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Original Article

Genetic Algorithm For Tourism Route Planning Considering Time Constrains

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Abstract - *Tourism route planning is an indispensable but time-consuming task before departure. Tourists need to study the places to visit, arrange the length of stay and determine the order of visits. In recent years, many intelligent route planning tools have been developed to extricate tourists from this tedious process. However, automatic route planning for tourism is still challenging, especially when it takes into account the preference of tourists and practical constraints (such as the operation time window of attractions). In this paper, we developed a multi-objective itinerary planning method based on a genetic algorithm to schedule traveling routes for multi-day trips and successfully applied the proposed method in Macau.*

Keywords — *tourism route planning, itinerary planning, multi-day trip, multi-objective optimization, genetic algorithm.*

I. INTRODUCTION

The tourism industry has evolved dramatically over the last few years. As an indispensable part of travel, route planning is a tedious and challenging task. Traditionally, tourism route planning was accomplished in a manual way, which is time-consuming and laborious. Tourists need to first search for relevant information about the destination from different sources, including attractions, transportation, hotels, etc., then identify the potential point of interest (POIs), estimate the time spent, and finally make a reasonable itinerary and budget according to their preference. Alternatively, tourists can seek advice from travel agencies, which is more efficient but not tailor-made for a specific personalized trip.

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To free users from the labor-intensive process, a myriad of intelligent travel planners have been developed and proliferated in recent years to help travelers schedule their itineraries. Most mobile apps and website services are designed for their own purpose and tailored for certain groups of people. For example, Badger Map (www.badgermapping.com) optimizes multi-stop routes after analyzing real-time traffic and distances, which is especially for field sales teams. Roadtrippers (roadtrippers.com) assists tourists to discover and explore points of interest along the route from A to B. Myrouteonline (www.myrouteonline.com) offers the fastest or shortest route by minimizing the distance or time among places. ViaMichelin (www.viamichelin.com) offers a variety of route calculation options, including costs, real-time road traffic updates, accommodation and restaurant reservations, and key tourist spots. TripAdvisor (https://www.tripadvisor.com) helps customers gather travel-related information, share travel experiences, exchange ideas, and interact in forums.

Apart from web services and apps, the method of searching for the optimal travel route has also been widely discussed in academia and has been solved from different fields such as graph theory, trajectory mining [1] [2], combinational optimization [3] [4] [5]. Generally speaking, the solution will consider factors such as tourists' interest [6], preference [7], satisfaction [8], cost budget [9] [10], time budget [9] [11] [12], as well as attractions popularity [3], category [13], travel comfort and convenience [14] [15] [16] for constructing tourism route planning models. However, the current tourism planning methods/ systems/ services have some limitations: (a) most of them provide one-day trip plans, but travelers usually divide their trips into several days. However, the optimal multiple-day tourism plan is not a simple combination of one-day itineraries [17]; (b) only one solution is offered, and some travelers intend to get alternatives so that they can select the most suitable one according to their preference or flexibly change their plans if accidental events occur; (c) some real-world constraints, such as the operation time window of point of interest, and the length of stay time is rarely considered.

To solve the shortcomings of the existing works, in this paper, we study the problem of multiple-day itinerary planning considering both the real-world constraints and traveler's preference and carry out a practical application in Macau by using a genetic algorithm. In summary, our contributions are: (1) propose a genetic algorithm-based method to generate itinerary plans for multi-day trips, which is not a simple combination of multiple single days' plans;

(2) consider time constraints in real word including the operation time window of attractions and suggested stay lengthy in our multi-objective GA optimization model; (3) add a fine-tune operation after the crossover and mutation to improve the user experience of them every single day's route.

The rest of this paper is organized as follows. Section 2 reviews the existing solutions for tourism route planning. Section 3 introduces the preliminary knowledge and formulates the problem as a mathematical model. Section 4 describes details of the genetic algorithms and how to use them to solve the problem. Using Macau as a case study, Section 5 presents the experiment and results. Finally, we conclude the paper in Section 6.

II. RELATED WORK

Tourism route planning has been extensively studied in the fields of data mining and operational research. In this section, we will summarise the related works from these two fields.

In the field of data mining, tourism route planning is often regarded as a recommendation problem. Current tourism planning research uses user-generated content (such as geotagged photos) to try to build intelligent systems that automatically make travel plans based on subjective factors (e.g., tourist preferences) and objective constraints (e.g., opening hours of attractions). For single-day plans, Lu et al. [18] developed a travel planning system to 1) recommend popular landmarks by the Internal Path Discovering algorithm and 2) find classical tourism path, and 3) suggest the visit sequence and time spent for each landmark for tourists under a given time budget. SenjutiBasu et al. [19] built an interactive itinerary planning system to provide optimized itineraries based on user feedback on candidate POIs. They proposed a method based on heuristic greedy to find the approximate optimal one-day route with the best score for the plan using the tourist time budget.

From the perspective of operational research, tourism route planning is usually regarded as a combinational optimization problem, which is derived from Traveling Salesman Problem (TSP) [20]. Existing methods search for the optimal route by focusing on different objectives such as shortest distance, shortest time, and minimum cost. Beirigo et al. [21] proposed a parallel Iterated Local Search (ILS) heuristic to find the time-dependent shortest path given a set of destinations and a travel time window. Brilhante et al. [22] used a local search-based algorithm to find the shortest path crossing the popular sightseeing itineraries. Xu et al. [23] formulated the TRP as a sequence generation task and divided it into two stages. In the first stage, an LSTM-based deep neural network was used to learn sequential patterns from historical visit trajectories and predict the probability distribution of the next point of interest to visit based on user preferences. Then, by incorporating the constraints in different scenarios, the beam search strategy was applied to generate candidate routes. Huang et al. [17] designed an automatic planning service that generated customized optimization solutions to meet any goal of diversified destinations, highly-rated POIs, and the shortest transit time on the road. They incorporated the neighborhood niching strategy into the genetic algorithm to create itineraries with a flexible number of POIs and travel days.

There are also some works that combine both data mining and optimization to optimize tourism itinerary planning [24]. These works usually adopt a two-step approach to recommend itineraries based on the orienteering problem. For example, Lim et al. [25] recommended POIs based on their popularity and the preferences of visitors. The route plan was created by minimizing the distance and travel time between POIs. Kenteris et al. [26] derived a near-optimal itinerary plan by constructing an itinerary tree. In the tree, selected POIs are positioned as nodes, and they are connected to each other at the minimum distance. The final itinerary is obtained through a post-order traversal of the tree. Chen et al. [27] transformed the orienteering problem of searching optimal itinerary to a set-packing problem and designed a two-stage model to generate multi-day itinerary planning. For the ranked POIs according to users' preference, single-day itineraries are precomputed in the pre-processing stage, and then an approximate search algorithm is used to combine single-day itineraries in the online stage.

III. PROBLEM FORMULATION

Tourism route planning (TRP) is to generate a satisfactory visit order, given a set of scenic spots, by satisfying a number of constraints such as the number of travel days, total cost, and total time.

In this study, we assume the target destinations (scenic spots) and the hotel are explicitly suggested by tourists. Each day, the tourists depart from the hotel at 9:00 am and return to the same hotel after leaving the last destination. We model the planning process of multi-day travel itineraries with time constraints as a multi-objective optimization problem.

Mathematically, the TRP problem over k days (k = 1, 2, …) can be expressed as a complete graph G(V, E) where V represents a set of vertices and E represents a set of edges. The vertices consist of two types of places, namely, the attraction set $A = \{v_1, v_2, \dots, v_n\}$ and the hotel set$H = \{v_{n+1}, v_{n+2}, \dots, v_m\}$. Each attraction v_i is univocally identified by its geographic coordinates (latitude and longitude), a name, an open time OT_i and a close time CT_i which specify its operation time frame and recommended stay time s_iFor stay. The visit to an attraction v_i can only begin within the specific time window $[OT_i, CT_i]$. Here we consider hard time windows, which means that the visitor's arrival time at_i at attraction v_i cannot later than its close timeCT_iAnd if the visitor arrives earlier thanOT_i, he/ she must wait for $(OT_i - at_i)$ until the place is open. A transmit time t_{ij} is associated with each edge $e(v_i, v_j)$ which is estimated by dividing the distance $dist(v_i, v_j)$ between vertices v_i and v_j By the assumed speed of the car (40km/h).

Based on the notations listed above, we formulate the problem as an integer program. A variable x_{ijk} is involved as an integer decision variable, where $x_{ijk} = 1$ if travel from v_i to v_j , otherwise $x_{ijk} = 0$. While $x_{ijk} = 1$ and the visiting order is from i to j, the distance $dist(v_i, v_j)$ is calculated by Haversine distance [28] as follows:

$$dist(v_i, v_j) = 2R \cdot arcsin(\sqrt{sin^2\left(\frac{\varphi_j - \varphi_i}{2}\right) + \cos(\varphi_i)\cos(\varphi_j)sin^2(\frac{\lambda_j - \lambda_i}{2})}) \quad (1)$$

where R is the radius of the earth,φ_i, φ_j are the latitude of place i and the latitude of point j (in radians), and λ_i, λ_jAre the longitude of place i and longitude of place j (in radians)? As we assume that the transportation speed is 40km/h, the transmit time from the place i to j is:

$$t_{ij} = \frac{dist(v_i, v_j)}{40} \quad (2)$$

The leaving time lt_i of place, i equal to its stay time s_i plus its arrival timeat_i, that is:

$$lt_i = s_i + at_i \quad (3)$$

The arrival time at_j of place, j equals to the leaving time lt_i from the place i plus the transportation timet_{ij} from i to j:

$$at_j = lt_i + t_{ij} \quad (4)$$

The objective of the problem is to minimize the transportation time and the penalty for waiting for the attractions to open, and the time spent being late is less than the suggested time. In summary, the problem can be expressed in mathematical formulas as follows:

$$min: w_1 \cdot COST_{\_trans} + w_2 \cdot COST_{\_wait} + w_3 \cdot COST_{\_delay} \quad (5)$$

$$min: \quad w_1 \cdot \frac{dist(v_i, v_j)}{speed} + w_2 \cdot max(OT_i - at_i, 0) + w_3 \cdot max(lt_i - CT_i, 0) \quad (6)$$

Subject to:

$$\sum_{k\in K} \sum_{j\in V} x_{ijk} = N + k \quad \forall i \in V \quad (7)$$

$$\sum_{j\in V} x_{0jk} = 1 \quad \forall k \in K \quad (8)$$

$$\sum_{i\in V} x_{i0k} = 1 \quad \forall k \in K \quad (9)$$

$$at_i + t_{ij} \leq at_j \quad (10)$$

$$at_i < CT_i \quad (11)$$

$$x_{ijk} \in 0,1 \quad \forall i, j \in V, k \in K \quad (12)$$

Specifically, equation (7) ensures that each attraction is visited exactly once, (8) and (9) that the start and end at the same hotel (which is indicated by the integer 0), (10) ensures that the visiting order is from i to j, and (11) guarantees the arrival time of i is earlier than its close time. (12) states the possible values of x_{ijk}, where $x_{ijk} = 1$ meaning a journey from v_i to v_j, otherwise $x_{ijk} = 0$.

IV. GENETIC ALGORITHM FOR TOURISM ROUTE PLANNING

In this study, we applied Genetic Algorithm (GA) to solve the problem of tourism route planning with time constraints being considered. GA is a stochastic search algorithm inspired by the natural selection process [29]. Biologically inspired operators, including selection, crossover, mutation, and recombination, form the essential part of GA as a problem-solving strategy for solving optimization and search problems [30].

In a general GA, the candidate solutions to a specific problem are called chromosomes, which are encoded as fixed vectors and allow the evolution and reproduction of a new generation. A subset of all the possible (encoded) solutions is called population. In each generation, the fitness of each chromosome is calculated to measure how well the objective function is optimized. Chromosomes with higher fitness values are stochastically selected from the current population, and each chromosome's genome is altered (recombined and mutated) to iteratively create subsequent generations. GA will be terminated if a satisfactory fitness level is reached or the maximum number of generations is reached.

Table 1 illustrates the terms in genetic algorithm and their meanings when mapped to tourism route planning problems. Fig.1 shows the working process of the general Genetic Algorithm.

Table 1 Reactive dyes used with their reactive systems and Colour Index numbers

GA Terms	Meanings in TRP Problem
Population	A subset of all possible routes
Chromosome (a.k.a individual)	A possible route (a permutation of all given places)
Gene	A place
Parents	Chromosomes in the mating pool
Offsprings (children)	Products of crossover
Fitness	How well the route optimizes the objective
Fitness function	The objective function that the problem is trying to optimize [30]

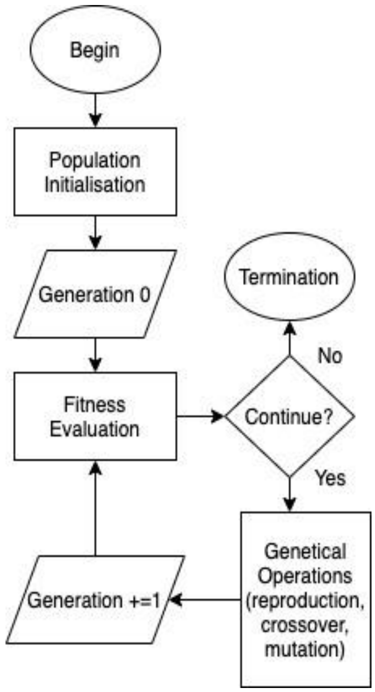


Fig.1. Working principle of Genetic Algorithm

A. Chromosome Representation

The way the chromosomes are expressed is closely related to the nature of the problem. In this study, we encode a set of places (hotels, attractions) as integer values and then arrange them into a chromosome. In particular, the hotel is represented by 0. Fig.2 shows an example of integer chromosome representation for a hotel and 10 attractions.

B. Initialisation

In the initialization stage, a feasible population that satisfies the constraints is randomly generated - the arrival time of an attraction must be earlier than its closing time.

C. Evaluation

After setting the weights of the three parts in the objective function (Equation (6)), the fitness value of a certain chromosome can be obtained by calculating the reciprocal of the result of Equation (6). A chromosome with a higher fitness value represents a better route that meets the preferences and constraints of tourists.

D. Selection

The selection operator chooses some of the parental chromosomes to produce successive generations by a fitness-based process [31]. A chromosome with a higher fitness value is more likely to be selected for reproduction.

To select the parent from the initial solution, we adopt two mechanisms to generate a new generation. One is called elitist selection [32], which is performed by retaining the best chromosomes in the current generation without modification and passing them to the successive generation. This mechanism ensures that the fitness of the solution will not be decreased from one generation to the next. Another selection mechanism is Roulette wheel selection [33]. The probability p_c of a chromosome c to be selected is associated with its fitness level f_c:

$$\boldsymbol{p_c} = \frac{\boldsymbol{f_c}}{\sum_{c=1}^{P} \boldsymbol{f_c}} \tag{13}$$

where P is the number of chromosomes in the population.

E. Crossover

The crossover in GA is similar to the biological crossover and recombination of chromosomes in cell meiosis [31]. This operation switches a subsequence of two of the selected chromosomes to create two offsprings. Crossover plays an important role in the genetic algorithm as it exploits the current search space to get a better fitness value in the next generation.

Here, the Partially Mapped Crossover (PMC) method [34] is used to perform crossover from the two selected parents. Specifically, PMC exchanges a subset of chromosomes from one parent to another with respect to the original position order.

F. Mutation

The mutation operator performs random flips, insertions, or deletions in the selected chromosomes [31]. Unlike selection and crossover, which are used to maintain genetic information of fitter chromosomes, mutation allows the algorithm to explore and expand current solution space, thereby preventing falling into local optima [35].

G. Fine-tune Operation

Since the *k*-day route is processed as a whole, crossover and mutation operations are conducted across sub-routes, which ensures the global optimum, but the sub-route for each day

Place	THE GRAND SUITES AT FOUR SEASONS	Maritime Museum	Archives of Macao	Cathedral	Tap Seac Gallery	Tam Kong Temple	SkyCab	Senado Square	Na Tcha Temple	Flora Garden	Casa Garden
Chromosome	0	6	2	8	4	5	1	10	3	9	7

Fig.2. An example of chromosome representation

may become sub-optimal since the optimal sequence within one sub-route may not be kept. Therefore, a fine-tune operation is required to repair sub-optimal sub-routes. Specifically, we implement a lightweight optimization on each sub-route.

V. EXPERIMENTS AND RESULTS

To analyze the feasibility of the proposed genetic algorithm, we conducted experiments using real information from tourist attractions in Macau. In this section, we will demonstrate how to effectively apply a genetic algorithm to plan a three-day itinerary for Macau tourists.

A. Dataset

The data used in this paper is obtained from the official website of the Macao Government Tourism Office (www.macaotourism.gov.mo), including 75 hotels and 100 attractions. Table 2 shows examples of attractions.

Table 2. Examples of attractions

Name	Latitude	Longitude	Open time	Close time	Suggested stay time (in minutes)
St. Francisco Barracks	22.2079215	113.547739	0:00 am	23:59 pm	75
Lin Fong Temple	22.209949	113.547749	7:00 am	17:00 pm	22
Pou Tai Sin Un	22.161169	113.551528	9:00 am	18:00 pm	45
Arts Garden	22.1906479	113.549078	6:00 am	23:59 pm	45
One Central Macau	22.1852296	113.547014	10:00 am	23:00 pm	90

B. Parameter Setting

The proposed genetic algorithm for tourism route planning has two types of parameters, 1) the weights of three parts in the objective function, and 2) genetic parameters (i.e., individual size, population size, the total number of generations, crossover rate, and mutation rate).

For the first type of parameters, considering the geographical proximity between some pairs of attractions, we assign a higher weight to the transportation cost in Equation (6) in the experiments. Specifically, we set the weights for transportation cost, waiting for cost, and delay cost as 20, 2, and 1, respectively. The weight can be flexibly changed according to the user's preference for the three objectives.

As for genetic parameters, in general, the individual size is set to 20, which is the total number of attractions selected by the tourist. For other parameters, we only provide a set of assignments to give an example for a case study: the population size is 200, the total number of generations is 500, the crossover rate is 0.8, and the mutation rate is 0.02.

C. Experiment Results

In this part, we demonstrate two cases (Fig.3 and 4) using the proposed genetic algorithm for tourism route planning and compare the suggested routes with and without the fine-tune operation (as described in Section 4.7). Specifically, we list the detailed schedules of three days with the table on the left-hand side and show the corresponding routes on the right. The routes in the same color represent the visiting places and orders for the same day. By comparing the generated routes in the upper and lower row, we can have an intuitive comparison between plans obtained without and with the fine-tune operation.

a) Case I

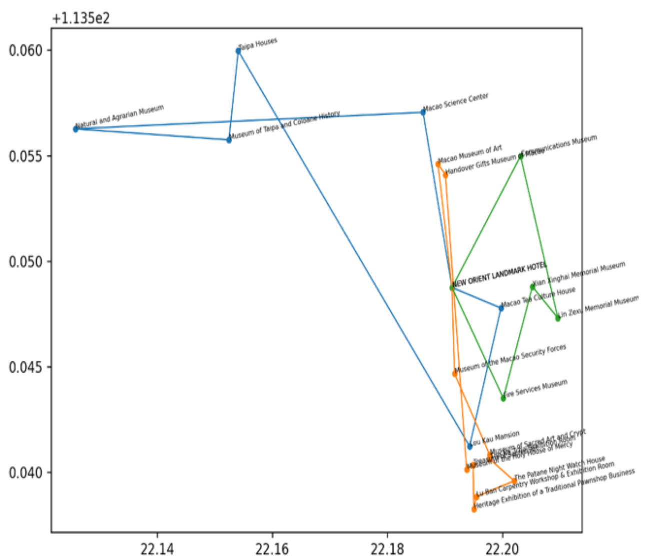
Fig.3(a) shows the scheduled timetable and route generated by the proposed multi-objective genetic algorithm without using the fine-tune operation, while Fig.3(b) shows the result by the algorithm using the fine-tine operation. The two timetables indicate the visit orders and the suggested time schedules for each place, while the route maps use different colors to visualize the 3-day itinerary. Comparing the time cost for transportation of these two plans, it can be seen that the inclusion of the fine-tune operation can reduce 1 minute (from 69 mins in Fig.3(a) to 68 mins in Fig.3(b)) though they both took 12 minutes to wait for the Museum of Sacred Art and Crypt to open (highlighted by the red rectangles). Although insignificant in terms of saving time (1 minute), the routes obtained by applying the fine-tuning operator improve the user experience because the route in Fig.3(b) is smoother than the route in Fig.3(a). Specifically, there is less cross path in the routes generated with fine-tune operation, and tourists are able to ***visit*** places in the same direction.

b) Case II

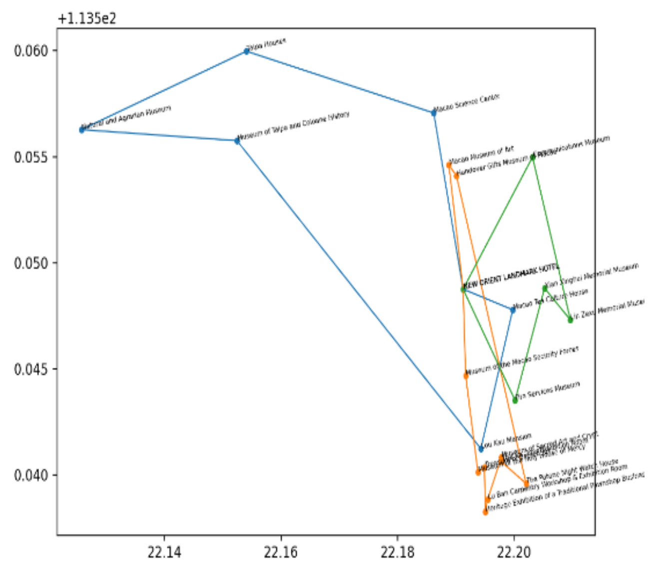
Comparing the results in Figures 4(a) and 4(b), it can be seen that the itinerary generated by the GA with using the fine-tune operation (Fig.4(b)) perform better: 1) it has a reduced transportation time cost (from 66 mins in Fig.4(a) to 65 mins in Fig.4(b), 2) there is no need to waste time waiting for Treasure of Sacred Art to open (highlighted by red rectangles), and 3) the route is smoother.

Day	Place	Transmit time	Arrive at	Suggested stay time	Leave at	Open time	Close time
	NEW ORIENT LANDMARK HOTEL	/	/	/	/	/	/
	Macao Tea Culture House	3	9:03	22	9:25	9	19
	Lou Kau Mansion	3	9:28	45	10:13	9	19
1	Taipa Houses	11	10:24	120	12:24	10	19
	Museum of Taipa and Coloane History	2	12:26	45	13:11	10	18
	Natural and Agrarian Museum	7	13:18	120	15:18	10	17
	Macao Science Center	16	15:34	120	17:34	10	18
	NEW ORIENT LANDMARK HOTEL	/	/	/	/	/	/
	Museum of the Macao Security Forces	1	9:01	45	9:46	9	18
	Museum of Sacred Art and Crypt	2	9:48	45	10:45	10	18
	The Na Tcha Exhibition Room	1	10:46	37	11:23	10	18
	The Patane Night Watch House	2	11:25	22	11:47	10	18
2	Lu Ban Carpentry Workshop & Exhibition Room	2	11:49	37	12:26	10	18
	Heritage Exhibition of a Traditional Pawnshop Business	1	12:27	37	13:04	10	19
	Treasure of Sacred Art	1	13:05	45	13:50	10	17
	Museum of the Holy House of Mercy	1	13:51	45	14:36	10	17
	Handover Gifts Museum of Macao	4	14:40	90	16:10	10	19
	Macao Museum of Art	1	16:11	120	18:11	10	19
	NEW ORIENT LANDMARK HOTEL	/	/	/	/	/	/
	Communications Museum	4	9:04	45	9:49	9	18
3	Lin Zexu Memorial Museum of Macao	3	9:52	45	10:37	9	17
	Xian Xinghai Memorial Museum	2	10:39	45	11:24	10	17
	Fire Services Museum	2	11:26	90	12:56	10	18
Total time		Transportation: 69	Waiting: 12				

Day	Place	Transmit time	Arrive at	Suggested stay time	Leave at	Open time	Close time
	NEW ORIENT LANDMARK HOTEL	/	/	/	/	/	/
	Macao Tea Culture House	3	9:03	22	9:25	9	19
	Lou Kau Mansion	3	9:28	45	10:13	9	19
1	Museum of Taipa and Coloane History	11	10:24	45	11:09	10	18
	Natural and Agrarian Museum	7	11:16	120	13:16	10	17
	Taipa Houses	8	13:24	120	15:24	10	19
	Macao Science Center	9	15:33	120	17:33	10	18
	NEW ORIENT LANDMARK HOTEL	/	/	/	/	/	/
	Museum of the Macao Security Forces	1	9:01	45	9:46	9	18
	Museum of the Holy House of Mercy	2	9:48	45	10:45	10	17
	Treasure of Sacred Art	1	10:46	45	11:31	10	17
	Heritage Exhibition of a Traditional Pawnshop Business	1	11:32	37	12:09	10	19
2	Lu Ban Carpentry Workshop & Exhibition Room	1	12:10	37	12:47	10	18
	Museum of Sacred Art and Crypt	1	12:48	45	13:33	10	18
	The Na Tcha Exhibition Room	1	13:34	37	14:11	10	18
	The Patane Night Watch House	2	14:13	22	14:35	10	18
	Handover Gifts Museum of Macao	5	14:40	90	16:10	10	19
	Macao Museum of Art	1	16:11	120	18:11	10	19
	NEW ORIENT LANDMARK HOTEL	/	/	/	/	/	/
	Communications Museum	4	9:04	45	9:49	9	18
3	Lin Zexu Memorial Museum of Macao	3	9:52	45	10:37	9	17
	Xian Xinghai Memorial Museum	2	10:39	45	11:24	10	17
	Fire Services Museum	2	11:26	90	12:56	10	18
Total time		Transportation: 68	Waiting: 12				



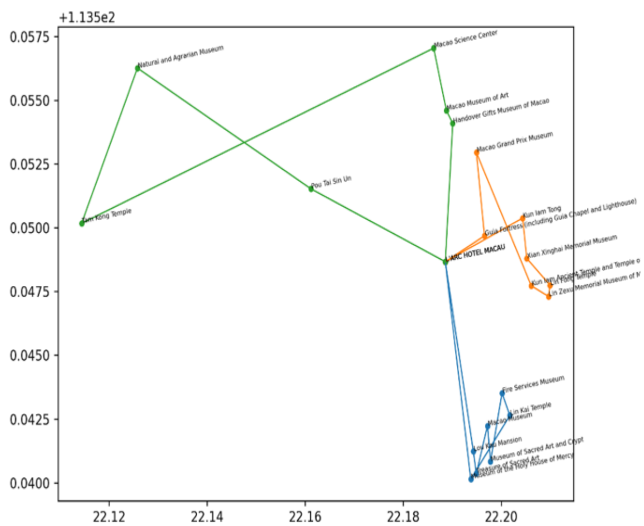
(a) Schedule timetable and route (without using the fine-tune operation)



(b) Schedule timetable and route (using the fine-tune operation)

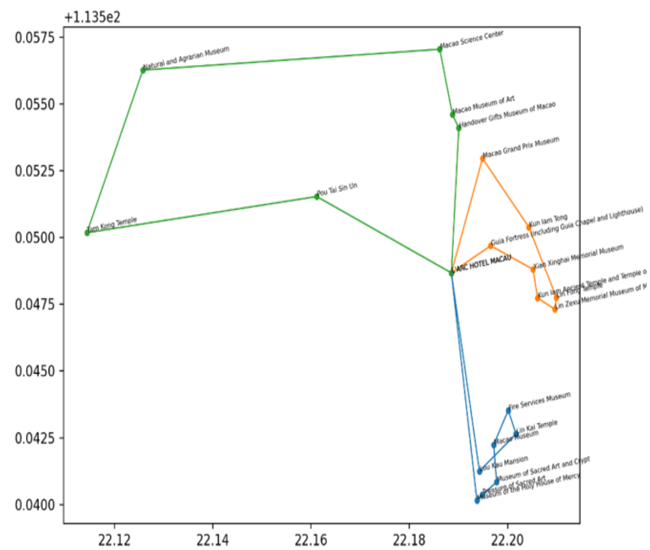
Fig.3. Results for Case I

Day	Place	Transmit time	Arrive at	Suggested stay time	Leave at	Open time	Close time
1	L'ARC HOTEL MACAU	/	/	/	/	/	/
	Lou Kau Mansion	3	9:03	45	9:48	9	19
	Treasure of Sacred Art	1	9:49	45	10:45	10	17
	Macao Museum	1	10:46	120	12:46	10	19
	Museum of Sacred Art and Crypt	1	12:47	45	13:32	10	18
	Fire Services Museum	1	13:33	90	15:03	10	18
	Lin Kai Temple	1	15:04	22	15:26	7	17
	Museum of the Holy House of Mercy	3	15:29	45	16:14	10	17
2	L'ARC HOTEL MACAU	/	/	/	/	/	/
	Kun Iam Tong	4	9:04	60	10:04	7	17
	Xian Xinghai Memorial Museum	1	10:05	45	10:50	10	17
	Lin Fong Temple	2	10:52	22	11:14	7	17
	Lin Zexu Memorial Museum of Macao	1	11:15	45	12:00	9	17
	Kun Iam Ancient Temple and Temple of City God	1	12:01	22	12:23	7	18
	Macao Grand Prix Museum	4	12:27	120	14:27	10	18
	Guia Fortress	1	14:28	60	15:28	0	24
3	L'ARC HOTEL MACAU	/	/	/	/	/	/
	Pou Tai Sin Un	7	9:07	45	9:52	9	18
	Natural and Agrarian Museum	9	10:01	120	12:01	10	17
	Tam Kong Temple	4	12:05	22	12:27	8	18
	Macao Science Center	19	12:46	120	14:46	10	18
	Macao Museum of Art	1	14:47	120	16:47	10	19
	Handover Gifts Museum of Macao	1	16:48	90	18:18	10	19
Total time		Transportation: 66	Waiting: 11				



(a) Schedule timetable and route (without using the fine-tune operation)

Day	Place	Transmit time	Arrive at	Suggested stay time	Leave at	Open time	Close time
1	L'ARC HOTEL MACAU	/	/	/	/	/	/
	Lou Kau Mansion	3	9:03	45	9:48	9	19
	Lin Kai Temple	2	9:50	22	10:12	7	17
	Fire Services Museum	1	10:13	90	11:43	10	18
	Macao Museum	1	11:44	120	13:44	10	19
	Museum of Sacred Art and Crypt	1	13:45	45	14:30	10	18
	Treasure of Sacred Art	1	14:31	45	15:16	10	17
	Museum of the Holy House of Mercy	1	15:17	45	16:02	10	17
2	L'ARC HOTEL MACAU	/	/	/	/	/	/
	Guia Fortress	3	9:03	60	10:03	0	24
	Xian Xinghai Memorial Museum	3	10:06	45	10:51	10	17
	Kun Iam Ancient Temple and Temple of City God	1	10:52	22	11:14	7	18
	Lin Zexu Memorial Museum of Macao	1	11:15	45	12:00	9	17
	Lin Fong Temple	1	12:01	22	12:23	7	17
	Kun Iam Tong	2	12:25	60	13:25	7	17
	Macao Grand Prix Museum	3	13:28	120	15:28	10	18
3	L'ARC HOTEL MACAU	/	/	/	/	/	/
	Pou Tai Sin Un	7	9:07	45	9:52	9	18
	Tam Kong Temple	12	10:04	22	10:26	8	18
	Natural and Agrarian Museum	4	10:30	120	12:30	10	17
	Macao Science Center	16	12:46	120	14:46	10	18
	Macao Museum of Art	1	14:47	120	16:47	10	19
	Handover Gifts Museum of Macao	1	16:48	90	18:18	10	19
Total time		Transportation: 65	Waiting: 0				



(b) Schedule timetable and route (using the fine-tune operation)

Fig.4. Results for Case II

VI. CONCLUSION

Intelligent tourism route planning (TRP) has become an increasingly active research area in interdisciplinary fields such as computer science, data mining, optimization, and artificial intelligence. This paper addresses the problem of automatic itinerary generation for multi-day trips considering time constraints in reality, such as the operation time window of attractions and stay lengthy. We proposed a multi-objective optimization method based on a genetic algorithm with an extra local fine-tune operation for flexible and user-experience-oriented travel route planning. The empirical results of applying the proposed method to scenic spots in Macau show that it can effectively provide routes and schedules for multi-day trips. Future research can be extended to include the themes of attractions, tourist interests, and real-time traffic conditions into the tourism routes planning.

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