality of the solution. When the population size increases, if the set evolutionary algebra increases, the efficiency and accuracy of the conservation genetic algorithm do not necessarily increase.

TABLE III
CHANGES IN POPULATION SIZE AND CONVERGENCE ALGEBRA

PS	EGN	Optimal path
30	150	298.17
60	142	239.09
90	146	227.19
120	132	218.97
150	124	209.61
180	126	228.69
210	107	299.15
240	113	311.80
270	105	293.80
300	104	291.09

The evolutionary algebra of the conservation genetic algorithm is the number of cycles set in the program. A certain number of cycles will converge to a certain interval, which is the convergence algebra (EGN). The more the number of loops, the more values the algorithm traverses, and the results obtained are not necessarily closer to the optimal value.

3) N= 30, P_c= 0.9, P_m =0.1, the program runs 5 times to find the shortest path, convergence algebra (EGN) and population size (PS) are shown in Table 3 and Fig. 5:

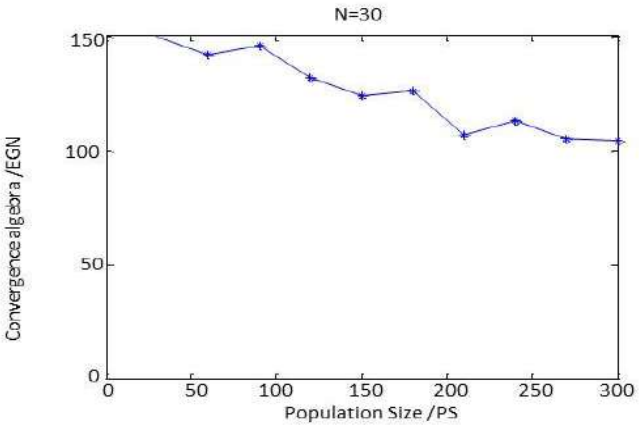

Fig. 5. Changes in population size and convergence algebra

VI. CONCLUSION

The logistics distribution of e-commerce has many characteristics such as there are lots of customers and uneven distribution of customers. Taking the e-commerce B2C model as the research background and do some research which in a certain area those different customers have different needs, finally the mathematical model is established. Combined with the saving genetic algorithm, the influence of the maximum

distance that the truck can travel on the vehicle distribution problem is detailed. Processing and obtaining an optimal path that is more realistic than previous studies. Future work, there are still a lot of deficiencies where the problem algorithm itself still needs a long calculation time, and the calculation degree is more complicated.

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