2013 Third International Conference on Instrumentation, Measurement, Computer, Communication and Control

Ant Colony Algorithm and Its Application in Solving the Traveling Salesman Problem

Shigang Cui
Tianjin Key Laboratory of Information Sensing & Intelligent Control, Tianjin University of Technology and Education
Tianjin, China
e-mail: cuisg@163.com

Shaolong Han
Tianjin Key Laboratory of Information Sensing & Intelligent Control, Tianjin University of Technology and Education
Tianjin, China
e-mail: 1040928772@qq.com

Abstract—**With the modernization of the rapid development of science and technology, high technology has been more and more widely applied. Ant colony algorithm is a novel category of bionic meta-heuristic system and parallel computation and positive feedback mechanism are adopted in this algorithm. Ant colony algorithm, which has strong robustness and is easy to combine with other methods in optimization, has wide application in various combined optimization fields, but the basic ant colony algorithm is of slow convergence and easy to stagnation and easily converges to local solutions. many scholars did a lot of effort to improve these weaknesses, but the research still needs improving. This paper expounds the basic principle, model, advantages and disadvantages of ant colony algorithm and the TSP problem， the concrete realization process of ant colony algorithm is put forward in solving traveling salesman problem and the simulation shows that solution is feasible.**

Keywords- ant colony algorithm; the TSP problem; pheromone

I. INTRODUCTION

First of all, let me introduce you two important concepts in order to make it easier for you to accept the content in this paper. One is the ant colony algorithm which was proposed by Dorigo[1,2] who is an Italian scholar in the early 1990s. Ant colony algorithm is a simulated behavior, it imitates foraging behavior of real ant. The ants release pheromone on the path when they look for food， they can perceive the pheromone concentration, they choose the path according to the pheromone concentration, all the ants will eventually go the shortest path which is from the nest to the food. Ant colony algorithm is used to solve the TSP successfully at the earliest, parallel computation and positive feedback mechanism are adopted in this algorithm，and it has strong robustness[3-5]. With the development of the algorithm, people put forward many improving methods of ant colony algorithm from different angles in short decades, such as the Ant - Q algorithm, MMAS algorithm which is put forward by Q - Learning, the ant colony algorithm based on negative feedback is very popular due to its application scope which almost throughout all areas, ant colony algorithm is a hot topic at home and abroad. Another is traveling salesman problem, it is one of famous question of mathematics, traveling salesman problem can be described like this: a traveling salesman will visit n cities, he must choose the shortest path to go according to the limitation : He must visit each city only once and return to the original departure city finally. The TSP problem is a complex combinatorial optimization problem, there is no good way to solve it at present. Literature research[6,7] demonstrates that such difficult problem can be effectively solved by ant colony algorithm, therefore, ant colony algorithm is used to solve traveling salesman problem in this paper.

Identify applicable sponsor/s here. If no sponsors, delete this text box. (sponsors)

II. THE BASIC ANT COLONY ALGORITHM

A. Basic Principle of Ant Colony Algorithm

All ants with no telling them where the food is begain to start looking for food, ant will release a volatile secretions which called pheromone into the surrounding environment when it finds food, (pheromone will gradually evaporate with the passage of time, path distance can be characterized by the size of the pheromone concentration) pheromone can attract other ants to come over, so more and more ants will find the food. Some ants not always repeat the same way as other ants, they will find new ways, if the other roads are shorter than the original, more and more ants are drawn to this short road gradually, after a period of time, there may be a shortest path which is repeated by most of the ants.

B. Basic Model of Ant Colony Algorithm[8-12]

Solving TSP problem is used to illustrate the model of the ant colony algorithm, if we put m ants in n cities, which constructs a artificial ant colony system, each ant actions shall comply with the following requirements:

1) *Concentrationof biological pheromone decides probability that ant selects the next city.*
2) *Ant cannot choose the city which had been choosen as the next city.*
3) *Ant updates concentration of biological on the path after throughing all of the cities.*

the following two parameters determine the probability of a city to be selected by ant mainly:

$\tau ij(t)$: Concentration of biological pheromone on the path between the city i and j at the time t, concentration of biological pheromone on every path is the same at the

978-0-7695-5122-7/13 $26.00 © 2013 IEEE
DOI 10.1109/IMCCC.2013.266

beginning, set tau ij (0) = c (c is constant) which is used to simulate the real ants pheromone.

ηij: Heuristic information on the path between the city i and j, heuristic information is given according to the specific problems, such as ηij=100/dij (dij generally refers to the distance between the city i and j in the TSP problem.).

$P_{ij}^{k}(t)$: Choose chance of ant k from city i to city j , shown in formula (1) :

$$P_{ij}^{k}=\begin{cases}\dfrac{\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)}{\sum s\in allow_k \tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)}, & j\in allow_k \\ 0 & ,otherwise\end{cases} \tag{1}$$

Pheromone stimulating factor α, expect stimulating factor β and residual factor ρ, the setting of three parameters has a great influence on the algorithm performance, α reflects that the accumulation of information guides ant colony search with the relative importance in the movement process, the larger α, the greater chance of selection path which han been choosen, it will make ant colony search early into local optimum when the α is too large. The larger β, the larger possibility that ant chooses local optimal path, it is easy to fall into local optimum. Global optimization performance of Ant colony algorithm first ask for the search procedure of ant colony with strong randomness, and fast convergence of ant colony algorithm asks for the search process of ant colony with high certainty, as a result, the two points are effect mutually, and related closely. Good or bad effect is decided by the scope of α and β. Normally α range from 0.5 to 5, β range from 1 to 5. In the ant colony algorithm, the size of the parameters of 1-ρ directly affects global search ability and convergence speed of the ant colony, because of the existence of pheromone volatility, when scale of problem is too large, it can make the amount of information which had never been to search reduce to zero, thus reducing the global search ability of the algorithm, and when 1-ρ is too large, the possibility of choosing the path which once chosen is too big, and it can also affect the random algorithm and global search ability of performance, reducing 1-ρ although can improve the performance and the algorithm of random global search ability, but also can lower the rate of convergence of the algorithm. We must consider the two performance metrics of the global search ability and convergence speed to choose 1-ρ, we should make a choice according to the actual situation when we solve practical problems.

When the ant arounds a circle, biological pheromone will update according to the formula (2):

$$\tau_{ij}(t+1)=(1-q)*\tau_{ij}(t)+\Delta\tau_{ij}(t) \tag{2}$$

Δ τij(t): the sum of the pheromone on the path (i, j)， it is defined as formula (3):

$$\Delta\tau_{ij}(t)=\sum_{k=1}^{m}\Delta\tau_{ij}^{k} \tag{3}$$

$$\Delta\tau_{ij}^{k}(t)=\frac{Q}{L_k} \tag{4}$$

Only when the ant K go through the path (i, j) in the loop, just as formula (4), otherwise 0.

Q is a constant, Q > 0, L_k is the total length of the path that the ant k had walked. The ants pheromone will be updated after building all the local solution, the formula has better performance in solving TSP, formula (1) shows the ants select tectonic path, formula (2) shows ants update the pheromones of path. The two steps search the entire space iterativly, the path with the most pheromone is optimal path finally.

C. *Main Advantages and Disadvantages of the Basic Ant Colony Algorithm[13]*

Compared with other optimization algorithm, it is not difficult to find the following features after a study.

The advantages of ant colony algorithm:

1) *It does not rely on specific mathematical expression and has a strong ability to find global optimal solution.*
2) *The algorithm has many advantages, such as positive feedback, stronger robustness, global, good universality, mechanism of distributed parallel computing, it is easy to be combined with other methods and so on.*

The disadvantages of ant colony algorithm:

1) *The success of the ant colony algorithm is mainly at the experimental level, there are few theories which can explain why using ant colony algorithm can successfully solve these problems, it doesn't have a solid mathematical foundation.*
2) *The model of ant colony algorithm cannot be directly applied to practical optimization problems.*
3) *The local search ability of ant colony algorithm is weak, local convergence, slow convergence speed and other problems are easy to occur, so some special auxiliary techniques often need to be embedded.*
4) *Ant colony algorithm requires a long computation time and stagnation phenomenon are easy to appear in the whole process[12].*
5) *Algorithms are not directly used to solve continuous optimization problems.*

III. SOLVING TSP PROBLEM BY USING ANT COLONY ALGORITHM

A. *Description of the Traveling Salesman Problem*

Traveling salesman problem is also called traveling salesma, this math problem is being suggested by Irish mathematician Sir William Rowan Hamilton and British mathematician

Thomas Penyngton Kirkman at the 19th century, n cities and the distance between each two cities are given, he must visit each city only once and return to the original departure city finally. The description of the problem is simple, so its actual model in the chain of goods distribution, network optimization problem such as wiring and printed circuit board has been widely used in the drilling line scheme, as a result, it attracts many researchers to study at home and abroad, they try to use different algorithms to solve TSP problem.

The graph theory of traveling salesman problem is described below[10][14]: Given graph G = (V, E), V: the set of vertices. E: the set of edges. D: a distance matrix which is composed by the distance between the point i and fixed-point j and it requirements to determine the length of the shortest loop.

B. *Basic Steps of Ant Colony Algorithm to Solve TSP*

Generally, it requires several steps to solve TSP problem by using ant colony algorithm, figure 1 can represente the steps intuitively:

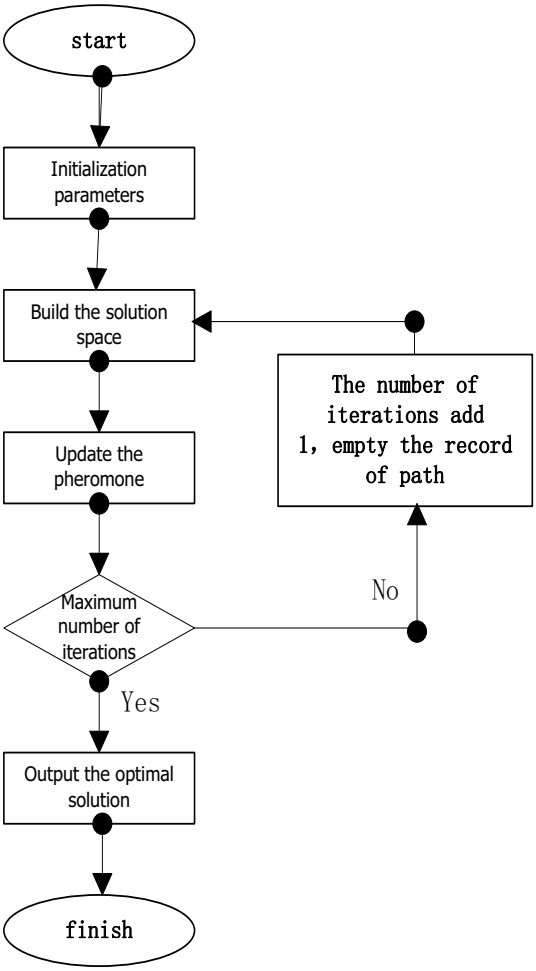

Figure 1. Realization flow chart of the ant colony algorithm

1) Initialization Parameter

Relevant parameter must be initialized at the beginning of the calculation, such as ant colony size (number of ants), important factor of pheromone, importance factor of heuristic function, volatilization factor of pheromone, pheromone amount, the maximum number of iterations, the number of iterative initial value.

2) Construction of the Solution Space

Each ant will be immediately placed in a different starting point, calculating which city is going to be visited according to the formula (1) until all the ants visit all the cities.

3) Updation of the Pheromone

Calculate every path length that the ants pass through, record of the optimal solution in the current iteration number (shortest path). Updating the pheromone concentration on the city path at the same time according to the formula (2), formula (3) and formula (4).

4) Determine Whether to Terminate

Determine whether reach the maximum number of iterations, if did not reach, the number of iterations adds 1, and clear the path form, and return to build the solution space, otherwise terminated, outputs the optimal solution.

IV. SIMULATION RESULTS

Experimental simulation environment： 32 bit operating system is Windows 7 ultimate version (DirectX11), 2.53 GHz dual-core notebook processor, 2 gb memory, the simulation experiment platform based on Matlab software, experiment parameters: $\alpha = 1.0$, $\beta = 2.0$, n=30, m = 30/1.5 = 20, the maximum number of iterations is NC_max = 200, pheromones increase strength coefficient Q=100.

The results: ant colony algorithm can solve the traveling salesman problem quickly and compute the shortest length of path rapidly. The result of traveling salesman problem optimization is shown in figure 2, the average distance and the shortest distance graphical representation is shown in figure 3.

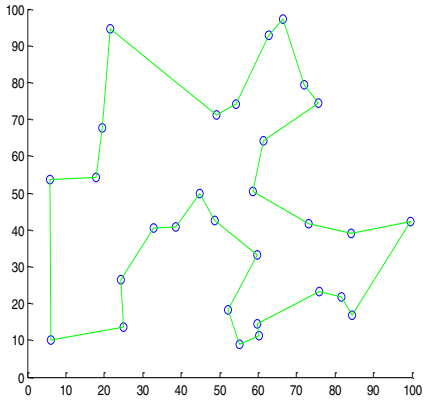

Figure 2. Optimization result of traveling salesman problem

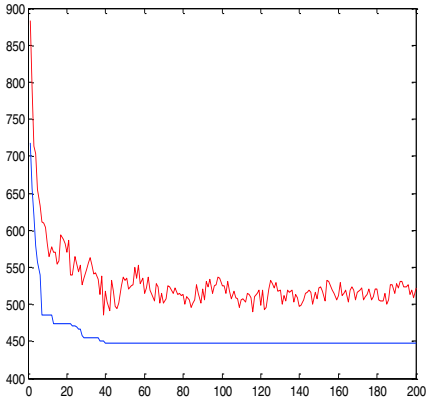

Figure 3. Average distance and the shortest distance

V. CONCLUSION

Parallel computation and positive feedback mechanism are adopted in this ant colony algorithm, its positive feedback mechanism ensures the quickness of the optimization process. Simulation shows that ant colony algorithm has many advantages, such as fast convergence speed, high precision of convergence, strong robustness and so on, but random exists in the movement when the number of ants is small and the search time will be longer when the number of ants is large. Local optimal solution may emerge easily in the search process, which results in the stagnation and premature of algorithm, therefore, it can be combined with other algorithms to improve the performance of ant colony algorithm in solving TSP, such as genetic algorithm, the algorithm needs further research.

REFERENCES

[1] Colorni A, Dorigo M, Maniezzo V, et a1. Distributed optimization by ant colonies. Proc. of the 1st European Conference on Artificial Life. 1991: 134 142.

[2] Dorigo M. Optimiztion, learning and natural algorithma(in Italian). Dipartimento di Elettronica, Politecnico di Milano, IT, 1992.

[3] .DORIGO M, MANIEZZO V, COLORNI A. Ant system: optimization by a colony of cooperating agents[C]. IEEE Transaction on Systems, Man, and Cybernetics-Part B,1996,26(1):29-1.

[4] Haibin Duan, Daobo Wang, Jiaqiang Zhu. Ant colony algorithm theory and application research progress[J]. Control and Decision, 2004,19(12): 1321-1326,1340.

[5] Haibin Wang, Daobo Wang. A fast global optimization of the improved ant colony algorithm and simulation[J]. Information and control,2004,33(2):241-244.

[6] Wencheng Wu, Jian Xiao. The Chinese traveling salesman problem based on ant colony algorithm satisfied solution[J]. Computer and automation, 2002,(8)

[7] Suoping Li, Xiuyuan Zhang, Haibo Yang. Worker ants swarm algorithm theory and its implementation in the classical TSP problem[J]. Transportation systems engineering and information technology, 2002,2（1）

[8] Shiyong Li, Yongqiang Chen, Yan Li. Ant colony algorithm and its application[M]. Harbin: Harbin industrial university press, 2004,9.

[9] Haibo Duan. Ant colony algorithm and its application principle[M]. Beijing: science press, 2005, 12.

[10] Liang Ma, Gang Zhu, Aibing Ning. Ant colony optimization algorithm [M]. Beijing: science press, 2008.2

[11] Qingjian Ni, Hancheng Xing, Zhizheng Zhang. Ant colony algorithm and its application research progress [J]. Journal of computer applications and software, 2008, 8 (25) : 12-16.

[12] Jihui Zhang, Xinhe Xu. a new evolutionary algorithm of ant colony algorithm [J]. Systems engineering theory and practice, 1999, 3:84-87.

[13] Wang jian, Li ping, Chunjie Yang. The principle and application of ant colony algorithm[J].Mechanical & Electrical Engineering Magazine,2003,20(5).

[14] Xiujuan Lei. Swarm Intelligent Optimization Algorithms and Their Applications[M].BeiJing: science press,2012.8.