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Independent travel recommendation algorithm based on analytical hierarchy process and simulated annealing for professional tourist

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Abstract Independent travelers, especially professional independent travelers, tend to plan their trip schedules according to their interests, preferred hotels, landmarks they wish to visit, budgets, time availability and various other factors. Hence, travel schedule planning is valuable for satisfying the unique needs of each traveler. In this paper, we propose an algorithm for independent travel recommendation, consisting of three steps. Firstly, landmarks in the destination are selected under the specific constraints, which is modeled as a 0-1 knapsack problem. Then, the landmarks will be evaluated comprehensively using AHP (Analytic Hierarchy Process) model, and the greedy simulated annealing algorithm is adopted to select the best landmarks with high evaluation scores. Next, with AHP-decision model, a most reasonable free line to the tourist destination is selected from multiple candidates. Lastly, the path planning among the landmarks is abstracted as a TSP (Travelling Sales Problem) problem, and the simulated annealing algorithm based on roulette wheel selection is adopted to solve it. Through simulation experiments, by comparing with package tour from the aspects of landmark selection, valid sightseeing time ratio, valid sightseeing consumption ratio and the tourist satisfaction, the proposed algorithm is evaluated and analyzed. Simulation results illustrate the feasibility and rationality of our approach, which can be used as an effective reference deciding individualized travel schedules and trip planning.

Keywords Independent travel · TSP(Traveling Sales Problem) · Simulated annealing · AHP(Analytic Hierarchy Process)

1 Introduction

With the economic development and the improvement of people's lives, independent travel attracts more and more tourists of all ages due to the flexibility and other customization requirements compared with group tours [1]. In package tours, tourists prepay the payments to travel agencies and accept a variety of related services provided under constraints. In independent travel, independent decision-making and better experience can help enhance happiness during the travelling process. Also, independent travel is closer to nature and more relaxing compared to package tours. Usually, package tours do not satisfy the demands of favorite landmarks and trip routes of many travelers, but their budgets might be insufficient for planning independent travel. Under such conditions [2], these tourists often hope to obtain more convenience and freedom with a lower budget. Thus, it is necessary to develop methods for independent travel recommendations and trip planning that can satisfy the tourists' demands to the maximum extent.

In some developing countries (e.g. China), independent travel is still immature, and many problems exist. For example, independent travelers may not be familiar with the conditions of the destination, may accidentally neglect certain

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details to their travel plans or may find it difficult to collect sufficient information for the landmarks at the destination [3].This may lead to situations where the travelers hardly understand the local conditions, local customs, landmarks and transportation modes of the destination [4]. However, it is time and labor-intensive at present to search for massive information through the search engine. Thus, to plan customized routes for the travelers, the majority of tourists can only refer to the route design of existing package tour plans, or from the experience-sharing posts of other independent travelers on different websites [5]. The experience is usually shared through pictures and words, which can only provide users with information about the visiting order of landmarks, without flexibility and customization. For the general independent tourists, they tend to choose mature tourist landmarks as destinations on the tourism peak period. However, the professional independent tourists pursue more freedom, such as some newly developed landmarks. In this paper, the independent travel recommendation algorithm is mainly targeted at the professional travelers.

With the current development of embedded technology, the maturity of mobile GIS (geographic information system) and GPS (Global Positioning System) positioning technology, more and more independent tourists experience the convenience brought by precise geographical location services, but the stability of the system cannot be guaranteed. Therefore, it is of great significance to study the recommendation algorithm of customized travel routes, based on the individual demands of professional travelers. It is important to address how to plan the optimal path for travelers to arrive at their destinations, making it possible for them to visit all their target landmarks and thus satisfying their needs as much as possible.

The remainder of this article is organized as follows. Section 2 provides the related work of independent travel schedule algorithm. Section 3 elaborates the detail analysis of independent travel schedule recommendation algorithm targeting at the problem. In Section 4, the experimental simulation results of feasibility and rationality of our approach are presented and analyzed. Section 5 concludes the whole paper and discusses about future work.

2 Related work

There has been some preliminary research about trip planning for travelers. Yi [6] proposed a personal travel route planning system based on genetic algorithm, which can give the scheduled order of landmarks. However, their algorithm was only applicable for one particular city – Hangzhou, and was unable to provide the freedom to choose the destination city. Thus the feasibility of the algorithm was limited. Zhang [7] implemented a mobile trip planning system on the IOS platform, that could facilitate the tourists to edit their trip plan in real time, but the edited plan in the system is not analyzed and processed. Therefore, it could not guarantee that the final tour route is the optimal one. Some researchers [8] adopted the genetic algorithm to plan the trips for independent travelers, but the algorithm is inefficient and unable to provide real-time planning services. Moreover, some scholars [9] adopted the improved ant colony algorithm to conduct the research of trip planning, but the accuracy of the algorithm is not good enough to get the global optimal solution. Li [10] implemented the independent travel planning system on PC, which indeed attracts a certain number of users, but the system does not provide personalized and customized service, and is unable to quickly offer corresponding independent travel services, lacking autonomy and flexibility. Some scholars [11] have combined domain reduction with genetic algorithm and simulating annealing to plan the tour route. It improved the accuracy of SA and GA and also minimized the searching process iterations for the large size instances. However, the implementation of the algorithm is too complex for travelers to understand and use. Maeda et al. [12] used merely the Analytic Hierarchy Process to evaluate the independent travel, but in decision model, the weight derived from the decision modal cannot evaluate the tour route comprehensively and the computation time is not optimal. In [13], a tourism information composition optimization algorithm based on context of travelers and ant colony algorithm is proposed, which is able to satisfy the customized demands of independent travelers. But it still has some problems, such as, the raw data of context of travelers in algorithm is not accurate; the system just design at the ant colony algorithm and more heuristic algorithm should be combined; the corresponding combinatorial optimization algorithm is not designed to the dynamic change of the independent travel. Wang et al. [14] implements the personal tour planning engine based on genetic algorithm according to independent travelers' tour requirements. However, the engine does not offer the method to reach the tourist destination. Therefore, the planning engine only offers the personal tour planning in nearby cities and is unable to satisfy the customized demand of landmarks from the source.

The above research results are closely related to the theoretical research of the independent travel. In this paper, we propose an independent travel recommendation algorithm based on AHP and simulated annealing. The algorithm can not only satisfy the individual and specific demands of independent travelers, but can also can solve a series of problems they might meet without the aid of package tours [15]. In order to help professional travelers enjoy the customization of the trip planning services, the independent travel recommendation algorithm for different destinations is also designed and implemented in the paper.

3 Route planning process

Here, the independent travel route planning process is divided into three steps. Firstly, professional independent tourists determine list of possible landmarks as the initial input. The list of landmarks is selected by greedy simulated annealing under all constraints. The next step is that professional tourist choose an optimal travel path from origin to destination from among various candidates. The last step is to decide the sightseeing order of the chosen landmarks according to the travelers' individual demands. The entire diagram of the algorithm is shown in Fig. 1.

3.1 Landmark selection

In the independent travel, the selection of landmarks greatly affects the travel experience of professional travelers. And it is necessary to visit the maximum number of landmarks they are interested in under various constraints, such as time, budget and so on. Algorithm requires travelers to provide the list of all possible landmarks, then the greedy simulated annealing algorithm is adopted to solve the problems under time and budget constraints. The sightseeing time and the weights of *i-th* landmark are denoted as t_i and f_i respectively, and the total time limit of visiting all the landmarks is denoted as T. In the model, the weights of the landmarks were graded by the AHP decision model [16]. Denote x_i as the 0-1 decision variable, as follows:

$$x_i = \begin{cases} 1, & i-th\ landmark\ is\ selected \\ 0, & otherwise \end{cases} \quad (1)$$

Then, the problem can be formulated as follows:

$$max \sum_{i=1}^{n} f_i x_i, \qquad x_i \in \{0, 1\} \quad (2)$$

$$s.t. \sum_{i=1}^{n} t_i x_i \le T \quad (3)$$

As it can be observed, this is a 0-1 knapsack problem, which is an NP hard problem. Hereafter, the greedy simulated annealing algorithm is adopted to solve the problem in order to select proper landmarks.

3.1.1 Evaluating the landmarks

Here, we use AHP to compare different landmarks quantitatively. The numerical transformation method in the Analytic Hierarchy Process is based on the comparison of different $C = \{C_1, C_2, ..., C_n\}$, where C_i represents the various attributes in the guideline layers [17], and the matrix generated is shown below.

$$\begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{12}^{-1} & 1 & \dots & a_{2n} \\ \vdots & & \ddots & \vdots \\ a_{1n}^{-1} & a_{2n}^{-1} & \dots & 1 \end{bmatrix} \quad (4)$$

Here, a_{ij} represents the comparison importance value of index i over index j, in the ranges from 1 to 9. The value of 9 means that index i is extremely important compared to

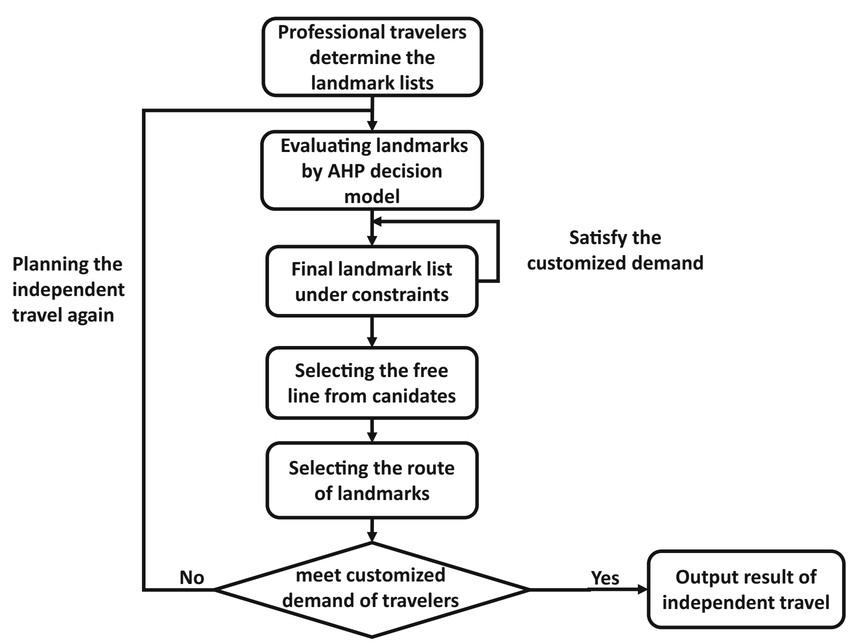


Fig. 1 Holistic diagram

Table 1 Definition of importance values in the comparison matrix

Intensity of importance	Definition
1–2	Equally important
3–4	Moderately
5–6	Strongly
7–8	Very
9	Extremely

index j, while the value of 1 means that index i is equally important compared to index j. The detailed information is shown in Table 1.

The selection of landmarks is determined based on the combination of various factors, including prices, time limit, natural scenery and humanistic resources to make decisions [18]. Lists of landmarks are selected as various kinds of schemes in the scheme layer. Then the landmarks are sorted according to the weights, and the necessity of each spot is quantified in the itinerary. The selection of the AHP factors is shown in Fig. 2.

Then the consistency must be examined. The results are accepted only if $CR_{max} \leq 0.1$. The detailed settings of weight factors at each layer for landmarks are shown in Table 2.

3.1.2 Validating the landmark selection candidates

In the simulated annealing algorithm, the initial randomly-generated candidates can be classified into two categories: valid solutions and invalid solutions.

In a valid scheme, the total time of visiting all landmarks might be quite less than the time T expected, which may lead to poor travel experience due to too much time wasted. Therefore, some additional landmarks should be added into such schemes. The modifying process is as follow: 1) sort the landmarks out of the current scheme in descending order, according to the comprehensive scores from AHP; 2) select the landmarks in order until the overall time is close to the constraint.

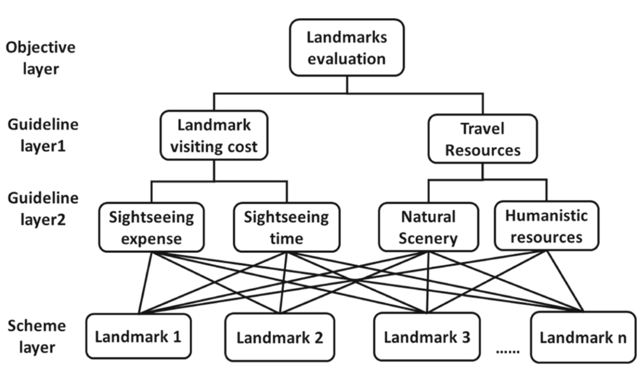


Fig. 2 The AHP model for evaluating and selecting landmarks

In an invalid solution, the total expenses and time exceed the predefined constraints. Thus, it is necessary to remove some landmarks to make the solution valid. However, when adjusting the scheme, which landmark should we remove to get better satisfaction level becomes a crucial problem. First, the landmarks already in the scheme are sorted in ascending order according to their weights in AHP, and then the landmarks are removed in order until the solution becomes valid. The diagram of scheme validating process is shown in Fig. 3.

3.1.3 Solution representation

Here, binary coding is used to represent the problem solution, and the solution space of selection problem can be abstracted as

$$S = \{(x_1, x_2, x_3, ..., x_n) | \sum_{i=1}^{n} t_i x_i \leq T \quad x_i \in \{0, 1\}\} \tag{5}$$

Every possible landmark is uniquely represented by 0-1 binary code. If the *i-th* landmark is selected, $x_i = 1$; otherwise, $x_i = 0$.

3.1.4 Solution candidate initialization

The process of generating the initial solution candidates is described as follows.

1. Generate the initial solution set $p = (x_1, x_2, x_3, \ldots, x_m)$ randomly, where m denotes the total number of landmarks.
2. Validate the initial candidates and get the modified scheme denoted as $p' = (x'_1, x'_2, x'_3, ..., x'_m)$.
3. Compare the current solution obtained with the solution given by the greedy algorithm. If the latter one is better, it will be used to replace the initial candidate.

After the adjustment of the above steps, the initial solution will be valid, while ensuring that the solution has good properties at present.

3.1.5 Energy function

In algorithm, the selection of the energy function becomes critical, as an essential criteria to evaluate the quality of current solution. In this paper, the value of fitness of solution in greedy simulated annealing is recorded as the energy function value. To evaluate the candidates, the energy function is defined as

$$g(x) = C - \sum_{i=1}^{n} f_i x_i \tag{6}$$

Table 2 Index definition for evaluating landmarks

Guideline Layer 1	Total weight	Guideline Layer 2	Weight
C_1 Landmark visiting cost	0.256	$C_{1.1}$ Sightseeing expense	0.161
		$C_{1.2}$ Sightseeing time	0.095
C_2 Travel Resources	0.744	$C_{2.1}$ Natural Sceneray	0.469
		$C_{2.2}$ Humanistic resources	0.277

where C is a proper and larger constant than $\sum_{i=1}^{n} f_i$, *i.e.* the sum of all the possible weights, and f_i is the weight of landmarks derived from AHP. As the temperature decays, the value of energy function decreases. Note that the input constraints $\sum_{i=1}^{n} t_i x_i \leq T$ should be satisfied.

3.1.6 Generation of new solutions

The perturbing process of new solutions is as follows: Firstly, the $i-th$ landmark is selected randomly. If landmark i is not in the candidate, then set $x_i = 1$ or delete another landmark j existing in the candidate at the same time and set $x_j = 0$. If the $i-th$ landmark has already been in the candidate solution, the current round is skipped to select another landmark randomly.

For the newly-generated candidate, there are three possibilities, and the corresponding changes of the scores in the trip can be calculated as

$$\triangle f = \begin{cases} f_i, & select\ i-th\ landmark \\ f_i - f_j, & select\ i-th\ and\ cancel\ j-th\ landmark \\ f_j - f_i, & select\ j-th\ and\ cancel\ i-th\ landmark \end{cases} \tag{7}$$

3.1.7 Acceptance criteria

The acceptance criteria is proposed firstly by Metropolis et al. in 1953 [19]. The main idea of the criterion is to accept the new status by probability. The physical system simulated in

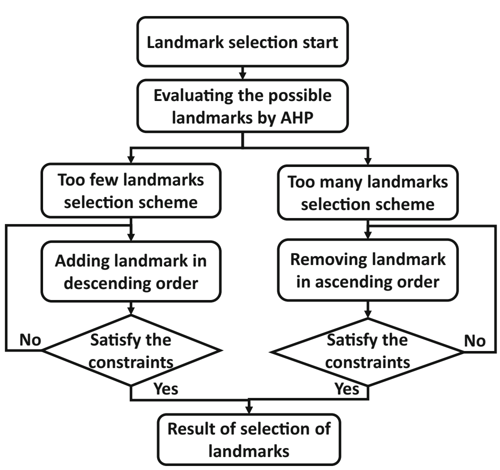


Fig. 3 The diagram of the scheme validating process

annealing algorithm tends to be lower energy, while the molecular thermal motion prevents it from falling to lowest state. Assuming that the energy of the state is E_{i_0}, and the new state is E_j. If $E_j < E_{i_0}$, the new state j is accepted as the current state. Otherwise, depending on the probability. From statistical mechanics, the nature of physical annealing process obeys the normal distribution shown in the following formula.

$$P\{E = E_j\} = \frac{1}{Z(T)} exp\left(\frac{-E_j}{kT}\right) \tag{8}$$

Where $Z(T)$ as the standard factor of probability distribution. T is temperature parameters for simulated annealing (SA) process. $f(x)$ represents energy function. $f(i)$ and $f(j)$ correspond to the objective function value of solution i and j. The Metropolis criterion for transition from solution i to j can be determined by the following formula:

$$P(t_k) = P\{i \to j\} = \begin{cases} 1, & f(i) \leq f(j) \\ exp\left(\dfrac{f(i) - f(j)}{t_k}\right), & f(i) > f(j) \end{cases} \tag{9}$$

For the landmark selection, the simulated annealing algorithm uses the extended Metropolis criteria to accept poorer solutions at a certain probability. The acceptance ratio is calculated as

$$x_i = \begin{cases} 0, & if\ T_{current} + t > T \\ 1, & if\ T_{current} + t \leq T\ \ \triangle f > 0 \\ exp(\triangle f / T), & otherwise \end{cases} \tag{10}$$

where $\triangle f$ is the weight change of the candidate. The acceptance criteria ensure that the list of selected landmarks is searched towards the global optimal solution.

The diagram of the greedy simulated annealing algorithm is shown in Fig. 4. After mass migration, the whole system tends to be lower energy equilibrium state, and the landmark lists satisfied the customized demand of professional independent travelers. After final landmark list and tourist destination are determined, the next step is how tourists choose a reasonable travel path to reach the destination.

3.2 Travel path recommendation

When travelers make plans from the departure city to visit the destination city for sightseeing, they first need to browse some online travel sites to choose a reasonable travel path.

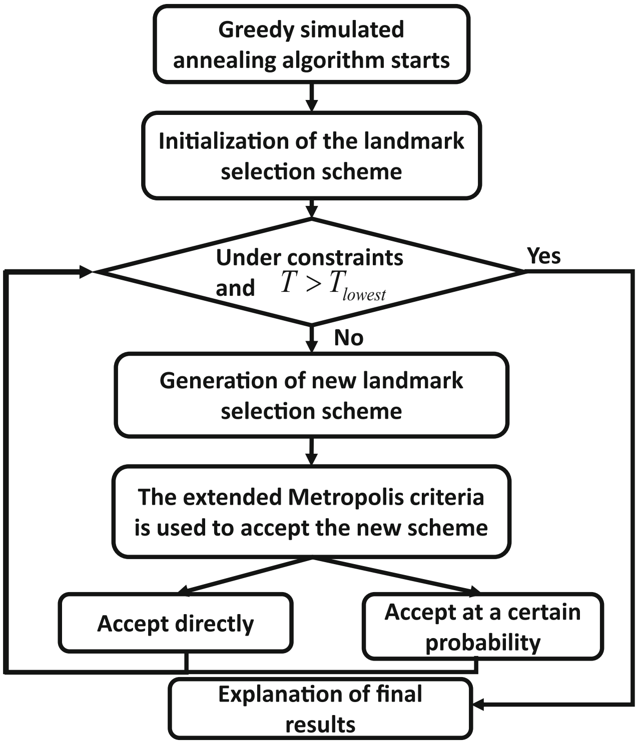


Fig. 4 Diagram of the greedy simulated annealing algorithm

Thus, the issue we need to address is how to choose the most reasonable path from departure to destination, aiming at maximizing satisfaction degree of the travelers.

In this paper, the recommendation of travel path is determined based on the combination of various factors including the hotel type, price, transportation and so on [20]. We use the AHP decision model to evaluate the candidate paths obtained from various websites and choose the best one with the highest customer satisfaction value. The detailed process so of the algorithm is shown in Fig. 5.

The decision-making layers of the path evaluation model of travel route are divided into three categories, including economic factors, life factors and travel modes, which is further subdivided into four categories, including price, accommodation type, hotel type and transportation modes.

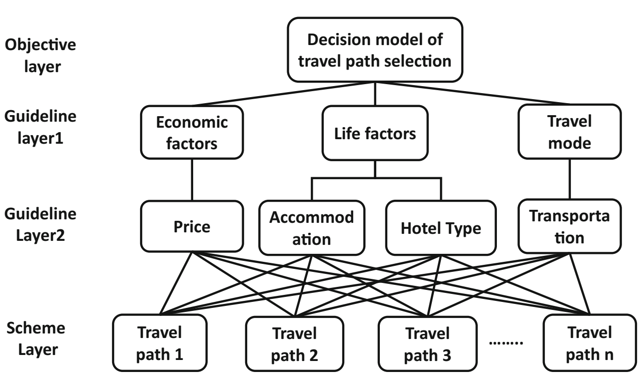


Fig. 5 Decision model of travel path selection based on AHP

The candidates are chosen from higher score independent travel line suggestions obtained from the travel websites to ensure the rationality of the path. The detailed explanations are shown in Table 3.

3.3 Travel path determination

After selecting the target landmarks and arriving at the destination, we need to decide how to visit these landmarks in a certain order, i.e. to determine the travel path. The main concerns include expenses and travel time. Furthermore, each landmark should be visited only once with the least expense and time spent.

The number of selected landmarks was denoted as n and landmark i as the $i-th$ component of the vector. The expenses C_{ij} and sightseeing time t_{ij} were set as the weights of the edge e_{ij} from landmark i to j [21]. In this way, the path planning problem can be abstracted into a weighted graph $G = \{V, E, W\}$, where the vertex set of graph is denoted as $V = \{x_1, x_2, x_3, ..., x_m\}$ and the edge set is denoted as $E = \{e_{1,2}, e_{2,3}, ..., e_{n,1}\}$. The weight of edge e_{ij} in the path is denoted as $w_{ij} = \{w^1_{ij}, w^2_{ij}\}$, where w^1_{ij} represents the expense from x_i to x_j and w^2_{ij} represents the time consumption. Then, the independent travel path planning problem can be modelled as the TSP problem, where the objective function is abstracted as

$$\begin{cases} min\ f_1 = \sum\limits_{i=1} \sum\limits_{j=i+1} w^1_{ij} \\ min\ f_2 = \sum\limits_{i=1} \sum\limits_{j=i+1} w^2_{ij} \end{cases} \tag{11}$$

The goal is to make the expense and time spent in the path as small as possible. However, the path planning problem is a multi-objective problem and is obviously NP-hard [22]. Hereafter, a simulated annealing algorithm based on roulette wheel selection is adopted to solve this problem.

3.3.1 Representation and initialization of the solutions

In the simulated annealing algorithm, a solution is represented as a chromosome, which is encoded in binary format, where the m landmarks selected are numbered respectively, recorded as $\{1, 2, 3, ..., M\}$. Then the visiting order of the landmarks is generated randomly, denoted as $x = (x_1, x_2, ..., x_n)$, $x_i \in \{1, 2, ..., M\}$. n is the size of solution; $[x_i, x_j]$ is the edge between landmark x_i and x_j; $w^1_{ij}[x_i, x_j]$ and $w^2_{ij}[x_i, x_j]$ denote the expenses and time consumption of the edge respectively.

In the initialization of the solution, the above method is used to encode the scheme of the independent travel. In this way, N chromosomes could be generated randomly, corresponding to the N types of independent travel planning schemes, implying different visiting order of the selected

Table 3 Criteria definition at different hierarchies

Criteria factor 1	Total Weight derived from AHP	Criteria factor 2	Weight derived from AHP
C_1 Economic factors	0.193	$C_{1.1}$ Price	0.193
C_2 Life factors	0.681	$C_{2.1}$ Accommodation Type	0.486
		$C_{2.2}$ Hotel Type	0.195
C_3 Travel mode	0.126	$C_{3.1}$ Mode of transportation	0.126

landmarks. For each initialized candidate, the energy value will be calculated accordingly.

3.3.2 Energy function

In the simulated annealing algorithm, it is crucial to select an appropriate energy function to evaluate the candidates, which should be able to give a value for each scheme that can reflect the rationality of the planned route [23]. Here, the dual objective is transformed into a single objective evaluation function using coefficient λ_i, and then the energy function corresponding to each candidate can be calculated as

$$f(x) = \lambda_1 f_1(x) + \lambda_2 f_2(x) \tag{12}$$

where λ_1 and λ_2 are the weight coefficients of expense $f_1(x)$ and time $f_2(x)$ respectively, obeying the constraint of $\lambda_1 + \lambda_2 = 1$. The smaller the energy value is, the higher the satisfaction level is.

3.3.3 The roulette wheel selection

In the algorithm, the roulette wheel selection is adopted to select the candidate. In roulette selection, individual fitness value is converted to the probability of selection, according to proportion on a disk. Obviously, the greater individual fitness is, the more chance of being selected. Taking the fitness of one generation value as example, the proportional disk is shown in Fig. 6.

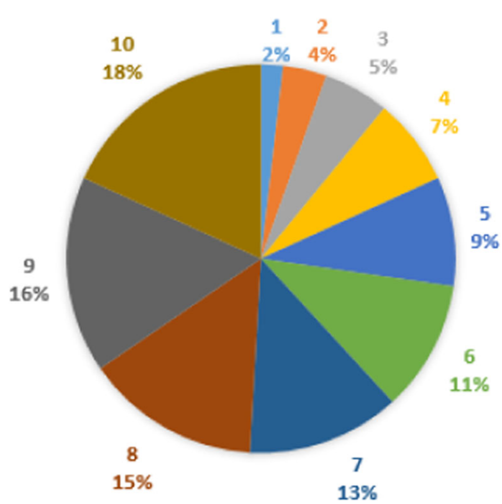


Fig. 6 Roulette selection method

According to the energy function value, if f_i is the evaluation value of the $i-th$ candidate, it is transformed to $f_i' = C - f_i$, where C is a proper and relatively constant. Denote p_i as the probability that the $i-th$ candidate is chosen, which can be calculated as

$$p_i = \frac{f_i'}{\sum_{j=1}^{M} f_j'} \tag{13}$$

Where M is the total number of possible candidates. Thus the lower its energy function value is, the more likely that candidate is selected, which means it is more reasonable to satisfy the travelers' requirements.

3.3.4 Generation of new candidates

To generate new candidates, the existing candidates in the current solution set will be disturbed slightly and randomly to obtain new schemes [24]. Individual neighborhood searching is used here, and the details of pseudo-code is in Algorithm 1.

Algorithm 1 Individual neighborhood searching algorithm

Require: *Variable* i, j $\quad i > 0, \; j > 0,$ //Variable i,j are defined
i=rand(1,M)
j=rand(1,M)
// i and j represent two landmarks in M possible landmarks
if $(i < j)$ **then**
  //Reversing the landmarks between *i* and *j* in order
  Reverse(*i*,*j*)
else$[i > j]$
  //Reversing the landmarks between the first one and *j* in order
  Reverse(*1*,*j*)
  //Reversing the landmarks between the last one and *i* in order
  Reverse(*i*,*M*)
end if

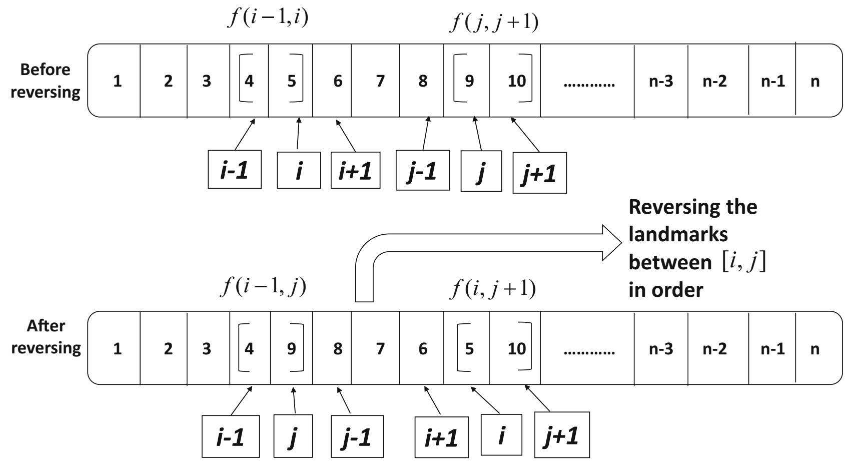


Fig. 7 Transformation of current candidate when $i < j$

Where $f[i, j]$ denotes the overall cost between landmark i and j. M represents the number of all possible landmarks which may appear in the travel path, while n represents the number of landmarks already in the path, which are selected from the M possible landmarks ($n \leq M$). Assuming that a visiting scheme is $(1, 2, 3, \ldots, n-1, n)$, i.e. travelling from the No. 1 landmarks to the No. n landmarks, and the two indexes chosen randomly are i and j, where limiting that index i is not equal to j. When $i < j$, reversing the landmarks between $[i, j]$ in order. Figure 7 shows the specific operations procedure.

The following is used to calculate the cost increment $\triangle E$ after exchanging i and j.

$$\triangle E = f(i-1, j) + f(i, j+1) - f(i-1, i) - f(j, j+1), \quad i < j \tag{14}$$

Also, when $i > j$, the landmarks between $[1, j]$ and $[i, n]$ will be reversed in order. Figure 8 shows the specific operations procedure.

While (15), as shown below, is used to calculate the cost increment after exchanging i and j with the first element and last element respectively.

$$\begin{aligned}\triangle E = {} & f(1, j+1) + f(i-1, n) + f(i, j) - f(j, j+1) \\ & - f(i-1, i) - f(1, n), \quad i > j\end{aligned} \tag{15}$$

After above operations, the new candidate is generated successfully.

3.3.5 Acceptance criterion

Here, the improved Metropolis criterion is used again to decide whether to accept the new candidate [25]. If the energy of new candidate after perturbation is decreased, then it will be accepted directly. If the energy of the new candidate increases, it will be accepted with probability p, which is calculated as

$$p(T_k) = \begin{cases} 1, & (f_{k+1} > f_k) \\ exp(-\frac{f_{k+1} - f_k}{T_k}), & (f_{k+1} \leq f_k) \end{cases} \tag{16}$$

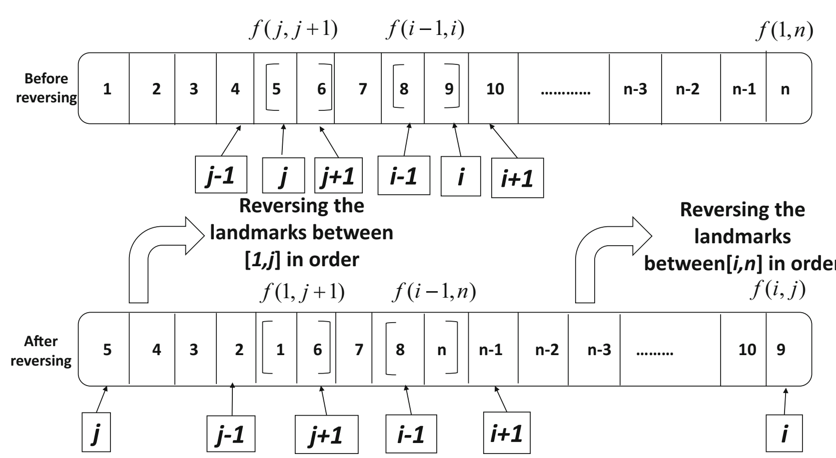


Fig. 8 Transformation of current candidate when $i > j$

where f_{k+1} and f_k are the energy of the new and old candidates respectively, and T_k represents the current temperature. The detailed diagram of the described algorithm is shown in Fig. 9.

3.4 Algorithm of independent travel recommendation

Combining the above sub-algorithms, here we present the independent travel recommendation algorithm. It has some necessary parameters, such as time and budget. The time is comprised of landmark visiting time and the travelling time, where the travelling time includes both the travel time from the departure place to the destination and the time spent between adjacent landmarks. The budget of the independent travel trip also consists of two parts, including the expenses of visiting the landmarks and the money spent on the road [26], where the latter further includes the expenses for travelling from the departure point to the destination and the transportation expenses between the landmarks [27]. Here, *TotalCost* and *TotalTime* are used to denote the total cost and the total time spent on the whole trip. *Satisfaction* is used to represent the satisfaction of independent travelers. The algorithm is described as in Algorithm 2.

Algorithm 2 Algorithm of independent travel recommendation

Require: $TotalTime = 0$; $TotalCost = 0$; $Satisfaction = 1$;
Input possible landmarks list provided by professional travelers
while (The current trip does not satisfy the specific demands of travelers) **do**
  $Satisfaction = Satisfaction \times \alpha$
  //Represents the reduction of independent travelers' satisfaction

  Select the target landmarks in the destination under constraints
  Determine the trip route to arrive at the destination
  Determine the visiting order of the landmarks in the destination
  Calculating the time and cost consumption of whole trip
end while

Through the above algorithm, the landmarks will be first selected in the destination, and then the trip path is determined. Finally, the order among the target landmarks will be figured out, and this is the final entire scheme generated by the independent travel algorithm.

4 Experiment

In this section, the independent travel recommendation algorithm for professional travelers was implemented on Android platform using Java language in the Eclipse development environment. Then, experiments were conducted accordingly and the results were analyzed.

4.1 Feasibility verification

(1) Selecting target landmarks in the destination

After the traveler provide the possible landmark list, the next step was to determine the landmarks under constraints. In this experiment, traveler choose the landmarks in Xining. Under the time constraint of 7 hour in total, the possible landmarks in the destination place were evaluated using AHP. The landmarks in the destination city (Xining) include Menyuan, Dongguan Great Mosque, Qinghai Lake, Caka Salt Lake, Ta'er Lamasery and so on. The evaluation results of these landmarks are shown in Table 4.

According to various factors, the list of the landmarks sorted in descending order of the scores was: Qinghai Lake > Caka Salt Lake > Ta'er Lamasery > Menyuan > Dongguan Great Mosque. This was coincident with the actual popularity of these landmarks. The greedy simulated annealing algorithm described in Section 3 was used to select the landmarks, and the selected landmarks under the time constraint are Ta'er Lamasery, Qinghai Lake, Caka Salt Lake and Menyuan.

(2) Selecting travel schedule

In the following experiment, travelers needed to select a reasonable travel schedule from the departure to the destination, taking the line from Beijing to Xining as an example. Firstly, some top-ranking routes were queried from several well-known travel sites, as shown in Table 5. Using the AHP decision model, the weight and score of each line were calculated. The sorted lines are shown in Table 6.

As it shows in Table 6, according to the calculated score summarizing the weights of four factors, including hotel type, price, transportation and accommodation, the selection order should be: line3 > line2 > line1 > line4. Thus, it was preferable to recommend that traveler to select line 3 as the trip schedule to arrive at the destination.

Then the result of landmarks in destination can be abstracted as a weighted graph, as shown in Fig. 10.

After selecting the landmarks, the weight of each edge in the generated graph was obtained by combining the money expenses and the travel time cost of the route. Setting the

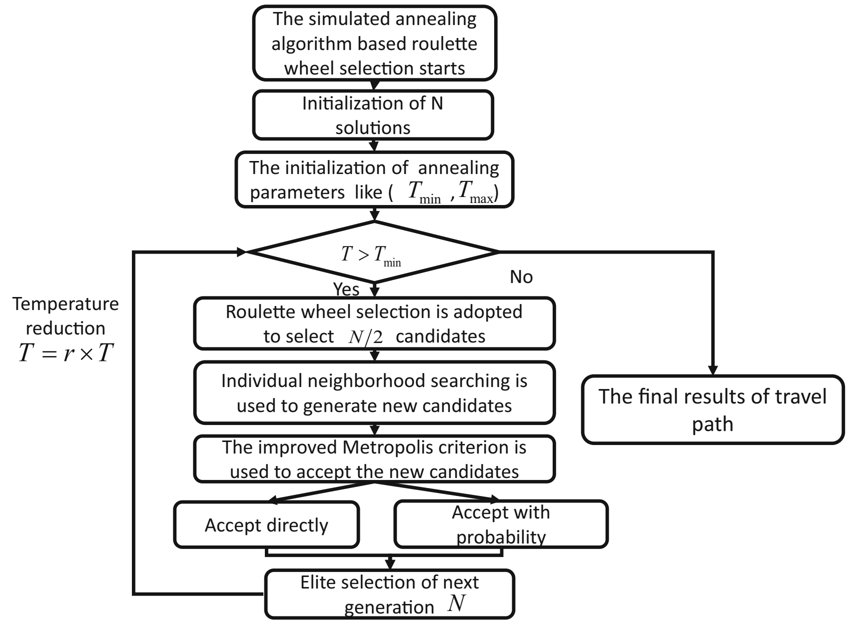


Fig. 9 The diagram of simulated annealing algorithm based on roulette wheel selection

Table 4 Evaluated score of different landmarks

Landmark name	Visiting time	Money cost	Natural scenery	Humanities landscape	Total score
Menyuan	2h	0.348	0.247	0.103	0.188
Dongguan Mosque	0.75h	0.161	0.076	0.301	0.139
Qinghai Lake	3h	0.700	0.348	0.09	0.276
Caka Salt Lake	2.5h	0.520	0.236	0.115	0.208
Ta'er Lamasery	1h	0.271	0.094	0.391	0.189

Table 5 Various possible schedules

No.	Hotel type	Price (RMB)	Transportation	Accommodation	Days
1	Deluxe	2254	Aircraft	Double-bed room	5
2	Comfortable	1642	Aircraft	Standard room	5
3	Economic	1296	Train	Big-bed room	5
4	Comfortable	1994	Train	Double-bed room	5

Table 6 Sorted lines based on their scores

No.	Hotel type	Price(RMB)	Transportation	Accommodation	Total score
3	0.023	0.161	0.182	0.017	0.383
2	0.048	0.132	0.059	0.037	0.276
1	0.079	0.089	0.059	0.039	0.266
4	0.042	0.104	0.059	0.033	0.239

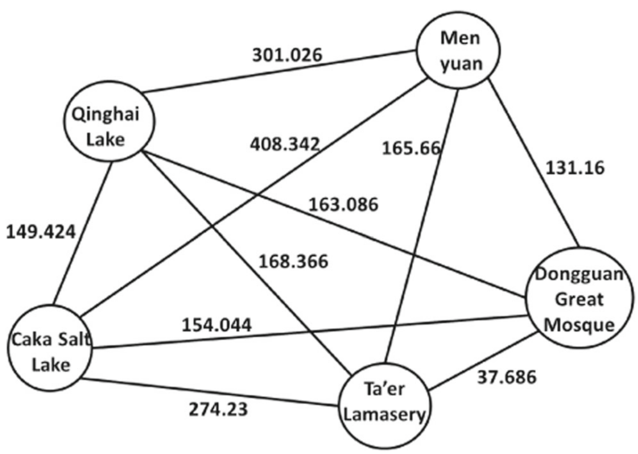


Fig. 10 The weighted graph for selecting landmarks

coefficient $\lambda_1 = \frac{2}{3}$ and $\lambda_2 = \frac{1}{3}$, the weight of the edge was calculated as $f(x) = \lambda_1 \times f_1(x) + \lambda_2 \times f_2$.

Then, the simulated annealing algorithm based on wheel roulette selection proposed in Section 3 is used for trip planning in independent travel schedule, and the result is shown in Fig. 11. Finally, the total distance of the four selected landmarks is $d = 483.45$, and the resulted trip plan was Men yuan→Ta'er Lamasery→Qinghai Lake→Caka Salt Lake. Therefore, the simulated annealing algorithm based on roulette wheel selection was proven to be feasible in obtaining a trip plan that can meet the travelers' requirements.

4.2 Effectiveness analysis

Here, to evaluate the algorithm effectiveness, we compared the results of our approach to the route given by package tours. Firstly, the total score of the landmarks $F(x) = \sum_{i=1}^{m} f(x_i)$ arranged by the package tour and the total score of the landmarks $F'(x) = \sum_{i=1}^{m} f'(x_i)$ planned by the independent travel plan algorithm. Then $\eta_{Landmark} = \frac{F(x)-F'(x)}{F(x)} \times 100\%$ was used to quantitatively measure the difference between the two schedules. The results are shown in Fig. 12.

From the Fig. 12, it can be seen that compared to the total score of landmarks in the package tours, the independent travel schedule was much better, with the increasing rate of $\eta_{max} = 45.4\%$. This shows landmarks planned by algorithm can better meet the travelers' demand [28], and can provide more satisfying landmark choices.

To evaluate the path planning algorithm, we used valid visiting time ratio, denoted as η_t and landmark expense ratio, denoted as η_c as the criteria. When calculating the total time and consumption of traffic between landmarks, it is necessary to discuss the mode of transportation with package tours and independent travel.

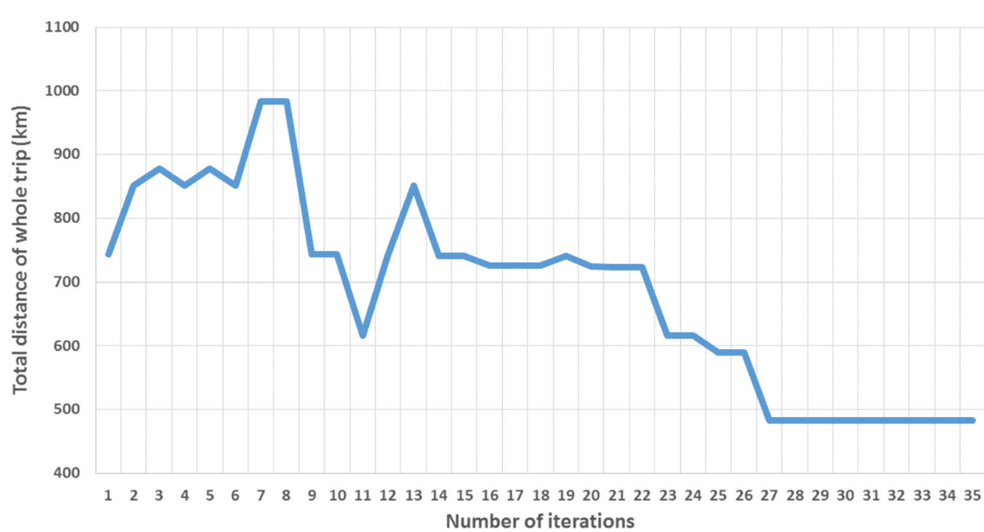
In the package tours, the coaches contracted by travel package is the main mode of transportation between landmarks. But the coach only goes on fixed routes. After coach's arrival, travelers need to walk a distance before arriving at landmarks, as shown in Fig. 13. Obviously, the mode of transportation will take more time, but the consumption is lower. In the independent travel, travelers tend to select taxis as the transportation mode between landmarks. It is guaranteed that independent travelers can park everywhere, which greatly enhance the travel experience of professional tourists, but the consumption is higher. The detailed information is shown in Fig. 14.

1. Valid visiting time ratio

Valid visiting time ratio η_t was defined as the ratio of time spent in visiting the landmarks to the total time of whole trip, which is the proportion of real sightseeing time at the landmarks during the tour. The calculation formula is

$$\eta_t = \frac{T_{sightseeing}}{T_{sightseeing} + T_{travel}} \times 100\% \tag{17}$$

Fig. 11 The optimizing process of the algorithm



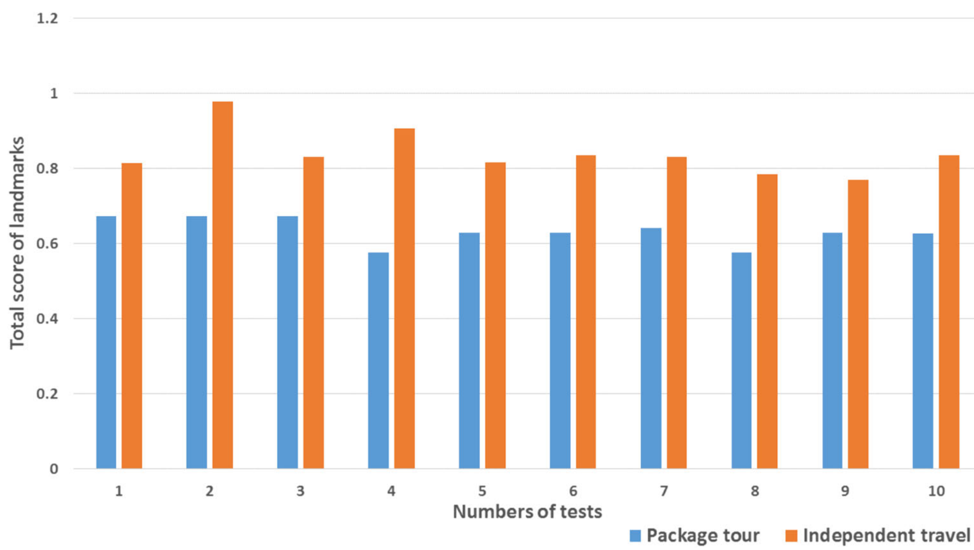


Fig. 12 Total score comparison of schedules by package tour and independent travel

where T_{travel} contains only the travel time in the destination without the time from departure to the destination [29]. The results of the independent travel planning algorithm were compared with the advice of package tour, and detailed information is shown in Fig. 15.

After comparing the valid visiting time ratio obtained by independent travel planning and package tours, the valid visiting time ratio reached $\eta_{max} = 47.9\%$. Notably, $\eta_{min} = -5.32\%$ showing that valid visiting time ratio of independent travel planning was sometimes worse than results of package tours. This was because simulating annealing based on roulette wheel selection is an artificial intelligence approach and a heuristic algorithm [30], which may lead to local optimal values. In summary, the solution generated by our approach ensures that the proportion of actual sightseeing time is higher.

2.Valid visiting expense ratio

Valid visiting expense ratio η_c is the ratio of expenses spent on sightseeing to the total cost spent on the whole trip [31]. However, the calculation of valid visiting expense ratio for independent travel and package tours were different [32]. The ratio for package tours was calculated as

$$\eta_{package} = \frac{\sum_{i=1}^{n} x_i c_i}{C_{totalcost}} \times 100\% \qquad x_i \in \{0, 1\} \tag{18}$$

which means the ratio of expenses spent on selected landmarks to the total expense of the package tour. However, the calculation of $\eta_{Independent}$ was different. The total cost $C_{totalCost}$ was comprised of three parts: landmark visiting cost $\sum_{i=1}^{n} x_i c_i$, traffic expenses between landmarks $C_{traffic}$ and the expenses spent on travelling procedure $C_{travelling}$. Therefore, $\eta_{Independent}$ was calculated as

$$\eta_{Independent} = \frac{\sum_{i=1}^{n} x_i c_i}{C_{traffic} + C_{landmarks} + C_{travelling}} \times 100\% \tag{19}$$

The comparison results between independent travel planning and the package tour are shown in Fig. 16.

It shows that compared to the package tour, the valid expenses ratio of independent travel planning can increase 55.6%. This means that our approach can ensure that under

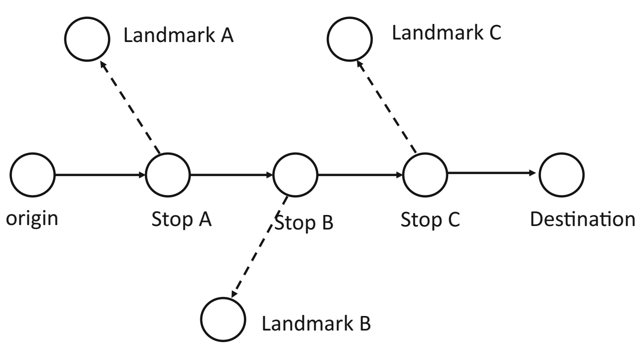


Fig. 13 Transportation mode of package tour

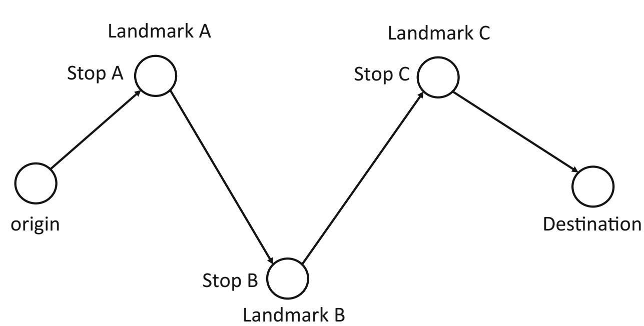


Fig. 14 Transportation mode of independent tour

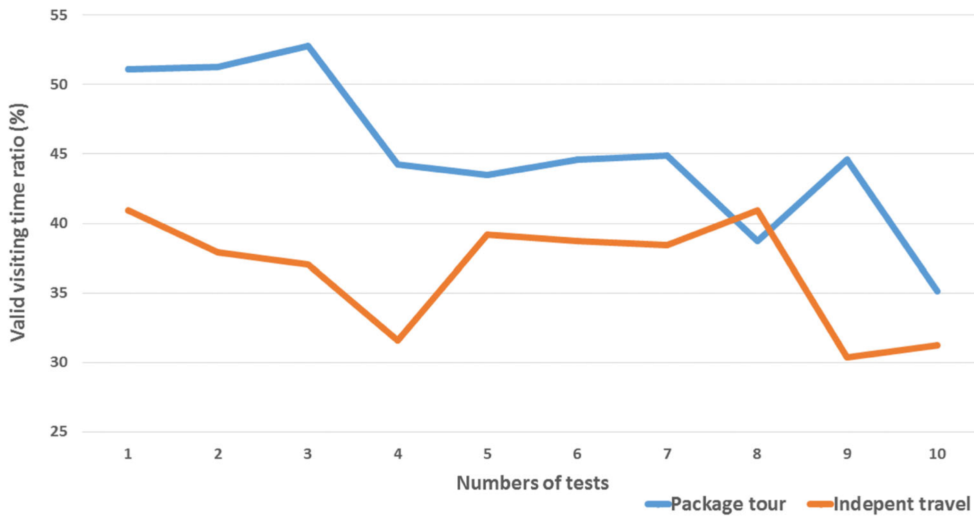


Fig. 15 Comparison of the valid visiting time ratio

the constraints of money budget and time limit, travelers can obtain a better travelling experience and be more satisfied.

4.3 Evaluation of user satisfaction

In order to evaluate the effectiveness of the method proposed in this paper, we conducted a survey and found 20 users, ten males and ten females, to participate in it. First, the users needed to input several individual factors (e.g. time and budget constraint, and personal preferences) [33] to get independent travel recommendations for professional travelers. The participants surveyed were only allowed to evaluate the schemes wherein the destination must be one of the places they have already travelled to at least once.

For the list of landmarks in the independent tour, various adjectives (eg. formal, relax, comfortable) [34] are used in the algorithm to express the psychological responses of independent tourists, which reflects the characteristics of the landmarks in different aspects. The detail information of adjectives is shown in Table 7.

Independent tourists score the characteristics of landmarks ranging from [−2, 2]. Firstly, the evaluation results of male and female are classified to analysis for various characteristics of landmarks. The results are shown in Fig. 17. It is known that the evaluation scores between females and males are quite similar. Therefore, in the evaluation results of the satisfaction of independent tour, the results of males and females are counted together.

The comparison of landmarks between the independent tour and package tour are obtained, the detail information is shown in Fig. 18. It is shown that there is a tremendous difference between the landmark list of package tours and independent travel. In package tour, the list of landmarks is usually unreasonable, which cannot provide good travel experience. However, the landmarks list of independent travel is more casual, unique and close to the real life of

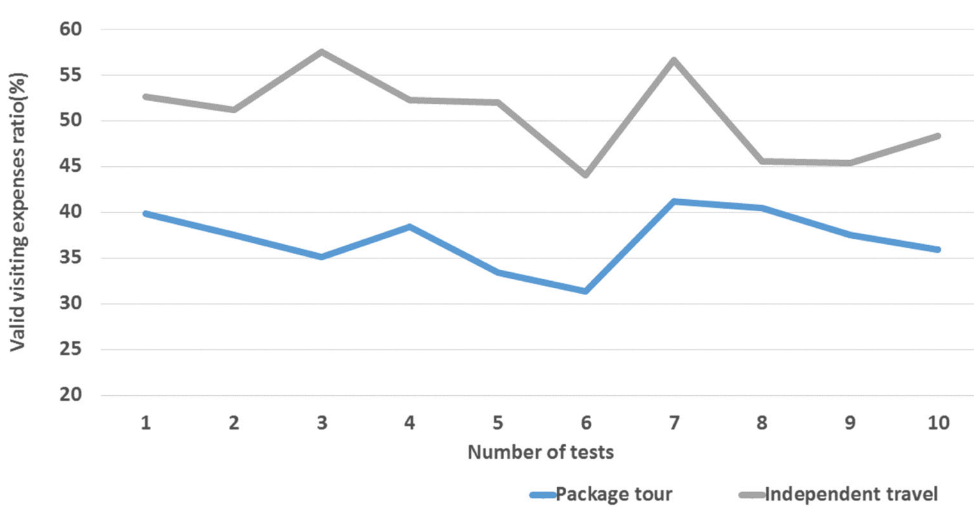


Fig. 16 Comparison of the valid visiting time ratio

Table 7 Pairs of adjective related to landmarks

No	Adjectives
1	Formal — casual
2	Lively — quiet
3	Ordinary — unique
4	Restless — calm
5	Realistic — romantic
6	Uncomfortable — comfortable
7	awkward — elegant
8	relaxing — stimulating

Table 8 Algorithm satisfaction evaluation mode

Satisfaction	Poor	Relative poor	Good	Satisfactory	Extremely Satisfactory
Representativeness	1	2	3	4	5
Diversity	1	2	3	4	5
Rationality	1	2	3	4	5
Summary	1	2	3	4	5

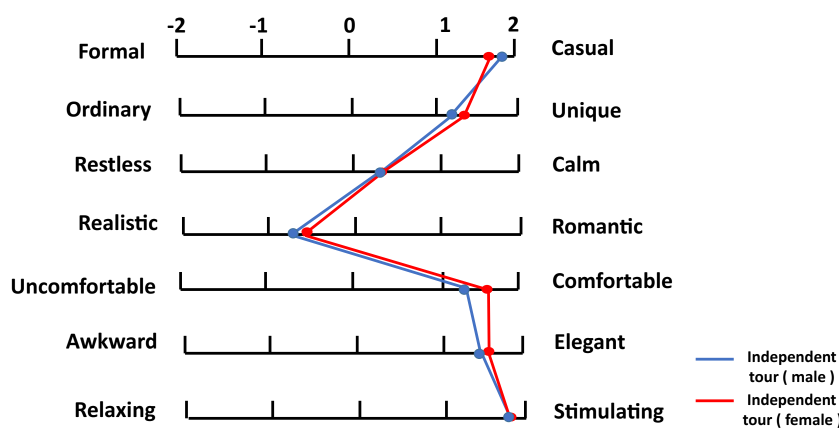


Fig. 17 Comparison of male and female

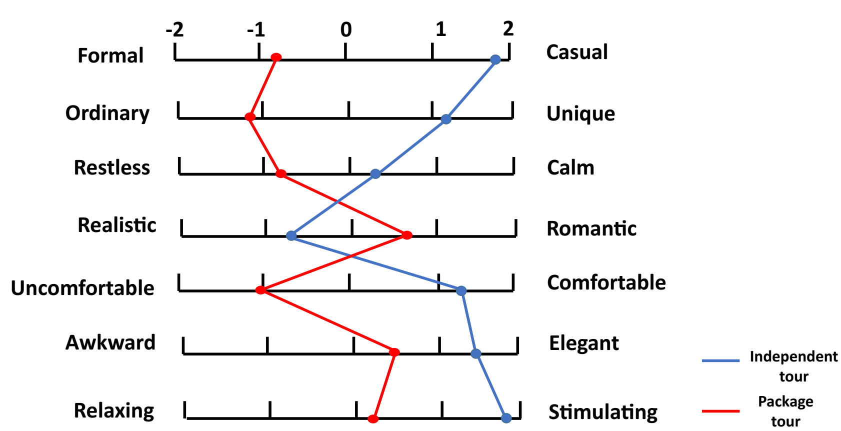


Fig. 18 Comparison of package and independent tour

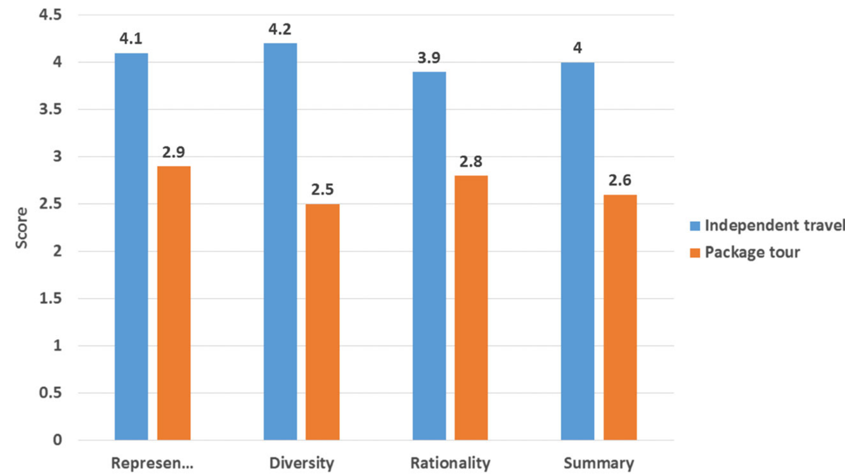


Fig. 19 The results of user survey

local residents, which may assist professional travelers with experiencing the local customs and practices.

For the generated solution of travelling order of landmarks, users participating in the survey were required to evaluate the generated solution from the following four perspectives [35]. The detailed information is shown in Table 8. The result is shown in Fig. 19.

1. **Representativeness**: the extent that the landmarks represent the style and culture of the destination city.
2. **Diversity**: whether the landmarks in the solution can cover different views of the city.
3. **Rationality**: whether the tour route is reasonable in the perspective of the time scheduling.
4. **Summary**: users' overall satisfaction with the recommended travel solution.

We can see from results that compared to the package tour, the independent travel recommendation algorithm we proposed can significantly improve the users' satisfaction from the various perspective, including representativeness, diversity and rationality, and thus better overall score could be achieved.

5 Conclusions and future work

In the paper, we designed an independent travel recommendation algorithm for professional travelers based on AHP, in which the simulated annealing algorithm is adopted. The approach we proposed includes the determination of a travel schedule of the selection of target landmarks in the destination city, how to arrive at the destination, and the determination of visiting order of landmarks in the destination. In our algorithm, the greedy simulated annealing algorithm solves the problem of selecting appropriate landmarks. Then the AHP decision model is used to decide the travel route from the departure to the destination. The final step is to use the simulated annealing algorithm based on roulette wheel selection to determine the visiting order of the selected landmarks. Finally, the feasibility and effectiveness of algorithm are verified by experiments and results show that the approach is not only feasible and effective, but also can provide convenience and meet the demand of travelers. In summary, the approach we proposed is practical and applicable for independent travelers to plan their trips before starting. Our approach can give a reasonable solution meeting the constraints of time and budget and helps the traveller get a better experience during the tour.

In the future, we intend to make the solution more humane by considering other factors including accommodation condition, hotel, personal diet, and so on. In addition, it is also necessary to consider that in the real world, overlapping routes may lead to trip planning failures, whichs needs to be studied in future efforts.

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