An improved ant colony algorithm for TSP application

Deqiang Jiao*, Che Liu, Zerui Li and Dinghao Wang
School of Electrical and Electronic Engineering, Changchun University of Technology, Changchun, China

*Corresponding author e-mail: jiaodeqiang@ccut.edu.cn

Abstract. Aiming at the problems of slow convergence speed and easy to fall into the optimal solution of ant colony algorithm, genetic algorithm and nonlinear optimization are used to optimize ant colony algorithm. After the initial iteration of the ant colony, the solution formed by all paths is the initial population, and then the genetic algorithm is used for selection, crossover and mutation to improve the ability of global search. Finally, the nonlinear optimization algorithm is used to increase the ability of local search of the algorithm. Through this improvement, the convergence speed of the ant colony algorithm is improved and the problem of easy to fall into the optimal solution is solved, which is applied to the traveling salesman problem.

1. Improvement of Algorithm

1.1. Thoughts on Algorithm Improvement

Genetic algorithm is a commonly used random search algorithm, which has a good application in machine learning, and can greatly reduce the situation of falling into local optimum. The classical nonlinear programming algorithm uses gradient descent method to solve, and the local search ability is strong. Therefore, the improved algorithm proposed in this paper combines the advantages of three algorithms. First, the ant colony algorithm quickly completes the initial path selection, all paths as an initial community, and then as the initial population of genetic algorithm for global search. Finally, after a certain algebraic iteration, the nonlinear programming algorithm is used for local search. Through this algorithm, the optimal path selection of TSP problem is improved.
1.2. Implementation of Algorithm
According to the idea of improving the algorithm, the flow chart of the algorithm can be drawn.

**Figure 1.** Improved algorithm flow chart.

The algorithm steps are
1. **Step 1 Initialize the parameters**
   Each parameter of the improved algorithm is initial assigned.
2. **Step 2 Solution Space Construction**
   In the process of the ant colony algorithm completing the initial path-finding, the set of paths that the ants reach the destination are the solution space and the initial population of the genetic algorithm.
3. **Step 3 How to Select the Next Node**
   First, it can be assumed that there are m ants starting from the starting point S and finally reaching the end point T. How to choose the position j of an ants at the present position and the next moment.

   \[ j = \arg \max_{K_{j \alpha}} \left| \tau_{i,j} / \eta_{i,j}^\alpha \right| \]  

   The transition probability of arriving node j is calculated by the following formula.
Step 4 combined with genetic algorithm

The solution space constructed by the above steps is used as the initial population of the genetic algorithm, and then the initial population is expressed as chromosomes or individuals in the genetic space by coding. Then, the fitness function of the genetic algorithm is obtained, and the individual is judged by the size of the fitness function. The fitness function is:

$$F[f(x)] = \frac{1}{f(x)}$$  (3)

Selection operation refers to the selection of individuals in the population to form a new population under a certain probability and to obtain a better next generation of individuals through evolution. The probability of an individual being selected is:

$$e_i = \frac{F_i}{\sum_{j=1}^{N} F_j}$$  (4)

Where $F_i$ is the fitness value of individual $i$; $N$ is the number of individuals.

The crossover operation is to randomly select two bodies in the population, inherit the advantages of the two individuals before the operation by exchanging combinations, and then generate new excellent individuals. The method of crossing the $k$th chromosome $\alpha_k$ and the 1st chromosome $\alpha_1$ at the $j$ position is:

$$\alpha_{ij} = \alpha_{ij}(1-b) + \alpha_{ij}b$$  (5)

$$\alpha_{ij} = \alpha_{ij}(1-b) + \alpha_{ij}b$$  (6)

$b$ Random number for $[0,1]$.

Variation operation refers to the process in which a body in a population changes a little and forms a better individual. The mutation of a gene fragment $j$ of a body $i$ in a population is:

$$\alpha_{ij} = \begin{cases} 
\alpha_{ij} + (\alpha_{ij} - \alpha_{\text{max}}) \cdot f(g), & r \geq 0.5 \\
\alpha_{ij} + (\alpha_{\text{min}} - \alpha_{ij}) \cdot f(g), & r \leq 0.5 
\end{cases}$$  (7)

Step 5 pheromone update

The pheromone update strategy mainly refers to real-time pheromone update and global path pheromone update.

$$\tau_{ij} = (1-\rho)\tau_{ij} + \rho\tau_0$$  (8)

where, $\tau_0$ is the initial value of pheromone, and $\rho$ is the adjustable parameter of interval $[0,1]$.

$$\tau_{ij} = (1-\rho)\tau_{ij} + \rho\Delta\tau_{ij}$$  (9)

Where, $\Delta\tau_{ij} = 1 / \ell^*$, $\ell^*$ is the shortest length in all paths, $\rho$ is the adjustable parameter in the interval $[0,1]$.

Step 6 is nonlinear optimization

After the genetic algorithm evolved to 20 generations, the results obtained at this time were taken as the initial value of nonlinear optimization. Then, the linear programming function in the MATLAB optimization toolbox was used to locally optimize the objective function, and finally the optimal solution was obtained.
2. Simulation results
In this paper, the improved ant colony algorithm is used to solve the TSP problem, and the advantages of the improved algorithm are analyzed. 31 node coordinates are set: (19,20), (8,10), (3,14), (30,9), (25,26), (15,16), (20,6), (33,8), (22,1), (0,18), (36,3), (18,23), (34,15), (27,14), (21,4), (30,2), (11,8), (7,22), (25,12), (6,5), (13,18), (1,27), (29,24), (39,37), (37,32), (19,30), (14,32), (4,40), (21,22), (11,21), (5,36). The simulation results of improved algorithm and basic ant colony algorithm are as follows.

![Comparison of simulation results.](image)

3. Conclusion
In this paper, through the improvement of ant colony algorithm through genetic algorithm and nonlinear programming, the search ability of the algorithm is strengthened, the convergence speed is accelerated, and the local optimum is avoided. Finally, through the experiment, it is proved that the improved ant colony algorithm can improve the accuracy and strengthen the self search ability.

References
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