An intelligent diversion method for tourists in scenic spots based on behavioral characteristics

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Abstract. This paper focused on the problem of time-space diversion and navigation of tourists in scenic spots. Through the analysis and research on the three major behavior characteristics of tourists in scenic spots, namely, the characteristics of recreation direction, the characteristics of recreation speed and the characteristics of recreation time, a method of real-time diversion with minimum cost is proposed, and an intelligent diversion model based on "behavior characteristics" is constructed Guilin Qixing scenic spot is used as an example for analysis and test. The test results show that the intelligent diversion model can effectively guide tourists to the scenic spots with the shortest waiting time and solve the problem of uneven load on each scenic spot. Through the scientific diversion design in time and space, it can not only improve the satisfaction of tourists, but also help the scenic spot personnel to grasp the use of resources in the scenic spot at any time, improve the quality of normalized management of scenic spots, and provide a theoretical and practical basis for the further development of smart Tourism in major scenic spots.

1. Introduction
At present, with the rapid development of tourism, tourists have proliferated, especially in the peak tourist season, some hot spots have strong capacity big, crowded degree, high load rate, and some of the less popular scenic spots appear fewer visitors, the attractions of low load situation, cause tourist scenic spot in each scenic spot uneven distribution, influence the tourists to the mood, increase the difficulty that the scenic area management[1]. Therefore, it is particularly important to establish a set of scientific tourist diversion scheme to realize the real-time balance of tourists in the scenic spots[2]. To solve this problem, there have been some experts have done the corresponding research, such as the high anaerobic Igawa to Jiuzhaigou load are studied, the problem of mathematical programming model is established and the dynamic prediction scheduling problems provides two analysis methods, such as tian-xiang zheng for theme park visitors space-time distribution navigation problems are studied, built a model based on load balancing of tourists navigation bypass[3]. Even so, there is still no analysis of the behavior of the tourists in the scenic spot and to study the distribution method, to bypass method to establish scientific evaluation system, so this article based on the analysis of the scenic area tourist behavior, puts forward a kind of tourists intelligent shunting method based on the "behavior", and to evaluate its methods[4].
2. Analysis on the behavior characteristics of tourists in scenic spots
The behavior characteristics of tourists in the scenic spot are very complex, and the whole tour flow process is shown in Figure 1. By analyzing the behavior characteristics of tourists in the scenic spot, such as recreation direction, recreation speed and recreation time, the activity situation of tourists in the scenic spot can be mastered.

![Figure 1. Tourist flow process](image)

2.1. Characteristics of tourist recreation directions in the scenic area
After arriving at any scenic spot, tourists have to decide the direction to move next[5]. The direction decision of tourists is related to the attributes of the next accessible scenic spot, such as state, attraction, etc., as well as some attributes of scenic spots, such as season and time; Visitors can make decisions based on predefined decision rules related to the properties of the current scenic spot and accessible stopping points. For the collected data of a given research target (the data quality reaches the specified index), the selection probability of the visitor's stopping point b directly connected to it (without passing through other connecting points and stopping points) is $P_a^b$ as follows:

$$P_a^b = \sum_{i=1}^{num_i} \sum_{j=1}^{num_j} (i = 1, ..., n)$$

In the formula, $num_i$ represents the i number of tourists of the observed team, $num_j$ represents the i number of tourists of the second observed team who choose the next stop point at the connecting point.

2.2. Characteristics of leisure speed in scenic spots
The speed of tourists is influenced by the attractions, service facilities, number of tourists and the physiological rhythm of tourists[6]. The number of tourists in different scenic spots usually shows their own rules or rhythm in a day, and they may visit at different speeds in different periods. Therefore, the recreational speed of tourists in different scenic spots should be determined dynamically based on this. For the collected data of a given research objective (the data quality reaches the specified index), the recreation speed is calculated according to the following formula:

$$V_{pi} = \frac{D(x, y)}{\sum_{k=1}^{m} f(x_k, y_k)}$$

Where, $i$ refers to the period when tourists have a rest at the same speed. The tourist's rest time in the scenic area is divided into $n$ such periods. $D(x, y)$ represents the recreation distance between the stopping points.
\( x \) and \( y; \quad t_{k(x,y)} \) represents the recreation time of the observed value \( k \) between the stopping points \( a \) and \( b; \)
m Represents the total number of observed samples.

2.3. Characteristics of leisure time in scenic spots

The sightseeing time of tourists \( t_{i} \) in the scenic area mainly includes the time of visiting scenic spots \( t_{i0} \) and the walking time \( t_{i1} \) between scenic spots, that is \( t_{i} = t_{i0} + t_{i1} \), the walking time between scenic spots is affected by the distance \( l_{i} \) between scenic spots and the walking speed \( v_{i} \) of tourists, which can be expressed as \( t_{i1} = l_{i}/v_{i} \). The overall leisure time of tourists in the scenic area can be expressed as shown in Figure 2.

![Figure 2. Analysis diagram of tourist's leisure time in the scenic spot](image)

3. Intelligent triage model construction method based on "behavior characteristics"

For any scenic spot, the load is the ratio of the current number of visitors to the capacity of the scenic spot. The increase in the load of the scenic spot will promote the diversion rate of tourists and inhibit the confluence rate of tourists to the current scenic spot. The diversion rate of the current scenic spot depends on the load potential of the current scenic spot and its downstream scenic spot. The higher the load potential, the higher the tourist diversion rate of the current scenic spot will be, which will lead to the increase of the load of the downstream scenic spot, the decrease of the number of tourists staying at the current scenic spot, and the decrease of the load potential and the diversion rate. Similarly, the confluence rate of tourists at the current scenic spot depends on the load potential of the upstream scenic spot and the current scenic spot. In the upstream scenic spots, if the tourists stay for a long time, the number of tourists will continue to increase, further increasing the invalid stay time of tourists, forming a vicious circle until congestion. As shown in Figure 3, the relationship between influencing factors of diversion of scenic spots is described in detail.

![Figure 3. Logical relation diagram of each influencing factor of scenic spot triage](image)

3.1. Calculation of tourist carrying capacity based on behavioral characteristics

A scenic tourist carrying capacity refers to the utmost to accommodate the ability of tourists, scenic spots at different time points in one day is not the same bearing capacity, bearing capacity are also
different in different seasons scenic spot, and assume a traveling scenic area, its internal spots distributed evenly, there are multiple entrances, tourists in the scenic spot without order, irregular walk, there are:

\[ D_s = S / d \]  
\[ D_a = D_s \times (T / t) \]

Where, \( D_s \) is instantaneous passenger flow capacity (unit: person); \( D_a \) is daily passenger flow capacity (person); \( S \) is the sightseeing area of the scenic spot; \( d \) is the best density of tourist activities (\( m^2 \)/person); \( t \) is the average time (hours or minutes) required for a tourist to visit; \( T \) is for the daily opening hours (hours or minutes) of the scenic spot.

Scenic spots are usually composed of several functional sub-scenic spots, and each scenic spot contains its own scenic spots. In the calculation of the overall resource space carrying capacity of scenic spots, due to the mobility of tourists, it is usually impossible to make a simple sum treatment. Therefore, the resource space carrying capacity of scenic spots can be summarized as:

- **Instantaneous capacity value:**
  \[ R = \sum_{i=1}^{n} (D_{mi} \times T) / t \]

- **Daily capacity value:**
  \[ Rd = \min \left( \frac{D_{m1}}{X_1}, \frac{D_{m2}}{X_2}, ..., \frac{D_{mn}}{X_n} \right) \]

3.2. Intelligent spatial and temporal diversion model for tourists in the scenic spot

In the peak period of tourism, some scenic spots in the scenic area have too many tourists gathering, and some scenic spots are neglected, leading to the different spatial distribution of passenger flow in the scenic area in different periods. When this period is reduced to a point (moment), the spatial distribution still exists. Ideally, if the load of each scenic spot is balanced at any time \( t \), then it can be considered that the load of each scenic spot is balanced in the whole period consisting of several consecutive moments \( T \). The problem is transformed into a model to make the load of all scenic spots in the best balance state at a time.

Mark A as scenic spots; B as Tourists set; C as Vehicle set; \( n \) as Number of scenic spots; \( c_j \) as Capacity of scenic spots; \( x_j \) as The capacity of scenic spots; \( t_j \) as the length of stay at the scenic spot \( j \); \( S_{jh} \) as the distance between Scenic spots \( j \) and \( h \); \( l_{kh} \) as The distance between the vehicle and the scenic spot; \( p_{jh} \) as the probability of tourists choosing the next scenic spot \( h \) in the scenic spot \( j \); \( r_{ij} \) as the probability that tourists \( i \) choose to take a bus in scenic spots \( j \); \( t_i \) as the moment when visitors \( i \) enter the scenic spot \( j \); \( v \) as the speed of the car. At time, define variables:

\[ x_{ij} = \begin{cases} 1, & \text{Tourists } i \text{ are located in scenic spots } j \\ 0, & \text{NO} \end{cases} \]

\[ y_{ijk} = \begin{cases} 1, & \text{Vehicles } k \text{ transport tourists to } hj \text{ from the scenic spot } j \\ 0, & \text{NO} \end{cases} \]

\[ q_{ij} = \begin{cases} 1, & \text{The tourist } i \text{ has completed the tour in scenic spot } j \\ 0, & \text{NO} \end{cases} \]

The mathematical model of time-space diversion of tourists in the scenic spot can be expressed as follows:

\[ z = \min \frac{1}{n-1} \sum_{j=1}^{n} (R_j - \bar{R})^2 \]
\[ R = \frac{1}{n} \sum_{j=1}^{n} R_j \ s.t \]  
\[ R_j = \frac{\sum_{a \in A} X_{ja}}{c_j} \ (0 \leq R_j \leq 1; \ j = 1, 2, \ldots, n) \]  
\[ \sum_{j=1}^{n} \sum_{h=1}^{H} X_{jh} \leq 1 (h \neq j) \]  
\[ 0 \leq p_h \leq 1 \]  
\[ 0 \leq r_j \leq 1 \]  

Where, formula (5) indicates that the variance of minimizing the load of each scenic spot is selected as the objective function; Equation (6) is the average load of each scenic spot; Equation (7) is the load of scenic spot J; Formula (8) indicates that a car can only drive one route at most in a certain shunt scheduling; Equations (9) and (10) represent the probability of tourists' choice.

3.3. Evaluation method of tourist diversion in the scenic spot

The capacity of tourists in the scenic spot is used to scientifically represent the capacity of tourists in both time and space. It can be expressed through the capacity of each scenic spot in the scenic spot. Its mathematical model can be expressed as follows:

\[ D_j = \frac{S_j \times T}{S_j \times T} \ (i = 1, 2, \ldots, n) \]

Where, \( D_j \) represents the tourist capacity of the number \( i \) scenic spot, \( S_j \) represents the area of the number \( i \) scenic spot, \( T \) represents the opening time of the tourist area every day.

By establishing the tourist intelligent diversion model based on "behavior characteristics", the scheduling effect evaluation can modify the time-space navigation scheduling model with real-time feedback in the short time domain, so as to realize the closed-loop control of tourists, vehicles and other motion behaviors in scenic spots, and reflect the quality of the diversion effect by establishing the tourist intelligent space-time diversion effect evaluation method.

Suppose that a certain scenic spot \( h \) that needs to be scheduled at the time \( t \), its upstream scenic spot is \( h - e (e = 1, 2, \ldots, E) \), and its downstream scenic spot is \( h + d (d = 1, 2, \ldots, D) \), and assume that the upstream and downstream scenic spot itself does not produce scheduling, and only accepts scheduling. The number of tourists from the scenic spot \( j \) to the scenic spot \( h \) on foot is defined as \( Q_{jh} \), then, \( Q_h = \sum_{j \in E} Q_{jh}(1 - r_j) h \), the number of tourists from the scenic spot \( h \) to the scenic spot \( j \) by invoking vehicles \( k \) is \( M_{hj} \). Generate schedules, so that each scenic spot at the next moment \( t' = t + \Delta t \) (among them \( \Delta t = \max \{(I_h + S_h)/v\}) \), satisfy:

\[ R'_{h} = \frac{X_h + Q_{h}(h - e) - Q_{h}(h + d) - M_{hj}}{C_h} < R_h \]

\[ R'_{h-e} = \frac{X_h - e + Q_{h-e}(h - e) - e - c(k + h - e)}{C_h} \leq 1 \]

\[ R'_{h+d} = \frac{X_h + d + Q_{h+d}(h + d) - e - c(k + h + d)}{C_h} \leq 1 \]

Where, \( R'_h \) is the load value after bottleneck scenic spot \( h \) scheduling, \( R'_{h-e} \) is the load value after any downstream scenic spot \( h \) scheduling, and \( R'_{h+d} \) is the load value after any upstream scenic spot \( h \) scheduling. The optimal scheduling scheme \( z^* \) can be obtained by substituting the load value of each scenic spot \( R'_{h-e}, R'_h \) and \( R'_{h+d} \) generated by each scheduling scheme into the objective function.
\[ z = \min \frac{1}{n-1} \sum_{j=1}^{n} (R_j - \overline{R})^2 \], and \( z^* \) the corresponding scheduling scheme is the optimal scheduling scheme at the moment \( t \).

4. Intelligent diversion simulation of tourists in guilin seven star scenic spot

Located in The Qixing District of Guilin city, Qixing Scenic Spot is a national 4A scenic spot and the largest comprehensive scenic spot in Guilin. Qixing Scenic Spot is the epitome of Guilin landscape culture. The number of tourists coming to Qixing Scenic Spot is endless every year, especially during the peak period, which is more than the maximum limit that the scenic spot can bear. This seriously affects the ecology and environment of Qixing scenic spot, hinders the sustainable development of the scenic spot, and affects the tourists' mood and damages the image of the scenic spot. Therefore, when the number of tourists exceeds its maximum carrying capacity, it is particularly important to make a scientific diversion plan.

As shown in Figure 4, the number of tourists in the Seven Star scenic area varies greatly with the seasons. The number of tourists in April, May, July, August and October is relatively large. Most of the tourists are more than 100000, and the maximum number is nearly 400000. December and January are off-season, and the number of tourists is generally around 100000, and the rest of the month is the normal season. Take 2016 as an example, the total number of visitors in April, May, July, August and October reached about 1 million, accounting for 65.8% of the whole year. October was the largest tourist with more than 200000 people. In the off-season, the number of tourists in January is less than 100000, and the total number in December and January is only 120000.

**Figure 4.** Changes in the number of tourists in Guilin Seven Star Scenic Spot from 2016 to 2018

During the peak period of May Day and 11th class tourism, the number of tourists exceeded the maximum strength that the scenic spot could carry, that is, the space-time load of the scenic spot exceeded. Qixingyan, Camel's Peak, Huaxia Light and other scenic spots in Qixing Scenic Spot concentrate 80% of tourists, but some scenic spots are very unpopular, almost nobody pays attention to them, leading to the extremely unbalanced distribution of tourists within the scenic spot. As shown in Figure 5, the space-time load of all scenic spots in Qixing Scenic Spot during October 1, 2018, is as follows:
Figure 5. Time and space load of tourists in seven stars scenic spot of Guilin during the 11th year of 2018

The first "arrival" event (random event) is generated and marked by the time the event occurred, which is inserted into the minimum heap. Do the following loop until the minimum heap is empty: if the top heap event takes place at the current time T, the top heap event pops up.

1) If it is an "arrival" event:
   The current scenic spot is recorded and set as A, which USES the above "real-time scheduling algorithm based on the minimum cost strategy" to calculate the scenic spot with the shortest waiting time and set as B. Generate "to play" events, where event occurrence time = current time T + walking time Twalk(from A to B); Generates the next "arrival" event, where the event occurs at a random time.

2) If it is a "play date" event (the tourist has just arrived at the scenic spot or is queuing to enter):
   If the scenic spot facilities are free at present, the tourist can enter the tour. At this time, the tourist's waiting time Twait is set to 0. Otherwise, waiting time Twait = tf - current time T + Tp* number of queue/load of scenic spot; Set the finished play time = Tp + Twait; Generate "completed play" event, where event occurrence time = completed play time;

3) If it is a "completed tour" event:
   Tf: If no tourists are waiting, it will be set as free; Otherwise, it is set as current time T + Tp for scenic spots; Record the current position, set as A; The "real-time scheduling algorithm based on the minimum cost strategy" above is used to calculate the scenic spot with the fastest playable time (the shortest waiting time), set as B; Generate the "play to be played" event, where event occurrence time = current time T + walking time Twalk(from A to B).

The simulation results show that this method can solve the load problem of each scenic spot and make the passenger flow of each scenic spot more balanced.

5. Conclusion
Aiming at the current problems of tourists overload and ineffective regulation measures of tourists' spatial and temporal distribution in scenic spots in China, this paper starts with the leisure behavior characteristics of tourists in scenic spots, analyzes the spatio-temporal relationship of the behavior characteristics, and builds a spatio-temporal diversion model. Finally, it takes Seven Star scenic spots as an example to conduct simulation research. The research shows that the model has practical significance for the analysis of tourists' spatial and temporal distribution and can provide a useful method and tool for tourists' management in scenic spots. Further research work will focus on the further refinement of the model, a more comprehensive calibration method and the collection of a large number of sample data in different categories of scenic spots.

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