American Journal of Information Science and Computer Engineering
Vol. 5, No. 2, 2019, pp. 66-71
http://www.aiscience.org/journal/ajisce
ISSN: 2381-7488 (Print); ISSN: 2381-7496 (Online)

Ant Colony Algorithm for Travel Route Planning

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Abstract

The developments of society and the living standards have greatly facilitated people's travel. Thus, how to choose a tourism strategy becomes an important problem in many tourist routes. Aiming at the tourist route optimization problem of nine cities in China, this paper first collects the track mileage and the actual high-speed train or train fares between every two cities. Second, the optimal distance and cost of the travel are solved by the ant colony algorithm (ACA) based on the datum collected, respectively. Finally, travel evaluation index of combination the travel time with the fare are computed. Then the values of the travel index matrix are regarded as the weights in the weighed graph of the traveling salesman problem. Similarly, the ACA is implemented to solve the optimal tourism route with travel time and fare. On the whole, reasonable and optimal travel route and booking schemes are proposed for this practical tourism problem and provided for the traveler to choose a suitable travel route.

Keywords

Ant Colony Algorithm, Shortest Distance, Least Cost, Travel Evaluation Index

Received: March 22, 2019 / Accepted: May 20, 2019 / Published online: May 28, 2019

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1. Introduction

Tourism is becoming one of the most important activities of economic development in the world [1-7]. More and more people join in the tourism activities, that's why the scientific and rational planning of tourism routes has become a hot issue. It is well known that this issue belongs to the typical Traveling Salesman Problem. Fortunately, a lot of methods have been implemented to cope with this difficult problem [8-9]. For example, linear programming method [3], branch and bound approach [4], improved circle algorithm [5], genetic algorithm and ant colony algorithm [6-7, 10-17], etc. In this paper, we utilize the ACA to cope with the optimization of the distance, cost and the combination of the two for the tourism route, respectively. Correspondingly, A multi-objective optimization model is established and solved by ACA, then the reasonable and practical tourism route planning is obtained.

This paper is organized as follows: In Section 2, we analyze the problem of the travel route and demonstrate the mechanisms of the ACA, respectively. In Section 3, the tourism strategy with the shortest distance and least cost are roundly evaluated by the ACA, respectively. In Section 4, the travel routes of the nine cities with the combination the travel time and fare is also solved by the ACA. Conclusions of the proposed methods in this paper are given at the end in Section 5.

2. Problem Analysis and ACA

The problem studied in this paper is a combination optimization problem with respect to travel paths, which can be specifically described as: the nodes are used to represent nine cities shown in Table 1, the edges connecting between two nodes are explained by travel paths, and the length, cost and comprehensive index of the two are regarded as the weights of the edges, respectively. Then the travel route network can be abstracted as a weighted directed graph [5-11].

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2.1. Problem Analysis

It is noted that the above optimal path problem is to find a path with the minimum sum of weights from the designated starting node to the target node in weighted digraph. Generally speaking, the weights are influenced by different demand conditions, such as road route, route length, travel time, ticket price and so on, which can give rise to different optimal route of travel. Based on these factors, we first create the city travel network map, and then we apply the ACA to searching the optimal tourist route.

2.2. Ant Colony Algorithm

The ACA is a probabilistic technique for solving computational problems, and initially proposed by Marco Dorigo in 1992 in his PhD thesis [2]. The first algorithm was aiming to search for an optimal path in a graph, based on the behavior of ants seeking a path between their colony and a source of food. The following describes the calculation process of the ACA [2-4, 16, 17]:

(1) Initialize. There are m ants and the number of cities is n. The value of m is generally not bigger than the value of n. Put these m ants into n cities at random, and initialize the pheromone intensity between cities is $\tau_{ij}(0)$.

(2) Cycle iteration. When the ant k turns to the next city, the concentration of pheromone will play a guiding role in the ant selection path. Use $tabu_k$ to represent the set of cities that the ant k walks through [9]. The transition probability p_{ij}^k is defined as

$$p_{ij}^k = \begin{cases} \dfrac{\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)}{\sum_{k\notin tabu_k}\tau_{iu}^{\alpha}(t)\eta_{iu}^{\beta}(t)}, & j\notin tabu_k, \\ 0, & j\in tabu_k, \end{cases} \quad (1)$$

which is used to describe the transition probability of the ant k from the city i to the city j. Where τ_{ij} represents the amount of pheromone deposited for transition from the city i to the city j, η_{ij} is the desirability of state transition ij and $\eta_{ij} = 1/d_{ij}$. The d_{ij} denotes the distance between the city i and the city j. Moreover, $0 \le \alpha$ is a parameter to control the influence of τ_{ij} and $\beta \ge 1$ is a parameter to control the influence of η_{ij}.

(3) Pheromone Concentration Update.

When an ant completes the traversal of all cities, the concentration of pheromone will gradually evaporate with the passage of time. Therefore, the pheromone concentration update is particularly important and can be updated according to the following formula:

$$\tau_{ij}(t+n) = (1-\rho)\tau_{ij}(t) + \Delta\tau_{ij}(t), \quad (2)$$

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

where ρ ($0<\rho<1$) is the pheromone evaporation coefficient. $\Delta\tau_{ij}(t)$ represents the increment of pheromone concentration in the traversal path (i, j). In the case $t=0$, $\Delta\tau_{ij}(0)=0$. $\Delta\tau_{ij}^k$ is the amount of pheromone deposited by k-th ant with moves corresponding to arcs of the graph by

$$\Delta\tau_{ij}^k = \begin{cases} Q/L_k, & \text{if ant } k \text{ uses curve } ij \text{ in its tour,} \\ 0, & \text{otherwise,} \end{cases} \quad (4)$$

where L_k denotes the distance traveled by the k-th ant in this traversal cycle, and Q is pheromone intensity and a constant, which affects the convergence speed of the ACO to some extent.

(4) Termination condition. If the number of iterations reaches the maximum number of iterations, the loop ends. Then the shortest path of each cycle is compared and we can obtain the optimal travel route. Otherwise, the tabu list is emptied and return to step (2).

3. Optimal Tourism Route Planning

The train mileage of nine cities collected from the National Railway Network is shown in Table 1 below.

Table 1. Railway mileage tables between the cities.

Railway mileage (Km)		1	2	3	4	5	6	7	8	9
		Chongqing	Xi'an	Nanjing	Wuhan	Chengdu	Kunming	Guangzhou	Yangzhou	Changsha
1	Chongqing	0	727	1358	845	220	810	2015	1429	1040
2	Xi'an	727	0	1214	1050	658	1548	2116	1335	1412
3	Nanjing	1358	1214	0	512	1665	2547	1803	101	874
4	Wuhan	845	1050	512	0	1185	1949	1069	584	362
5	Chengdu	220	658	1665	1185	0	1112	1507	2266	1357
6	Kunming	810	1548	2547	1949	1112	0	1330	2588	1169
7	Guangzhou	2015	2116	1803	1069	1507	1330	0	1904	707

Railway mileage (Km)		1	2	3	4	5	6	7	8	9
		Chongqing	Xi'an	Nanjing	Wuhan	Chengdu	Kunming	Guangzhou	Yangzhou	Changsha
8	Yangzhou	1429	1335	101	584	2266	2588	1904	0	966
9	Changsha	1040	1412	874	362	1357	1169	707	966	0

Now, the ACA is implemented to find the optimal distance and cost for the above nine cities, respectively.

3.1. Optimization of the Distance

The train mileage of the nine cities is regarded as the weights of the weighted directed graph, then the optimal travel route is searched by the ACA with MATLAB software. The parameters of the ACA are set as follows: the number of ants is M = 50, the pheromone factor alpha = 2.4, the heuristic function factor beta = 3.5, the pheromone evaporation coefficient rho = 0.1, the pheromone intensity Q = 1 and the maximum iteration iter_max = 200. The results are shown in Figure 1 and Figure 2.

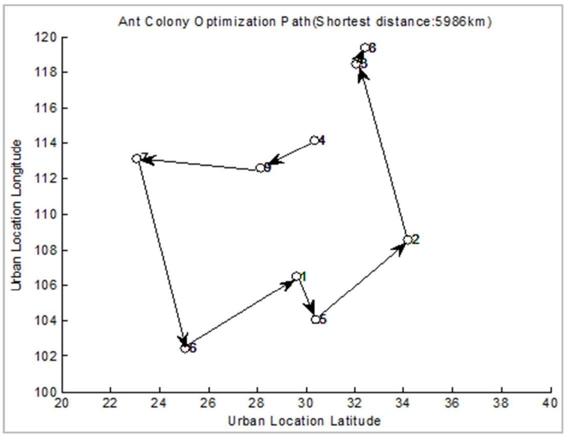

Figure 1. The optimal route obtained by ACA.

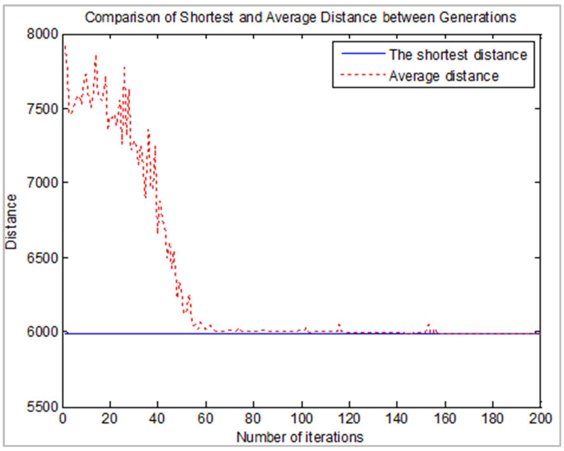

Figure 2. Varation of the distance with iterations.

In Figure 1, we obtain the optimal distance is 5986 km by the ACA and the specific optimization route is described as:

Wuhan→Changsha→Guangzhou→Kunming→Chongqing→Chengdu→Xi'an→Nanjing→Yangzhou.

From Figure 2, we can see that the shortest path and the average path have basically coincide when the ant colony iteration is about 60 generations, so the optimal path obtained by the ACA is effective.

3.2. Optimization of Total Cost

For the problem of minimum total cost, we first use Ctrip network to query the most economical train tickets between every two cities, and form a new cost matrix. Then, we use the logical attributes of fares between the cities in the original travel network to replace the physical attributes of route length between the cities. Therefore, on the weighted map of the urban travel network, the weighted edge shows the cost of the most economical way of travel between the two cities. The ACA is applied to solving the optimal cost and the corresponding parameters are set as: M = 50, alpha = 2.4, beta = 3.5, rho = 0.1, Q = 1 and iter_max = 200, respectively. Finally, the optimal cost is shown in Figure 3 and figure 4 below.

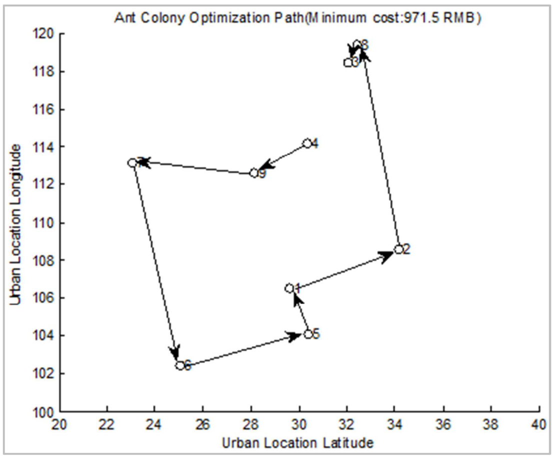

Figure 3. The optimal cost obtained by ACA.

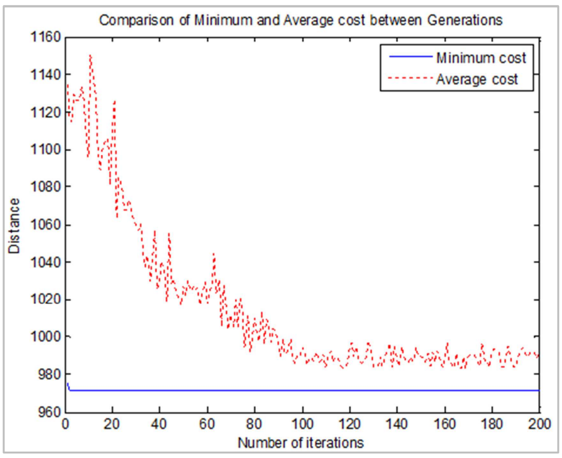

Figure 4. Varation of the cost with iterations.

From Figure 3, we can see that the optimization route with the cost by the ACA is demonstrated that

Yangzhou→Nanjing→Wuhan→Changsha→Guangzhou→Kunming→Chengdu→Chongqing→Xi'an, and the minimum cost is 971.5 yuan.

In Figure 4, we can see that the minimum cost and average cost are similar when the ant colony iteration is about 100 iterations, and there is no obvious change after that. So the route with optimal cost obtained by the ACA is effective and meets the requirements.

In brief, the optimal length of the above nine cities is 5986 km and the optimal cost is is 971.5 yuan by the ACA with corresponding parameters, respectively.

4. Multi-objective Optimization of the Time and Cost

In this section, the comprehensive travel factors such as saving money, saving time and convenience are analyzed and the tourism evaluation index is established by travel indicator below. Then this tourism index is regarded as the weights in the above weighed graph and the optimal route with the comprehensive travel conditions is solved by the ACA.

First of all, we give priority to the through train so as to avoid the transfer during the journey. The corresponding datum are found through the Internet. On this basis, the cost matrix and travel time matrix between the every two cities are obtained. Then we consider the economic and time-saving situations on travel and observed that the two factors are not absolutely independent. If the tourist needs to save time, i.e. shorten the journey time by adopting the faster mode of transport, then the traffic costs will be correspondingly increased in the opposite relationship of the travel time. In this paper, we implement the travel indicator to find the relation of the cost and time as [1]

$$I = rC + \rho t, \quad (5)$$

where r is the cost heuristic coefficient that reflects the relative importance of the fare C on travel, and ρ is the time heuristic factor, which reflects the relative importance of the time t spent in travel. The travel index I is the objective function of normalizing the weighted values of the expenditure and time on travel.

According to the actual travel fare and mileage by train, the relation between the mileage and the fare is fitted by using MATLAB software and the result is shown in Figure 5 as

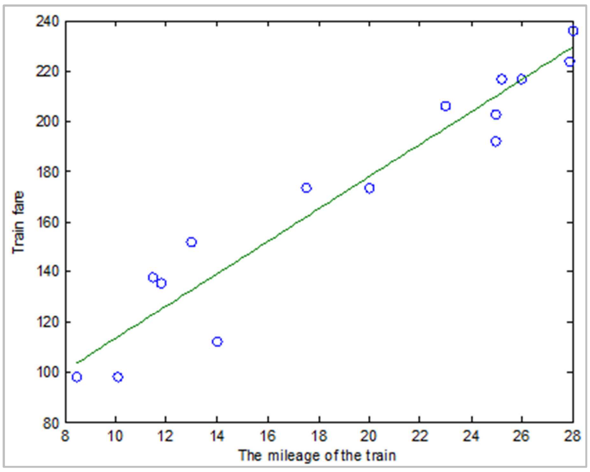

Figure 5. Fitting relationship between the mileage and time fare.

As can be seen from Figure 5, the train cost and mileage are approximately linear functions, then the ratio of the r and ρ is about 8.5. This means that an hour spent on travel is equivalent to 8.5 yuan for travel fare. Consequently, we get the relationship of travel evaluation index as

$$I = C + 8.5t, \quad (6)$$

which is understood as a travel plan, i.e. the smaller the travel index it is more valuable for traveler. Assuming that the traveler is more concerned about the travel cost, then we multiply the original cost heuristic factor and time heuristic factor by the balance coefficients 0.6 and 0.4 to obtain the alternative travel evaluation index as

$$I = 0.6C + 3.4t, \quad (7)$$

which is applied to obtaining the index matrix shown in Table 2 as

Table 2. Travel index matrix.

Travel index		1	2	3	4	5	6	7	8	9
		Chongqing	**Xi'an**	**Nanjing**	**Wuhan**	**Chengdu**	**Kunming**	**Guangzhou**	**Yangzhou**	**Changsha**
1	Chongqing	0	2530.6	4737.8	2964.5	775.9	2831.1	6969.8	5043.1	3613.1
2	Xi'an	2530.6	0	4219.1	3651.3	2304.4	5383.8	7336	4643.1	4904.9
3	Nanjing	4737.8	4219.1	0	1859	5800.8	8820.9	6271.8	353.3	3191.8
4	Wuhan	2964.5	3651.3	1859	0	4133.1	6756.8	3717.7	2120.6	1262.9
5	Chengdu	775.9	2304.4	5800.8	4133.1	0	3863.9	5258.2	7850.2	4711.9
6	Kunming	2831.1	5383.8	8820.9	6756.8	3863.9	0	4637.2	8963.3	4088.3
7	Guangzhou	6969.8	7336	6271.8	3717.7	5258.2	4637.2	0	6603.8	2437.4
8	Yangzhou	5043.1	4643.1	353.3	2120.6	7850.2	8963.3	6603.8	0	3520.8
9	Changsha	3613.1	4904.9	3191.8	1262.9	4711.9	4088.3	2437.4	3520.8	0

Based on the travel evaluation index, the weights in the weighed graph are replaced by the values in Table 2. Then the ACA is implemented to solve the above problem and the parameters are set as: M = 50, alpha = 2.4, beta = 3.5, rho = 0.1, Q = 1 and iter_max = 200. Finally, the optimal results are described in Figure 6 and Figure 7 as

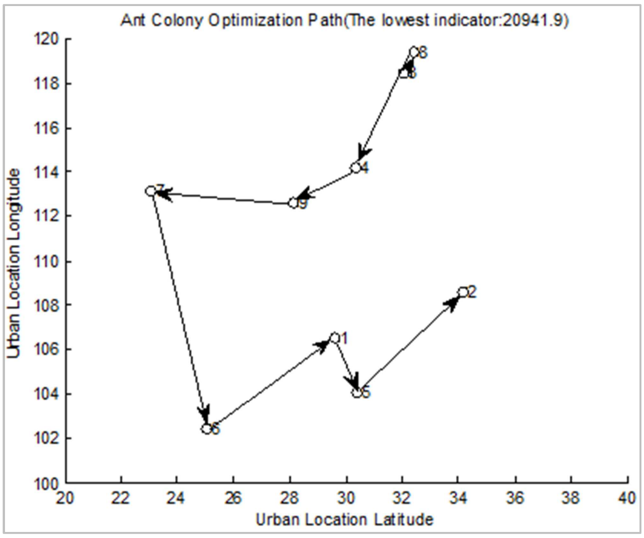

Figure 6. Optimal Roadmap Solved by Ant Colony Algorithms.

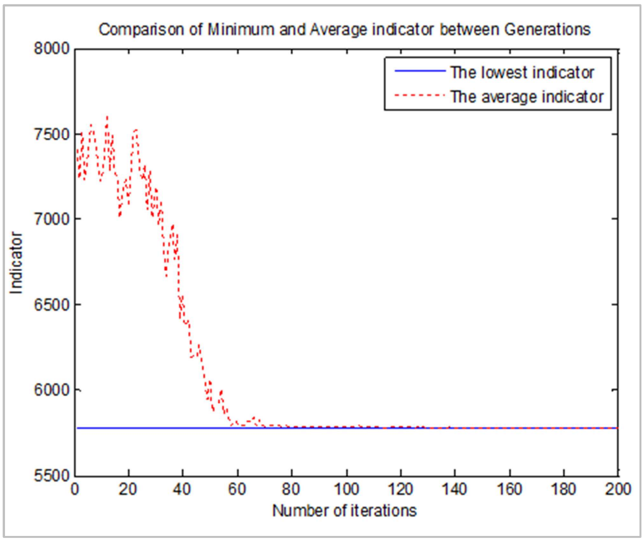

Figure 7. Path Evolution Process Map of Ant Colony Algorithms.

From Figure 6, the optimization route with the travel evaluation index is obtained as:

Nanjing→Yangzhou→Wuhan→Changsha→Guangzhou→Kunming→Chongqing→Chengdu→Xi'an.

In Figure 7, it can be seen that the lowest index and the average index basically coincide when the iteration is about 60. Thus the result obtained by the ACA is effective and a relatively comprehensive tour planning because of computing the travel time and the total cost of the trip.

5. Conclusion

In this paper, the shortest distance and least cost of the travel route have been solved by the ACA for the nine cities. Furthermore, the tourism evaluation index was implemented to cope with the comprehensive travel factors such as saving money, saving time and convenience. Finally, the tourism index obtained was regarded as the weights in the above weighed graph and the optimal route with the comprehensive travel conditions has been obtained by the ACA. Then the reference schemes were provided for the traveler to choose a suitable travel route. These methods can be widely used in other fields, such as manufacturing system, vehicle routing system, communication system and so on.

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