Mudanjiang Travel Routing Problem by Simulated Annealing Approach

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Abstract. With the improvement of people's living standards and the increase of rural tourism quality requirements, Mudanjiang snow town tourism has become a popular tourist resort. The travel website provides plenty of information, and tourists can arrange the route according to their own plans. However, most of the tourists on the road trip are out-of-towners who do not know the local routes, which makes it difficult for tourists to develop a tourism planning. Therefore, snow and ice tourism route planning has attracted the attention of scholars. Ice and snow road trip route selection is a typical Traveling Salesman Problem (TSP) problem. In this paper, we propose the Traveling Salesman Problem of ice and snow tourism routes. The main purpose is to provide the maximum number of attractions and travel satisfaction for tourists. The distance between 15 tourist attractions in Mudanjiang selected in the experiment was used as data to establish the Traveling Salesman Problem model. To verify the feasibility and the effectiveness of the model, we use the Simulated Annealing (SA) to solve the model in this paper. The author uses Python software to simulate, and the result shows that the algorithm solves the TSP problem well.

Keywords: TSP problem · Simulated annealing · Satisfactory solution

1 Introduction

With the increase of people's quality of life and the need to get close to nature, it is a popular choice to experience nature and idyllic rural life in fields, gardens, and farms instead of crowding into high-level services in modern tourist destinations. This trend has created a focus on sustainable development within tourism. Agritourism is an alternative tourism experience that demonstrates high potential for the tourism industry while positively impacting agricultural production in rural areas [1, 2]. Some famous tourist attractions such as snow town and Jingpo Lake attract millions of visitors every year, this shows that with the improvement of people's living standards, people's demand for self-driving travel is also increasing. However, there are several problems that need to be solved, such as tourists wanting to visit more scenic spots in the premise that the time in the holiday is limited. Due to the distance between scenic spots, tourists spend most of their time on highways. Therefore, with limited time and energy, quickly planning out

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the best way to visit as many scenic spots as possible has become the most concerned issue for tourists. Moreover, for the economic development of Mudanjiang tourism, the satisfaction of tourists is the fundamental of sustainable development of the scenic spot. With a higher satisfaction rating, Mudanjiang can attract more tourists. If the tourist evaluation score is very low, it will also affect the development of tourism economy in Mudanjiang.

Previous studies have focused on a large number of satisfaction questionnaires. However, the difference is that this paper helps individual users to plan routes, improve travel efficiency and increase tourist satisfaction. We call this type of problem the road trip routing problem (TSP). Route planning for individual users is generally divided into two categories: 1. The purpose of one category is to find an effective route through the selected attractions. 2. Another approach is to select a number of sites to visit and maximize the total score of the sites visited in the limited time available, with the departure and destination specified in advance [3]. The study in this paper belongs to the second category and does not require prior designation of scenic spots.

From a mathematical modeling perspective, our problem can be described as follows. Give a set of points, along with associated scores, and a network of connections. Under this assumption, it is necessary to find a path specifying the maximum total score between the starting point and the ending point at a given time. From the above description, we find that such problems can be attributed to TSP..TSP is very well known as one of the optimization problems of circuit of Hamiltonian, which will seek for the shortest route that must be passed by a number of city salesmen exactly once and will return to the initial city [4]. The genetic algorithm (GA) solves the TSP and, through several genetic operators, can be modified to improve the performance of a particular implementation. These operations include parent selection, crossover, and mutation. Selection is one of the important operations in genetic algorithm [5]. Ant algorithms are a recently developed, population- based approach which has been successfully applied to several TSP combinatorial optimization problems [6].

In this paper, solving TSP for self-driving Tours by using Simulated Annealing conditions, the mathematical models of 15 scenic spots have been established, and the optimal routes of self-driving Tours have been given by simulation. The 15 scenic spots include Hengdaohezi Railway Station, Snow Township, Yangzirong Martyrs Cemetery, Jingpo Lake, etc.

2 Problem Formulation for TSP

2.1 Problem Description

The TSP problems are said to be NP-hard optimization problems, which mean that there is no known polynomial time algorithm that can specifically guarantee the attainment of its optimal solution and that is why heuristic or approximation approaches remain the preferred methods often reommended for solving the TSP problems [7].

Lemma1: Let it be a connected undirected graph $G = (V, E)$:

A path that passes through each vertex of G exactly once is called a Hamiltonian path of G, or H path for short.

The circle that passes through each vertex $G = (V, E)$ of G exactly once is called G is Hamiltonian circle, or H circle for short.

The graph containing H cycle is called Hamiltonian graph, H graph for short.

Lemma2: In the weighted graph .

The H circle with the least weight is called the optimal H circle.

The least weighted closed path that passes through each vertex at least once is called the best salesman loop.

Theorem1: In a weighted graph $G = (V, E)$, if I take any $x, y, z \in V, z \neq x, z \neq y$, both have $w(x, y) \leq w(x, z) + w(y, z)$, then the best H circle of graph G is also the best salesman loop. The best salesman loop problem can be transformed into the best H loop problem. The method is to construct a complete graph $G = (V, E)$ with V as a set of fixed points from a given graph $G' = \left(V, E'\right)$. The weight of each edge E' of (x, y) is equal to the weight of the shortest vertex x and y in the graph.$w(x, y) = \min d_G(x, y), \forall x, y \in E'$.

Theorem2: The weight of each edge E' of (x, y) is equal to the weight of the shortest vertex x. The weight of the best salesman loop of a weighted graph G is the same as the weight of the best H loop of G'. Therefore, the problem of finding the best salesman loop in a weighted graph can be transformed into the problem of finding the best H loop in a complete weighted graph, which is called TSP.

There are already n tourist attractions, each of which is interconnected, and the distance between the attractions is known. Tourists have fixed starting points and can only pass through each place once. Finally, they return to the starting point to get the optimal route to make the total distance they have experienced the shortest. The mathematical expectation model [8] is defined as follows

$$\min D = \sum_{i=1}^{n} \sum_{j=1}^{n} d_{i,j} x_{i,j} \tag{1}$$

$$s.t. \sum_{j=1}^{n} x_{i,j} = 1, (i = 1, 2, \cdots, n) \tag{2}$$

$$\sum_{i=1}^{n} x_{i,j} = 1, (j = 1, 2, \cdots, n) \tag{3}$$

$$\sum_{i,j \in S} x_{i,j} \leq R - 1, 2 \leq |R| \leq n - 2, R \subset \{1, 2, \cdots, n\} \tag{4}$$

$$x_{i,j} \in \{0, 1\}, (i, j = 1, 2, \cdots, n) \tag{5}$$

In the above model, $d_{i,j}$ in formula (1) represents the weight from the scenic spots i to j; Constraints (2) and (3) respectively require that the scenic spots i and the scenic spots j once, and (4) require that the participants do not form a loop in any true subset of the scenic spots. (5) represents the value of decision variable.

3 Simulated Annealing Algorithm

Simulated annealing algorithm is a famous method which is designed based on Monte Carlo [9] idea and used to approximate solve optimization problems. The basic idea of this algorithm is to search for the optimal solution by simulating the physical annealing process [10]. Thermodynamic, annealing is a process of gradual cooling of an object. The physical phenomenon of when the temperature of the object is low, the energy state of the object will also be low. If the temperature is low enough, the object will gradually condense and crystallize. According to thermodynamic knowledge, when an object is in a state of crystallization, the energy state of the object is in an equilibrium state of minimum energy. When the object is cooled slowly, the object can reach the lowest energy state, that is, the crystal state, but when the cooling process is too fast, the object will be in the non-minimum energy non-crystalline state. The process of physical annealing is as follows: for a substance in an amorphous state body, the first object will be heated to a sufficiently high temperature, at this time the object particles will become disordered as the temperature rises, while the internal energy increases, and then the object slowly cooling, that is, the annealing, the object particles gradually become ordered, so that it reaches equilibrium at each temperature, then finally in the threshold temperature, the object reaches the particle arrangement of the lowest internal energy crystal state.

The basic steps of algorithm implementation are as follows:

Select the initial temperature, Markov attenuation function, end temperature, beginning To begin the solution, provide the constructor of the solution neighborhood.

At each temperature, starting from the previous solution, by adding the machine perturbation mechanism generates the solution neighborhood of the original solution. The text should be set to single line spacing.

Whether the new solution is accepted or not is determined by the acceptance function, the acceptance function, The number of the main parameter temperature is formed by accepting the new solution to a certain length Markov chain.

According to the attenuation function, with the decrease of temperature, accept the new solution. The probability also goes down, when the temperature goes down to the lowest temperature, the solution is stable. Determine the optimal state of the optimization problem.

4 Experiments

In the experiment, we take Mudanjiang scenic spot as an example. Firstly, we take 15 scenic spots as examples to verify the effectiveness of the model and algorithm. Second, in order to improve the stability of the model and algorithm, we adjusted the cooling rate and obtained the optimal model through comparison.

Firstly, 15 scenic spots were selected as test objects to verify the correctness and effectiveness of the proposed model and algorithm. In the attraction network, 0 represents the starting point and the ending point, and the rest is the attraction. For this problem, we focus on a tourist leaving the departure point, visiting the site, and then leaving the departure point. The purpose is to improve the utilization rate of scenic spots. Table 1 lists the shortest road trip distance between any two attractions, measured in kilometers.

As can be seen from Table 2 and Table 3, in the experiment, the faster the cooling rate is obtained by using the cooling rate 0.2 and the cooling rate 0.8. The shorter the path distance is given in finite time. Table 3 is a simulation of 15 TSP using SA when cooling rate is 0.8. Figure 1 the result of 15 TSP using SA.

Table 1. Shortest road trip (Location data from a map of Baidu).

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0	0	124.5	97.3	26.6	58.3	180.2	25.1	91.5	71.1	16.7	160.9	146.5	214.8	134.9	34.2
1	124.5	0	175.9	145.4	189.8	300.3	157.4	214.8	199.4	134.1	188.2	249.6	238.3	144.3	157.5
2	97.3	175.9	0	75.2	166.6	319.6	134	191.4	171	107.8	240.7	226.2	291	214.6	134.1
3	26.6	145.4	75.2	0	76.8	230	44.4	121.7	101.3	42.4	182.1	167.7	232.3	156	64.4
4	58.3	189.8	166.6	76.8	0	160.2	43.2	138.4	118	77	217.3	202.9	267.5	191.3	81.2
5	180.2	300.3	319.6	230	160.2	0	65.2	61.5	71.8	96	247.2	205.4	297.4	221.2	66.3
6	25.1	157.4	134	44.4	43.2	65.2	0	105	84.6	40.9	183.9	169.5	234.1	157.8	27
7	91.5	214.8	191.4	121.7	138.4	61.5	105	0	26.3	101.8	242.3	227.9	292.5	216.2	63.4
8	71.1	199.4	171	101.3	118	71.8	84.6	26.3	0	81.3	221.9	207.4	272	195.8	43
9	16.7	134.1	107.8	42.4	77	96	40.9	101.8	81.3	0	170.8	156.3	224.6	144.7	43.1
10	160.9	188.2	240.7	182.1	217.3	247.2	193.9	242.3	221.9	170.8	0	184.7	75.1	33.2	184.8
11	146.5	249.6	226.2	167.7	202.9	205.4	169.5	227.9	207.4	156.3	184.7	0	234.1	157.8	170.5
12	214.8	238.3	291	232.3	267.5	297.4	234.1	292.5	272	224.6	75.1	234.1	0	83.5	235.1
13	134.9	144.3	214.6	156	191.3	221.2	157.8	216.2	195.8	144.7	33.2	157.8	83.5	0	159.3
14	34.2	157.5	134.1	64.4	81.2	66.3	27	63.4	43	43.1	184.8	170.5	235.1	159.3	0

Table 2. Cooling rate = 0.2 (The result of a Python operation).

Initial route:	[14, 8, 11, 10, 3, 4, 13, 12, 9, 7, 15, 5, 1, 2, 6]
Initial total distance:	2383.2
End temperature:	0.00020480000000000001
Optimum route:	[11, 14, 2, 10, 6, 7, 5, 4, 3, 1, 15, 8, 9, 12, 13]
Optimum distance:	1405.7999999999997

Table 3. Cooling rate = 0.8 (The result of a Python operation).

Initial route:	[5, 13, 3, 6, 14, 7, 11, 9, 4, 10, 1, 2, 8, 12, 15]
Initial total distance:	2642.2
End temperature:	0.000803469022129498
Optimum route:	[9, 8, 6, 7, 5, 1, 4, 3, 2, 14, 11, 13, 12, 10, 15]
Optimum distance:	1261.3

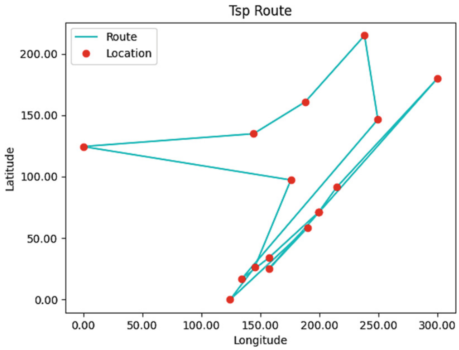

Fig. 1. Shortest road trip distance between any two attractions (Figure is from Python).

5 Conclusion

TSP problem has wide application prospect and scientific research value. Annealing is also an important means to solve these problems. In the actual experiment, the stable optimal solution can be obtained by adjusting the value of the change rate. Less experimental data can be further verified by adding scenic spots in the future. In the future, we can further explore and optimize the initial solution to achieve better experimental results.

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