Computing, Performance and Communication Systems (2021) Vol. 5: 1-5
Clausius Scientific Press, Canada
DOI: 10.23977/cpcs.2021.52001
ISSN 2371-8889

Research on WSN network planning based on multiple models

Zhiguo Tao*, Kang Liu, Zhaozhao Li, Jianbing Hao

School of Energy and Power Engineering, Lanzhou University of Technology, Lanzhou, Gansu, 730000

Keywords: simulated annealing, optimal route, multi-objective optimization

Abstract: From the perspective of the optimal route and minimum capacitance, this paper establishes a mathematical model based on the simulated annealing algorithm, multivariate inhomogeneous linear equations and multi-objective optimization, which provides the optimal route for the mobile vehicle and establishes the minimum capacitance [1]. Solve the model to maximize the total charging efficiency, and use the optimization model to obtain the optimal path for 4 mobile vehicles. The optimal route of a single/multiple mobile vehicles is visualized through multiple models. On the basis of the optimal route, the minimum capacitance required by each sensor is solved by using multivariate inhomogeneous linear equations.

1. Model preparation

Quote the idea of transformation in Global Mappe, and convert GPS latitude and longitude to UTM coordinates. UTM coordinates are a projected coordinate system that divides the earth into 60 areas. In programming, set k_0 as the projection ratio coefficient, and calculate through UTM sub-zones, and finally convert the latitude and longitude into plane X, Y coordinates [2].

$$X:\ X = X_0 + k_0 a v\left[A + (1 - T + C) \times \frac{A^3}{6} + (5 - 18T + T^2) \times \frac{A^5}{120}\right] \tag{1}$$

$$Y:\ Y = Y_0 + k_0 a\left[s + v\tan\phi\left(\begin{matrix}\frac{A^2}{2} + (5 - T + 9C + 4C^2)\frac{A^4}{24} \\ +(61 - 58T + T^2)\frac{A^6}{720})\end{matrix}\right)\right] \tag{2}$$

2. Model establishment and solution

2.1 Problem one model establishment

Energy consumption = energy consumption of sensor node charging + energy consumption of mobile charger charging sensor:

$$Z = X + V \times S (V \geq 0) \tag{3}$$

The problem is to find the shortest distance through n sensors. The simulated annealing algorithm has asymptotic convergence and is a global optimization algorithm that converges to the global optimal solution [3].

Step 1: data initialization

Step 2: Randomly generate a solution curRoad, and calculate the objective function value currL corresponding to the solution curRoad.

Step 3: select the shortest route through iteration: a new route is generated after passing through the neighborhood structure. If the new route is better than the current route, the current route newRoad is updated. By calculating the percentage difference between the total distance between the new route and the current route, a random number in the range of [0,1] is generated. If the random number is less than P, the new route is accepted.

$$\text{delta}=(\text{newL}-\text{currL})/\text{currL} \tag{4}$$

$$P=\exp(-\text{delta}/T) \tag{5}$$

Step 4: When the maximum outer loop is reached, the iteration is terminated, and the most optimal solution and route length are returned.

2.2 Problem one model solving

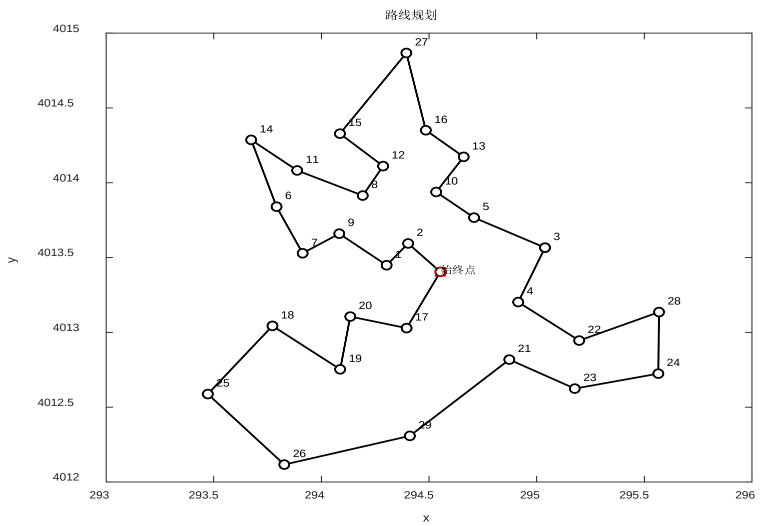

Figure 1: Results of the final iteration of 10000

After many iterations, it is finally determined that the path of 10,000 iterations is the final path.And $S_{总}$ =11.4429km.

2.3 Problem two model establishment

The optimal charging path should consume the least energy and ensure the continuous and stable operation of the entire sensor network. The minimum battery capacity of each sensor battery:

$$Q_i = X_i + f \tag{6}$$

Only need to calculate the minimum amount of electricity that each sensor needs to be charged; it can be obtained according to a simple physical relationship:

$$X_i = t_z \times M_i \tag{7}$$

$$t_z=\frac{s}{V}+\frac{1}{r}\times\sum_{i=1}^{29}X_i \tag{8}$$

Starting from the data center, the mobile charger will charge all the sensors and the shortest distance back to the starting point is 1.1429×10^4 m. Substituting the sensor values and formula 6 into formula 7 can obtain the 29-dimensional equations:

$$X_i=\frac{11429\times M_i}{V}+\frac{M_i}{r}+\frac{M_i}{r}\times\sum_{n=1}^{29}X_n \tag{9}$$

Solving equation 8 can get $X_1,X_2,X_3\cdots\cdots X_i\cdots\cdots X_n$ which is the amount of electricity each sensor needs to charge.

2.4 Problem two model solving

Assuming V=10m/s, r=0.1mA/s, substituting it into the model can solve the minimum capacity of each sensor battery.

Table 1: The minimum capacity of each sensor battery

Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7	Q_8	Q_9	Q_{10}
3.3094	4.7802	2.7578	3.3707	2.2063	2.7578	3.9222	2.8191	2.7578	3.3707
Q_{11}	Q_{12}	Q_{13}	Q_{14}	Q_{15}	Q_{16}	Q_{17}	Q_{18}	Q_{19}	Q_{20}
2.7578	4.5351	3.9835	2.7858	2.3288	2.7578	3.3707	4.5964	3.3707	2.7578
Q_{21}	Q_{22}	Q_{23}	Q_{24}	Q_{25}	Q_{26}	Q_{27}	Q_{28}	Q_{29}	
2.145	3.3707	4.5964	2.145	3.3707	2.6353	2.2063	3.9222	3.3094	

2.5 Problem three model establishment

Convert the relationship between the sensors into a graph theory problem, set the number of sensors as n, and d_ij represents the distance between the two sensors. The distance between any two points can be obtained by using the distance matrix. The mathematical model of the path problem[4]:

$$\min\sum_{i\neq j}d_{ij}\,x_{ij} \tag{10}$$

It is assumed that each mobile vehicle is charged with at least one sensor. Build a road map through genetic algorithm:

Step1: Individual coding, using path notation.

Step2: The genetic algorithm uses the fitness function as the basis in the evolutionary search, and uses the fitness value of each individual in the population to search.

Step3: Genetic operation, through iteration, to ensure that the search is progressing in the direction of optimization.

Step4: Perform crossover and mutation operations on the path to generate a new solution to further ensure the optimal solution.

Step5: Record the optimal individual in the iteration, that is, record the optimal line segment.

Step6: Iterative update, repeat step3~step5.

Step7: The evolution is terminated and the optimal solution is obtained.

Using the RWS method, suppose the number of distances is N and the fitness value f_i of an individual z in the distance, then the probability P_i of this individual i is selected as:

$$P_i=\frac{f_i}{\sum_{i=1}^{N}f_i}(i=1,2.....,N) \tag{11}$$

2.6 Problem three model solving

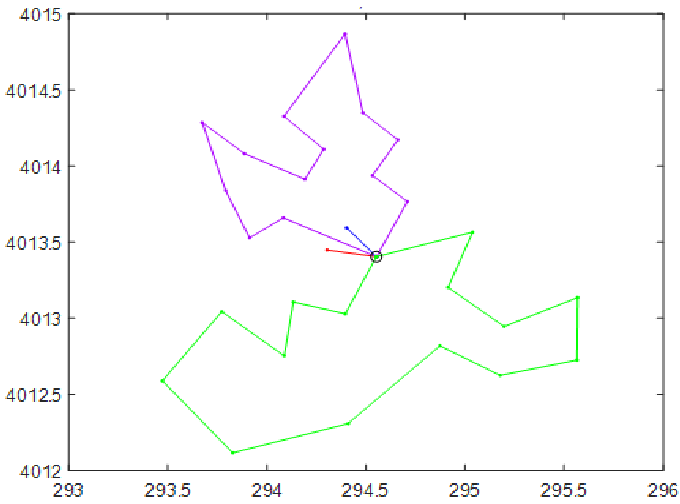

Figure 2: General map of the optimal route

According to the analysis in the figure, the optimal path length is 12.7658km, there are two mobile vehicles with a longer route, and the other two vehicles have only taken one sensor station.

2.7 Capacity problem model

For the shortest path of four moving vehicles, it is solved by establishing multiple linear equations. Take the mobile car 4 as the model construction, find the total time required for the mobile car to complete this distance:

$$t_{z4} = \frac{s_4}{v} + \frac{1}{r} \times \sum_i X_i \ (i = 3,4,17,\cdots,26,28,29) \tag{12}$$

Minimum power of each sensor:

$$\mathrm{X_i = M_i \times t_{z4}(i = 3,4,17,\cdots,26,28,29)} \tag{13}$$

$$X_i = M_i \times (\frac{s_4}{v} + \frac{1}{r} \times \sum_i X_i)(i = 3,4,17,\cdots,26,28,29) \tag{14}$$

Get the minimum capacitance of each sensor involved in mobile car 1, mobile car 2 and mobile car 3:

car1:

$$X_i = M_i \times (\frac{s_1}{v} + \frac{1}{r} \times X_i)(i = 1) \tag{15}$$

car2:

$$X_i = M_i \times (\frac{s_2}{v} + \frac{1}{r} \times \sum_i X_i)(i = 5,6,\cdots 16,27) \tag{16}$$

car3:

$$X_i = M_i \times (\frac{s_3}{v} + \frac{1}{r} \times X_i)(i = 2) \tag{17}$$

Due to the existence of parameters v and r, the solution of the solution model will become extremely complicated, so the parameters are limited, and their values are respectively set, v=10m/s, r=0.1m/s, through the solution, the location of each sensor can be obtained. The minimum capacity required, the capacity Q1 of line 1 is 0.0736mA, and the capacity Q2 of line 3 is 0.1123mA.

3. Model evaluation

3.1 Advantage

1. Simulated annealing will accept a solution that is worse than the current solution with a certain probability when iteratively update the feasible solution when solving the route problem, so it may jump out of this local optimal solution and reach the global optimal solution.
2. Multivariate linear equations can accurately solve this problem, combined with reality, the result is correct.

3.2 Disadvantage

1. It is necessary to continuously increase the number of iterations to obtain the optimal path.
2. The dimension of the equation is too large, and the program runs slowly.

References

[1] Optimization of Multiple Traveling Salesman Problem Based on Genetic Algorithm, Shu Donglai, Anqing Normal University, 2018,6,15.

[2] "Fundamentals of Geodesy", Kong Xiangyuan, Liu Zongquan, Wuhan University Press, 2008, 5.

[3] Liu Chuang, Wang Jun, Wu Han, et al. Research on mobile charging problems in wireless rechargeable sensor networks [A] \\Computer Technology and Development Volume 26, Issue 3.

[4] Research on Multiple Traveling Salesman Problem Based on Improved Genetic Algorithm, Hu Shijuan, Jiangnan University, 2019, 6, 1.