Analysis and Optimization of Garbage Removal System in Jiamusi City

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Abstract. With the development of the social environment, the amount of urban domestic garbage has increased rapidly, and garbage removal has become particularly important, which severely affects social-environmental resources. At present, the level of waste disposal in Jiamusi City is far behind the rate of discharge of garbage, removal of garbage, and recycling efficiency is not high. To reduce environmental damage and waste of resources, it is necessary to improve the efficiency of waste removal and recycling. This paper analyses the current situation of the garbage removal and transportation system in Jiamusi City, establishes a mathematical model to solve it in MATLAB, and uses genetic algorithm and particle swarm optimization to obtain the optimal path for garbage transportation. Combined with example verification, the results of the two algorithms are obtained and compared respectively, and an algorithm suitable for optimizing the waste removal path is derived.

1. Introduction

With the continuous development of urbanization and the increase of the population, the discharge of domestic garbage in Jiamusi City has increased exponentially. Still, the waste treatment methods have not been further improved, resulting in the problem of garbage being very prominent in the cities [1]. Secondly, Jiamusi City has a large population, and the amount of waste discharged in daily life is considerable, which places a burden on waste disposal [2]. In the process of municipal domestic garbage management, the clearing and transportation of urban domestic garbage is a vital link, which includes garbage collection and garbage transportation. At present, the garbage output of Jiamusi city is growing at an average annual rate of 10% - 12%, according to this trend, the daily garbage output of Jiamusi city will reach 2830 tons by 2020. Improper waste disposal or untimely will cause severe environmental pollution, thereby affecting people's healthy life. Besides, the primary waste treatment in Jiamusi City is landfill. This method may cause potential safety hazards and reduce the available land resources. Therefore, effective disposal of waste requires another approach. In the process of garbage removal and collection, Jiamusi City implements a mixed waste treatment method. This treatment method not only fails to effectively recycle the resources that can be recycled, resulting in the waste of resources, and the waste may be mixed [3]. Some harmful and dangerous materials are natural to cause environmental pollution and are not conducive to the next step of cleaning up the garbage, which increases the difficulty of garbage disposal. Also, although the garbage classification system has been established in Jiamusi City, the specific content is not complete, and there is no clear guidance on garbage classification.
methods [4]. The management ideas and authority for garbage classification are not very clear, and some corresponding management measures are lacking. At the same time, most of the residents in our city lack the awareness of garbage classification and cannot systematically predict and deal with garbage classification. In addition, Jiamusi City covers an area of extensive, widely distributed garbage collection facilities, quantity, inevitably there are some omissions and duplication in the recovery process, resulting in garbage clean-up is not timely, which resulted in inefficient waste disposal. In such a large-scale environment, it is necessary to optimize the algorithm of garbage transportation routes to avoid problems such as increasing urban traffic pressure and transportation costs. Based on the current study, the status of garbage removal Jiamusi City for analysis, genetic algorithm, and particle swarm optimization transport route [5]. Genetic Algorithm is a computational model that simulates the natural selection and genetic mechanism of Darwin’s biological evolution. It is a method of searching for the optimal solution by mimicking the natural evolution process. It is mainly used in the following aspects: searching for the optimal solution, scheduling field, etc. Particle Swarm Optimization is a random search algorithm based on group collaboration developed by simulating the foraging behaviour of birds. It is mainly used in the following areas: function optimization, constraint optimization, transportation, and other fields. Using Mat lab programming, the mathematical model is established, the two are solved, and several experimental results are compared to get the optimization algorithm of waste transportation path.

2. Materials and methods

2.1. Material

In the garbage transportation process, the distribution cost accounts for a large proportion of the entire collection and transportation cost, and the main factor affecting the price is how to plan a reasonable transportation route. Therefore, vehicle routing optimization is a method to solve the transportation link efficiency problem in the garbage collection and transportation system.

Vehicle Routing Problem was first proposed by Dantzig and Ramser in 1959. The distribution centre sorts and assembles according to the demand for different quantities of goods. Under the premise of a certain number of customers, the fleet organizes reasonable driving. The route is responsible for the distribution so that the customer's needs are meet. under certain constraints, the shortest distance, the least transportation cost, and the least time consumption are achieved.

Since the vehicle routing problem is an NP problem, the waste transportation problem can be seen as the travelling salesman problem (TSP), which is a classic combinatorial optimization problem. The classic TSP can be described as: a merchandiser needs to go to different cities to sell merchandise, how to choose an appropriate route, so that the merchantiser starts from a town, passes through all the towns, and returns to the place of departure with the shortest journey. Therefore, garbage transportation can be described as: the vehicle departs from the sanitation vehicle management centre. It returns to the place at least once after going to the garbage collection site. How should the transportation route be arranged to minimize the total transportation distance and meet the following conditions: The vehicle management centre begins and ends at the vehicle management centre. The sum of the weight of garbage on the path must not exceed the carrying capacity of the vehicle, and the route taken by the car cannot be repeated.

This article focuses on the distribution path of a single car. Assume that there are N given recycling stations. To achieve the shortest total transportation distance, find a way = (r₀, r₁, ..., rₘ) to minimize the objective function value:

\[ f(\text{path}) = \sum_{i=0}^{M-1} \text{dis}(r_i, r_{i+1}) + \text{dis}(r_M, r_0) \] (1)

\[ s,t,i = 0,1,2,\ldots,N \] (2)

Note: Rᵢ indicates that the order of garbage collection sites in the transportation path is I (r₀ represents the sanitation vehicle management center), dis (Rᵢ, Rⱼ) represents the distance between the collection site i and the collection site j, and f (path) represents the distribution the total distance.
2.2. Research method

2.2.1. Genetic algorithm. Genetic Algorithm is a random global search and optimization method that imitates the evolutionary mechanism of biological evolution in nature. It draws on Darwin's theory of evolution and Mendel's genetic theory. Its essence is an efficient, parallel, global search method, it can automatically acquire and accumulate knowledge about the search space in the search process, and adaptive control of the search process to find an optimum solution.

The implementation of a genetic algorithm is through three processes: chromosome coding, individual fitness detection and evaluation, and genetic operator.

Among them, let \( \{k_1, k_2, ..., k_N\} \) be a chromosome, \( d_{ij} \) \((i, j = 1, 2, ..., N) \) represents the distance from city \( K_i \) to \( K_j \), then the fitness of the individual is:

\[
\text{fitness} = \frac{1}{\sum_{i=1}^{N-1} d_{i,j+1} + d_{N1}} \quad (3)
\]

Let the population size be an inn, and the competence of individual \( I \) be \( f_i \), then the probability that individual \( i \) is selected is:

\[
P_i = \frac{f_i}{\sum_{k=1}^{inn} f_k} \quad (i = 1, 2, \cdots, inn) \quad (4)
\]

The following steps are required to complete the genetic algorithm:

Step 1: To solve the problem of traveling salesman, an integer population coding is used to establish an initial population, the population size is \( in = 100 \), the maximum genetic generation number \( \text{max} = 200 \), the cross probability \( P_c = 0.8 \), and the mutation probability \( P_m = 0.8 \);

Step 2: Set the number of initial iteration steps \( k = 1 \);

Step 3: Calculate the fitness for the individual according to formula (3), calculate the probability of selection according to (4), and select the two chromosomes with the highest fitness to directly enter the next generation;

Step 4: Perform a crossover operation on the chromosome chosen so that a partial mapping crossover operator is used; use a mutation operation on the converter;

Step 5: Perform a one-way evolution inversion operation on the chromosome;

Step 6: Makes \( k + 1 \rightarrow k \), if \( k \leq \text{inn} \), go to step 3, otherwise go to step 7;

Step 7: Outputs the optimal membership function value and the optimal solution corresponding to each criterion.

2.2.2. Particle Swarm optimization. A Particle swarm algorithm was proposed by Kennedy and Eberhart in 1995. Based on the process of birds searching for food, each optimization problem solution is imagined as a bird, called a "particle". All particles are searched in a D-dimensional space, and a fitness-function determines the fitness value to determine the current position. Each particle must be endowed with a memory function that can remember the best location it has searched for, and a speed to determine the distance and direction of flight. This speed is dynamically adjusted according to its own flight experience and the flight experience of its companions to find the optimal solution.

In the PSO algorithm, a group of particles is initialized in a feasible solution space. Each particle represents a potential optimal solution to an extreme value optimization problem. The characteristics of the particle are represented by three indicators: position, velocity, and fitness value. The particle swarm searches in a D-dimensional space, and there are m particles, where each particle's position represents a solution to the problem.

Particle i position: \( X_i = (X_{i1}, X_{i2}, ..., X_{iD}) \), particle i speed: \( V_i = (V_{i1}, V_{i2}, ..., V_{iD}) \), \( 1 \leq i \leq m \), \( 1 \leq d \leq D \); particle i has the best history Position: \( P_i = (P_{i1}, P_{i2}, ..., P_{iD}) \), the best position experienced by all particles in the group: \( P_g = (P_{g1}, P_{g2}, ..., P_{gD}) \).

Each time the particle updates its position, the fitness value is calculated, and the extreme individual value Pbest and the population extreme value Guest position are updated by comparing the fitness value.
of the new particle with the extreme individual importance, the fitness value of the group extreme importance, and the individual extreme value post. It refers to the optimal position of the fitness value calculated from the areas experienced by the individual, and the extreme value guest of the group relates to the optimal position of the fitness found by all the particles in the population. The particles update their speed and position through individual extremes and group extremes during each iteration. The update formula is as follows:

\[
V_{iD}^{k+1} = \omega V_{iD}^{k} + c_1 r_1 (P_{iD}^{k} - X_{iD}^{k}) + c_2 r_2 (P_{iD} - X_{iD}^{k})
\]

\[
X_{iD}^{k+1} = X_{iD}^{k} + V_{iD}^{k+1}
\]

In the method: \( V \) is the speed, and the current rate plus two correction terms: the gap between the individual and the optimal individual in the current travel path, and the deviation from the optimal value of the group. \( c_1 \) and \( c_2 \) are coefficients, and \( r_1 \) and \( r_2 \) are random numbers. \( X \) is the position, plus the current position plus speed.

3. Results and analysis

It is known that the number of garbage collection sites is 31, and \( x \) and \( y \) are the horizontal and vertical coordinates of each section. The specific coordinates are shown in Table. 1. The delivery vehicles must be distributed among these 31 sites, and each section can only be accessed once.

The above genetic algorithm is implemented using Matlab programming, and the random route trajectory before the optimization is shown in Figure 1. The results calculated using the Matlab genetic algorithm are shown in Figure 2. After the genetic algorithm is optimized, the shortest path is 9-8-20-25-26-28-27-29-13-7-6-5-2-4-16-17-19-24-23-11-12-14-15-1-31-30-21-22-18-3-10, the shortest distance was shortened from 31496.4948 to 18638.9525, and the entire program running time was 40.165s.

![Fig. 1 Initial path of waste transportation](image1)

![Fig. 2 Genetic algorithm optimization path](image2)

| Numbering | Coordinate | Numbering | Coordinate | Numbering | Coordinate |
|-----------|------------|-----------|------------|-----------|------------|
| 1         | (1304, 2132) | 12        | (2562, 1756) | 23        | (3429, 1908) |
| 2         | (3639, 1315) | 13        | (2788, 1491) | 24        | (3507, 2367) |
| 3         | (4177, 2244) | 14        | (2381, 1676) | 25        | (3394, 2643) |
| 4         | (3712, 1399) | 15        | (1332, 695)  | 26        | (3439, 3201) |
| 5         | (3488, 1535) | 16        | (3715, 1678) | 27        | (2935, 3240) |
| 6         | (3326, 1556) | 17        | (3918, 2179) | 28        | (3140, 3550) |
| 7         | (3238, 229)  | 18        | (4061, 2370) | 29        | (2545, 2357) |
| 8         | (4196, 1004) | 19        | (3780, 2212) | 30        | (2778, 2826) |
| 9         | (4312, 790)  | 20        | (3676, 2578) | 31        | (2370, 2975) |
| 10        | (4386, 570)  | 21        | (4029, 2838) |           |             |
| 11        | (3007, 1970) | 22        | (4263, 2931) |           |             |
After solving with particle swarm optimization, the results are shown in Figure 3. The optimal path is 19-17-18-20-30-31-27-28-26-21-22-25-12-14-15-1-29-11-6-7-13-5-4-2-9-10-8-16-23-24-3, which the shortest distance is 18407.0392, and the program execution time is 13.607s.

Obviously, after the optimization of the genetic algorithm and the particle swarm algorithm, the distance of the original garbage transportation path was shortened, and a new transportation route was planned to achieve the purpose of reducing transportation costs.

4. Discussion and conclusion

In this paper, the waste removal and transportation system in Jiamusi City are taken as the research object, and the shortcomings of the existing garbage collection mode in Jiamusi City are analysed. Based on the current transportation, the algorithm is used to optimize the waste transportation path to achieve the purpose of further optimizing the removal system. By programming in Matlab, using genetic algorithm and particle swarm optimization algorithm for waste transportation route optimization problems. Through the comparison of many experimental results, it is found that both the genetic algorithm and the particle swarm optimization algorithm initialize the population randomly, and both use the adaptive value to evaluate the system and perform a sure random search according to the adaptive value. Neither method is guaranteed to find an optimal solution. But the genetic algorithm is more comfortable to implement than the particle swarm algorithm. The selection, crossover, and mutation operators do not need to be changed for specific problems. The parameter settings are easy to modify, but they also have the disadvantages of non-standard coding and slow convergence. Although the particle swarm algorithm does not have crossover and mutation calculation processes, it relies on particle speed to complete the search. In the iterative evolution, only the optimal particles pass information to other particles. The search speed is fast. At the same time, the particle swarm algorithm is memorable, preferably the memory location and history can be transmitted to other particles, fewer parameters to be adjusted, the structure is simple, easy to implement the experiment.

It is merely, two different starting points optimal path algorithm in experiments each get, get different optimal route, the shortest distance is different. But compared with the genetic algorithm, in most cases, all of the particles may be faster convergence to the optimal solution, and results with the results obtained by the genetic algorithm are close to the optimal global solution. Through the comparison, it can be seen that PSO can solve the vehicle routing problem well, is a simple, small-scale garbage removal system, and can quickly find the optimal path.

Fig. 3 Particle swarm algorithm optimization path
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