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Research on Traveling Routes Problems Based on Improved Ant Colony Algorithm

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ABSTRACT

This paper studies how to obtain a reasonable traveling route among given attractions. Toward this purpose, we propose an objective optimization model of routes choosing, which is based on the improved Ant Colony Algorithm. Furthermore, we make some adjustment in parameters in order to improve the precision of this algorithm. For example, the inspired factor has been changed to get better results. Also, the ways of searching have been adjusted so that the traveling routes will be well designed to achieve optimal effects. At last, we select a series of attractions in Beijing as data to do an experimental analysis, which comes out with an optimum route arrangement for the travelers; that is to say, the models we propose and the algorithm we improved are reasonable and effective.

Keywords: Traveling Routes; Ant Colony Algorithm; Parameter Adjustment; Searching Ways

1. Introduction

To effectively manage the traveling route problem, many researchers have devoted themselves to this area. How to establish a reasonable traveling route has caused hot discussion. Travelers are willing to expect a high quality and reasonable price traveling experience, that is to say, they want to visit attractions as much as possible in a limited time. Only in this way can they obtain the satisfaction of traveling. As a result, for the travelers, one of the most important factors they value is the route designed for them.

Traveling route setting is a optimization problem. Many researchers at home and abroad have studied this issue. Overseas researcher Cooper and others have discussed the traveling route problems [1-3], while domestic researcher Dongyun Fang has a wide range of study about the nearest insertion method to search for the nearest traveling lines based on graph theory [4]. And Linzhi Liu has designed different traveling routes for different travelers' demands [5].

This paper mainly concentrates on the personal traveling, especially for the large amount of attractions condition. The optimization objective for it is to make traveling time shorter. Our essay sets an objective optimization model based on the improved Ant Colony Algorithm. Above all, the algorithm has been proved to be effective and reasonable.

2. Problem Description

Traveling routes setting contributes to the travelers' satisfaction. When people choose the attractions, there is a strong desire to establish a good route. Besides, the route arrangement should satisfy travelers' demands. Within this limit, the route setting deserves better optimization.

For this problem, we need to make the following assumptions:

- The time of traveling every day is limited. When time out, travelers should come back to the hotel to end that day's trip.
- When setting the route, we only take the visiting time into account except the time of having meals and resting.
- The speed of the cars is fixed, so that we can count the time of transfer to another spot.
- The distance between the various attractions is calculated by latitude and longitude.

3. Model Building

3.1. The Transfer Time Among Attractions

Suppose the earth radius is R and the center of earth is O. Thus, the distance between two points $A(\alpha_1,\alpha_2)$ and $B(\beta_1,\beta_2)$ is.

$$d(A,B) = R\times\arccos[\cos\beta_1\cos\beta_2\cos(\alpha_1-\alpha_2) + \sin\beta_1\sin\beta_2]\times\frac{\pi}{180} \tag{1}$$

And v stands for the speed of transfer. Then the transfer time T_{AB} among attractions can be counted by:

$$T_{AB} = d(A,B)/v \tag{2}$$

3.2. Optimization Objective

1) The first goal: traveling days

Traveling days are relatively large unit of time in consideration, which is the most direct measure of the route arrangement. Not only related to the time of trans-fer among attractions, but also it is connected to the order of visiting. Different attractions have different visiting time, thus reasonable arrangement will make the days shorter and better.

Travel order to set the dwell time for each attraction, different specified time with the number of days, reasonable attractions with the number of travel days will be optimized.

2) The second goal: time spent on roads

This time stands for the one spent on roads, that is to say the transfer time among attractions. When the traveling days are the same, the less time spent on roads the better results it obtains.

3) Model of traveling routes Setting

$$\begin{array}{ll} \min & z = T \\ & y = t \\ \text{s.t.} & T \le T_{\max}, \\ & t + a \le b, \\ & m_c \le m_p. \end{array} \tag{3}$$

Suppose the limited time of traveling days is $T_{\max}$. While a stands for the visiting time of attraction, b shows the limited time of traveling every day. The journey cost is m_c, and the money expected is m_p.

4. Design for Improved Ant Colony Algorithm

4.1. Design for the Max-Min Ant Colony Algorithm

As the basic Ant Colony Algorithm for the shortest path, the search often falls into local optimal solution, that is to say after searching for a long time, the solutions found by all individuals are exactly the same. Thus the process will break off, which lead to the consequence that it may not be able to find the global optimal solution. So we take the Max-Min Ant Colony Algorithm into consideration. This algorithm owns the maximum and minimum values of the pheromone concentration in case of the big gap between the relative concentration resulting in the early ending of searching. Besides, the Max-Min Ant Colony Algorithm has been proved by Stutzle for the best effect [6].

Referring to the studies of Dorigo [7-14], the parameter adjustment can be summarized as follows: The pheromone concentration $\tau_{\min} = \tau_{\max}/4n$, the number of ants m is twice as the number of attractions. And the pheromone residues ρ are 0.7. Besides, the importance of pheromone α and the inspired factor β change within the whole iteration process. The degree of pheromone is bigger in the later period, while the inspired factor in the former period.

4.2. The Adjustment of Inspired Factor

Basic Ant Colony Algorithm inspired factor is set as $1/d_{ij}$. And d_{ij} stands for the transfer time between the two attractions i and j. In this way, however, the distance between the hotel and attractions is not taken into account. In fact, the distance is too important to ignore. Besides, regarding the traveling route setting problem as a TSP simply is unable to find the shortest time arranged attractions combination. So we consider making the inspired factor in the Ant Colony Algorithm adjusted by the method of dynamic distance. The calculating of inspired factor is divided into two conditions:

$$\begin{array}{l} if \quad Q_a + t_c > b \\ \qquad d_{ac} = d_{a1} + d_{1c} \\ else\ d_{ac} = d_{ac} \end{array} \tag{4}$$

Suppose Q_a is the cumulative time between the hotel and the attraction a and t_c stands for the visiting time of attraction c. The inspired factor of attraction a and c can be counted by the Equation (4).

Summarized by the testing process, the adjustment of desired factor makes great contribution to the optimization. But there are still some problems like unreasonable routes established. This situation can be explained as follows.

The dashed line indicates the general algorithm route: from A to O and then from O to B and C till back to O. And the solid line shows the improved algorithm route: from A to C and O, and then from O to B and O. It has been four hours when reaching point A, which means that there are only two points left. For sake of the time limit, the improved algorithm will let C in, but the distance on roads will increase. Besides, the two choices are same in total days.

Therefore, in such conditions, it is useless to take the improved algorithm. Maybe the optimal solution will be ignored.

4.3. The Adjustment of Searching Ways

According to the defects of inspired factor's adjustment, we can classify the searching ants into two parts. One group searches the solution by general algorithm, and the other by improved algorithm. Thus, we can compare the former one with the latter one in order to find a better one. Also, we can avoid choosing a long route.

For example, as to the case of **Figure 1**, the route taken by the above searching ways is adjusted to the former one instead of the latter choice. Only in this way can we avoid the loss of optimal solution.

4.4. Steps for Solving Model

- Step 1: Assuming the setting problem as a TSP problem, this aims at visiting all the attractions from hotel and back to hotel in the end.
- Step 2: Turn into the Ant Colony Algorithm, setting the inspired factor as the reciprocal of the transfer time, thus getting a route according to the probability.
- Step 3: Single-day TSP route is divided into a multi-day trip. When the day's total travel hours reach the maximum time, return to the hotel. Calculate the number of days and the time spent on roads.
- Step 4: After searching for each route, choose the best route according to the constraint condition. Then repeat step 2.
- Step 5: After getting the best route, optimize the single day's arrangement again.

5. Simulation

5.1. The Simulation of the Algorithm

The data for simulation of the improved Ant Colony Algorithm come from the capital city in China, Beijing. And 100 attractions are chosen, which possess the coordinate, cost and visiting time shown in **Figure 2**.

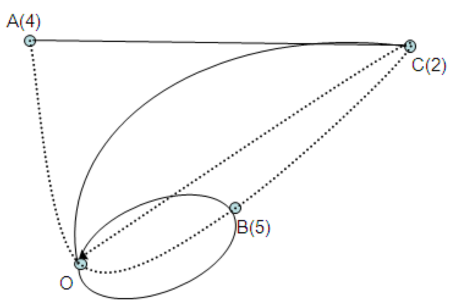

Figure 1. Route explanation.

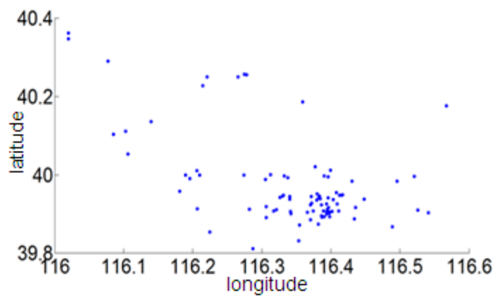

Figure 2. Attractions chosen in Beijing.

After more than 100 testing times, it is found that the improved Max-Min Ant Colony Algorithm roles effectively. And the parameters are set as follows:

Within the process of 300 iteration, the former 200 iteration owns $\alpha = 0.5, \beta = 2$, while the latter 100 owns $\alpha = 2, \beta = 0.5$. And the pheromone residues ρ are 0.3.

Take a number of different attractions as examples to test the algorithm. Such conditions are tested 100 times. Simulate every case and get the number of attractions (NA), the optimization rate (OR), the average reduction of the number of days and the rate (AD), and the maximum reduction of the number of days and the rate (MD). **Table 1** shows the details. Besides, the benefit can be shown in **Figure 3** more directly.

It can be observed that the improved Ant Colony Algorithm can greatly reduce the number of days of the trip, which contribute to the cost reducing. So, the improved algorithm has good features to solve such problems.

5.2. The Simulation of the Real Example

The data for this part come from a travel agency. It shows a traveling route in Beijing for 6 days, which includes 20 attractions shown in **Table 2**.

Solve the case using MATLAB, based on the improved algorithm. And assuming that tourists only have 8 hours to visit attraction each day, we can get the route as follows:

- Day 1: Hotel > Temple of Heaven > Tiananmen Square > Nanluoguxiang>National Art Museum of China > Hotel
- Day 2: Hotel > Winter Palace > Summer Palace > China Millennium Monument > Military Museum > Hotel
- Day 3: Hotel > Great Hall of the People > National Grand Theatre > Forbidden City > Wangfujing > Monument to the People's Heroes>Chairman Mao Memorial Hall > Hotel

Table 1. Indexes of all attractions.

NA	OR	AD	MD
10	37%	1(18.8%)	1(25%)
14	43%	1.1(14.9%)	2(25%)
18	55%	1.1(12.2%)	2(22.2%)
22	70%	1.2(10.7%)	3(23.1%)
26	75%	1.2(9.2%)	3(18.8%)
30	89%	1.4(9.1%)	3(20.0%)
34	94%	1.7(9.8%)	4(19.1%)
38	96%	1.7(9.2%)	4(21.0%)
42	99%	2.0(9.7%)	4(18.1%)
46	100%	2.1(9.2%)	4(16.7%)
50	100%	2.3(9.4%)	4(15.4%)

Table 2. Attractions information (unit: hour).

Attractions	Time	Attractions	Time
Temple of Heaven	2	Forbidden City	2.5
Tiananmen Square	1	Wangfujing	2
Nanluoguxiang	1	Xidan	4
National Art Museum of China	2	Chairman Mao Memorial Hall	1
Winter Palace	2.5	Jingshan Park	0.5
Summer Palace	2.5	National Stadium	0.5
China Millennium Monument	1	National Aquatics Center	0.5
Military Museum	1	The Great Wall	4
Great Hall of the People	0.5	Monument to the People's Heroes	0.5
National Grand Theater	1	Grand View Garden	2.5

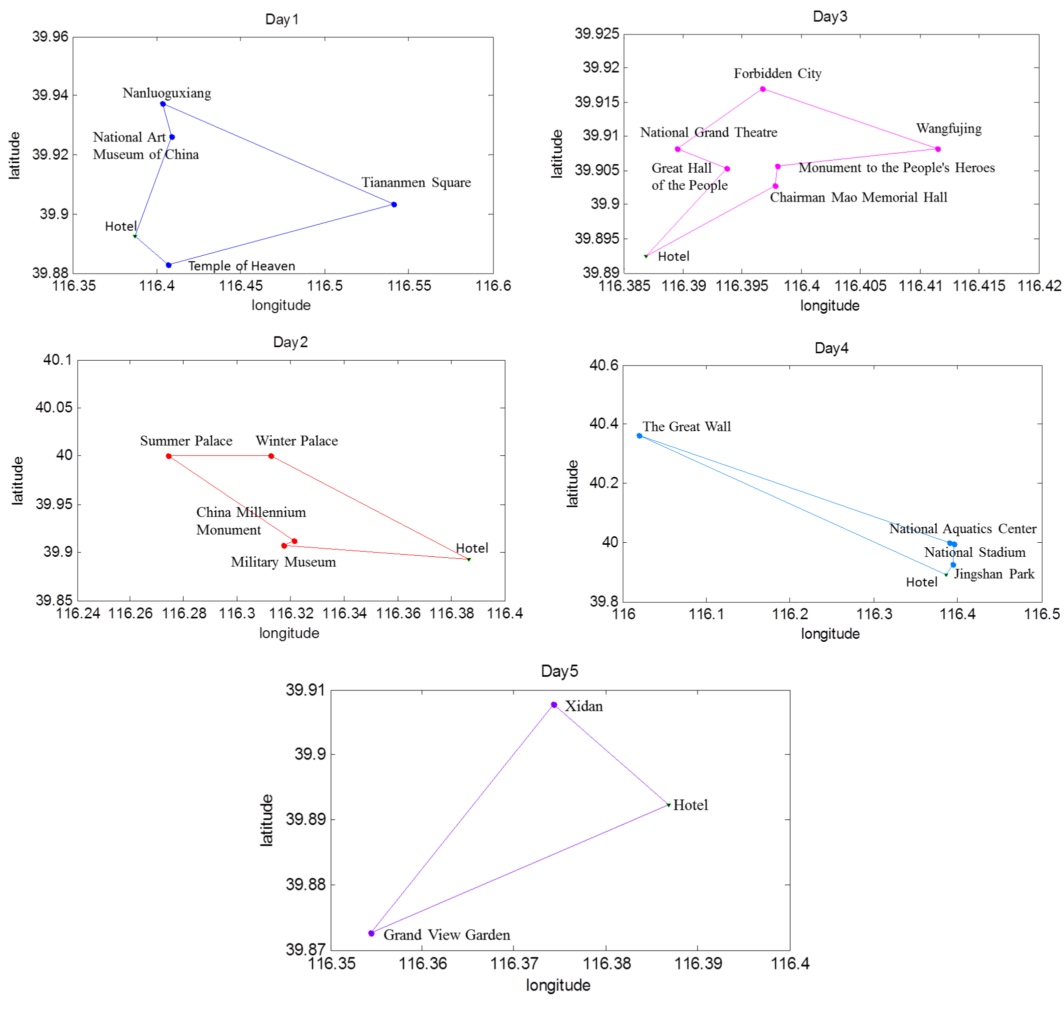

Figure 3.

- Day 4: Hotel > Jingshan Park- > National Stadium > National Aquatics Center > The Great Wall > Hotel
- Day 5: Hotel > Xidan > Grand View Garden > Hotel

Compared with the route provided by the travel agency, the result not only reduces the number of days, but also makes the route more reasonable. Tourists will enjoy themselves in Beijing within the 5 days. And the detailed route pictures are shown in **Figure 3**.

6. Conclusion

The essay shows how to obtain a reasonable traveling route among given attractions. We set an objective optimization model, using the improved Ant Colony Algorithm to simulate as well. The models are simple and can be extended. Even when the number of attractions is huge, the algorithm can still get a good solution in a short time. If other detailed information about attractions can be added into the model, the result may be more useful. This is a new researching direction.

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