Sightseeing Guidance System to Maximize Satisfaction Using Real-Time Spot Information

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Abstract

This study proposes a personalized sightseeing planning system that optimizes travel routes to maximize tourist satisfaction considering cost and time constraints. The proposed mathematical model considers the places the tourist wants to visit, cost, and time available and recommends the optimal number of places that can be visited and the shortest routes to these places. The proposed system could successfully suggest local tourist spots that can be visited in the given time and budget. We believe that our study makes a significant contribution to the literature because travelers at present have to rely on information available from websites, guidebooks, social networking sites, or from family and friends to gather information of places they plan to visit. Such information may be brief or need not be up-to-date as real-time factors like weather, seasons, temperature, time of day, and crowding or recent attractions added may not be available. Further the model can be easily adopted by tourism industry worldwide, while the tourists receive reliable and accurate travel advise to enhance the travelling experience.

Keywords: Sightseeing guidance system, Mathematical optimization problem, Operations research

I. INTRODUCTION

Recent developments in transportation networks and modes such as railways and airlines have made it easy to travel worldwide. A reliable and accurate source of information can enhance the experience and satisfaction levels of tourists. While websites, guidebooks, and social networking services may briefly introduce individual spots, their information need not be up-to-date.

In recent years, it has been observed that an increasing number of tourists with similar preferences plan their trips in small groups. The purpose of travel (trip type) can vary between individuals and groups and include nature tourism, outdoor experiences, visiting theme parks, historical and cultural sightseeing, sampling the local cuisines, city sightseeing, relaxing in hot springs, and shopping. However, external factors can affect satisfaction even if a trip is planned and implemented according to personal preferences. For example, in nature tourism, satisfaction depends on factors such as season, weather, temperature, time of day, and crowding. Similarly, when the purpose of a trip is to experience gourmet food, tourists' satisfaction level will be low if the restaurant is closed, the menu is not in season, or the prices are high. Therefore, it is necessary to have a source that provides the latest information on ever-changing sightseeing spots (including facilities and stores) in real-time to maximize satisfaction. Tourists also have various constraints, such as time and cost, within which they expect to maximize their traveling experiences [1]–[3].

Thus far, much research has been conducted on the development of travel guidance systems aimed at optimizing costs and improving satisfaction: In Reference [4], Tsuchiya discusses the information management model using crawling/analyzing technology to retrieve information diffused on the internet and proposes a local information platform that predominantly collects sightseeing information in the Suwa area of Nagano Prefecture. In Reference [5], Hasuike proposes versatile and interactive route planning for sightseeing under various conditions considering the constraints of required traveling times and the total satisfaction of sightseeing activities, which are time-dependent. In Reference [6], Kourouthanassis presents a mobile augmented reality (MAR) travel guide, which supports personalized recommendations. They reported the development process and devised a theoretical model that explores the adoption of MAR (mobile augmented reality) applications based on the impact of tourists' emotions. Nevertheless, the authors of this study were unable to find research focused on a sightseeing guidance system that uses real-time spot information (weather, temperature, congestion, satisfaction, etc.).

Therefore, this study proposes a sightseeing plan system that optimizes travel routes to maximize tourist satisfaction. Our proposed system has the following functions:

- Present sightseeing routes in line with tourists' preferences
- Present sightseeing plans that maximize tourists' satisfaction within their time and cost constraints
- Present alternate plans in real-time in response to various conditions such as worsening weather, suspension of transport networks, and change in plans due to urgent business

The system takes desired trip type, acceptable time (expected departure and arrival times), and acceptable cost (amount of money they are willing to spend at each tourist spot) as input and presents a sightseeing plan that maximizes user satisfaction within the given constraints. In the event of unforeseen circumstances, such as worsening weather, travel delays, and closure of tourist spot facilities, the system immediately reorganizes the routes in unforeseen circumstances and suggests a new optimal plan considering the above factors.

The system immediately reorganizes the routes allowing tourists to enjoy vacations even in an unfamiliar place and serves as a tool to support the tourism industry.

II. SYSTEM SPECIFICATIONS

For realizing this system, it is essential to obtain real-time information such as weather, temperature, traffic situation, and congestion at the tourist spot; this study assumes that in the near future, all tourist spots will have sensors to acquire such information and communication networks to disseminate it.

This study used the Doto district in Eastern Hokkaido, Japan, to test the proposed system. Hokkaido is one of the four major islands that constitute the Japanese archipelago and is located in the northern part of Japan (Fig 1). In the "Prefecture Attractiveness Ranking" by the Brand Research Institute [7], it has been selected as number 1 for 13 consecutive years. It ranks first in terms of popularity of tourism and products, and third in terms of degree of satisfaction with living. Furthermore, it is highly evaluated for motivation.

Doto is in the eastern region of Hokkaido (Areas F, G, and H shown in Figure 2. It is blessed with abundant nature and delicious food. Doto houses world-renowned sites with breathtaking scenery and many attractive tourist spots such as Shiretoko Peninsula and Kushiro Marsh. With two national parks and a World Natural Heritage Site, it is one of the most popular areas in Japan and attracts tourists year-round. In addition, it has abundant scenic beauty year-round, and tourists can enjoy delicious food, hot springs, and the vastness of nature.

However, because it has many famous tourist spots and unexplored locales across its vast area of 31,000 km^2, planning a trip to Doto can be difficult for beginners; therefore, it was considered a suitable study target. To verify the system's accuracy, we added 100 fictional spots in addition to the existing ones.

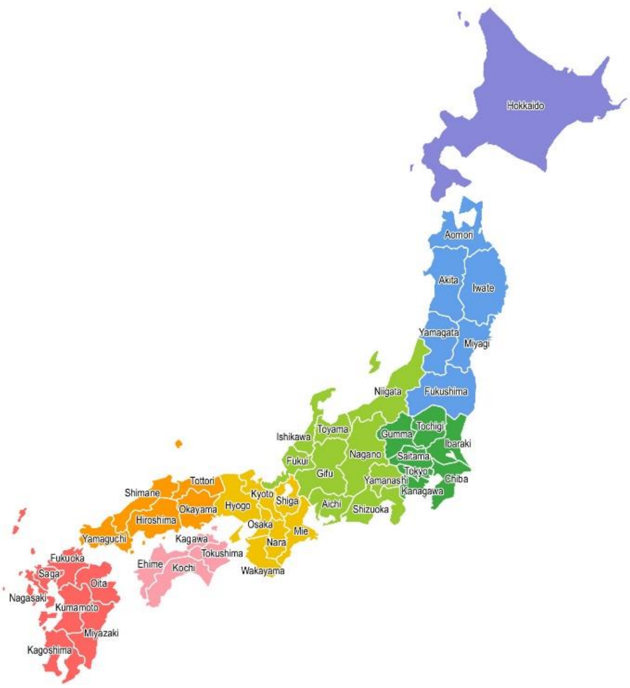


Figure 1: The map of Japan

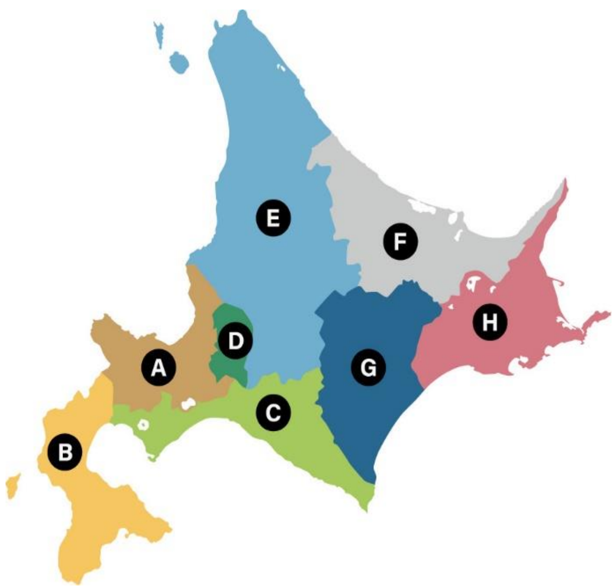


Figure 2: The map of Hokkaido (Doto areas F, G, and H)

Below are some of the popular tourist spotss in Doto.

(1) Tancho Sanctuary

Wild red-crowned cranes gathering at the feeding ground can be observed outdoors or from the nature center through a telescope.

(2) Kushiro Marsh

Kushiro Marsh is Japan's largest marsh and is located in Kushiro Plain, Hokkaido. The area covers about 26,000 ha, of which 7,863 ha in the center is a Ramsar Convention-registered wetland.

(3) Lake Mashu

Lake Mashu is known globally for its high transparency and is called a mysterious lake.

(4) Sunset from Nusamai Bridge

Kushiro’s sunset was once considered one of the three major sunset attractions worldwide. Even now, the evening scenery attracts many tourists.

Figure 3: Popular tourist spots in Doto

A. System Overview

Based on the user input information, such as time limit, hobbies, and preferences, and real-time information, such as date and time, weather, and congestion, the route that maximizes the total satisfaction is derived for each tourist spot using a mathematical optimization method. The following is the operation flow of this system.

1. Input user's travel preferences (restrictions and likes)
2. Generate satisfaction and map data based on input data
3. Derive route with maximum satisfaction using a mathematical model
4. Check the integrity of the derived route
5. Output proposed sightseeing route

The following subsections describe the types and structures of the data used and the specific operation of the system.

B. Data Structure

This system requires basic information on tourist spots and map data connecting tourist spots.

Basic information of tourist spots includes the name of the spot, area to which the spot belongs, opening/closing time, gourmet information, average staying time, cost per person, and satisfaction data. Satisfaction data for each tourist spot consists of a base value (attractiveness) that differs across seasons and an attractiveness adjustment coefficient that considers external factors such as weather, congestion, and user preferences. The attractiveness adjustment coefficient varies significantly depending on the characteristics of the tourist spot. Table 1 shows an example of the attractiveness of a tourist resort in summer and the attractiveness adjustment coefficient.

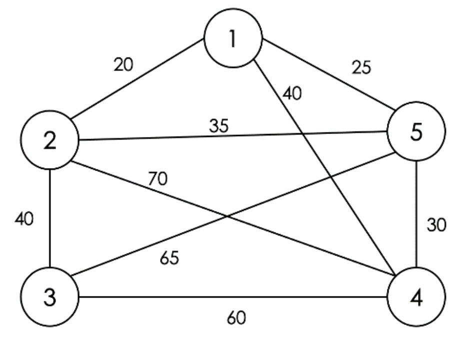
Table 1: Example of attractiveness

		Weather				Purpose of travel				
Tourist spot	Attractiveness	Sunny	Cloudy	Rainy	Snowy	Nature	Food	Culture	Shopping	Activity
The Lake Mashu	1.8	2	1.8	1.2	0.8	2	0.7	1	1	0.8
Washo Market	1.4	2	2	2	2	0.1	2	1.2	2	0.1
Ainu village	1.4	2	1.8	1.4	1.6	1	1.2	2	0.3	1.4

Here, the basic attractiveness of each tourist spot in Table 1 was assigned according to the evaluation values of various information magazines that are tourist guides and as per assessments of tourist sites.

The map data are represented by a graph model such that each vertex and edge correspond to each tourist spot, and the road connecting them, respectively. The travel time between tourist spots was weighted on each edge of the map data. The map data consisted of a two-dimensional array data structure.

The two-dimensional array representing an example map in Figure 4 is shown below.



$$A = \begin{pmatrix} 0 & 20 & 0 & 40 & 25 \\ 20 & 0 & 40 & 70 & 35 \\ 0 & 40 & 0 & 60 & 65 \\ 40 & 70 & 60 & 0 & 30 \\ 25 & 35 & 65 & 30 & 0 \end{pmatrix}$$

Figure 4: Example of a map data

C. Data Entry

To use this system, the user enters the information by following the steps below:

1. Departure and final arrival points
2. Departure and arrival time
3. Number of tourers
4. Desired plan
5. Desired tourist spot
6. Desired tourist area

The system calculates the time that can be spent sightseeing based on the departure and arrival times. The desired plan lets tourists select all the wishes from the five categories of "nature," "food," "culture," "shopping," and "activity." After Step 4, the systems' users will be presented with a list of popular and representative tourist spots. They can choose any number of places. If the number of tourist spots selected is too large to make a realistic plan, they will be prompted to re-enter their selections. Furthermore, if a small number of tourist spots are selected, the most popular ones are automatically recommended. The desired sightseeing area is specified if tourists want to visit a place far away from the departure point.

D. Determining Satisfaction

The system calculates the degree of satisfaction when visiting tourist spots based on the desired locations entered by the user and their real-time information. The degree of satisfaction of each tourist spot is obtained by multiplying the attractiveness for each season by the attractiveness adjustment coefficients derived from the real-time tourist spot information. If real-time information shows that the tourist spot is very crowded, the calculated degree of satisfaction is halved. Thus, even if the attractiveness of several tourist spots is the same, their final satisfaction will differ significantly depending on the user's likes and real-time information.

E. Map Generation

The system creates a two-dimensional array graph data using the two-dimensional array map data and the duration of stay from the user information. The map data are updated by integrating the travel time between tourist spots and the stay time at each tourist spot on the map data. In this process, the stay time at the next tourist spot is added to the travel time information between the tourist spots assigned to the edges of the map.

III. OPTIMAL SOLUTION DERIVATION

After receiving basic data from the user and constructing the map data, the optimum solution is derived by solving the following mathematical optimization problem.

A. Mathematical Optimization

In mathematical optimization, a mathematical model comprising a set of mathematical equations is used to determine the most desirable (optimal) solution. A mathematical model consists of three elements: variables, objective functions, and constraints. The objective function is the mathematical equation that should be solved to find the optimal solution. The constraint condition defines the upper and lower limits of the values that the variables can take. If we imagine these in a vector space, the constraint condition is the point that reaches the farthest in the direction of travel in the space surrounded by the wall.

B. Mathematical Model

The purpose of this study is to maximize traveler satisfaction, and this section describes the formulated mathematical model to achieve this. The mathematical model is expressed using PuLP, which is a module for mathematical optimization problems in Python. For the optimum solution derivation, the CBC solver in PuLP was used [8], [9]. The CBC solver can be applied only to linear optimization problems, in which the objective function and constraints are linear equations. Therefore, the problem of deriving the tourist route that maximizes the satisfaction level is essentially similar to the traveling salesman problem (the problem of finding the shortest path through all vertices). However, it differs from the traveling salesman problem in that the objective function is to maximize satisfaction, and it is not necessary to visit all the vertices.

Thus, this problem is formulated as follows.

$$Maximize \quad \sum_{i=0}^{N}\sum_{j=0}^{N} x_{ij} \times sf_{ij}$$

Here, N is the number of tourist spots, vertex number '1' is the departure point, and N is the final arrival point. When moving from tourist spot i to j, x_{ij} is 1; otherwise, it is 0. sf_{ij} is a two-dimensional array storing the attractiveness of tourist spot j. The inner product of x_{ij} and sf_{ij} are the goals to be maximized.

$$\sum_{j=1}^{N} x_{1j} = 1 \qquad (1)$$

$$\sum_{i=1}^{N} x_{iN} = 1 \qquad (2)$$

Equations 1 and 2 are conditions that set the number of movements from the departure point and to the final arrival point to exactly one, respectively. Thus, the departure and final arrival points are included in the route.

$$x_{i1} = 0, \qquad i = 2, 3, \dots, N-1 \qquad (3)$$

$$x_{Nj} = 0, \qquad j = 2, 3, \dots, N-1 \qquad (4)$$

Equations 3 and 4 satisfies the constraints that travelers do not move to the place of departure and from their final arrival point, respectively.

$$\sum_{i=0}^{N}\sum_{j=0}^{N} x_{ij} \times cs_{ij} \leq C \qquad (5)$$

$$\sum_{i=0}^{N}\sum_{j=0}^{N} x_{ij} \times ts_{ij} \leq T \qquad (6)$$

Equation 5 ensures that the total cost of visiting tourist spots does not exceed the upper limit set by the user. Here, cs_{ij} is the sum of the cost of traveling from tourist spot *i* to *j* and indicates the cost of visiting tourist spot *j*.

Equation 6 indicates that the total time required for sightseeing according to the schedule is within the available time set by the user.

$$\sum_{i=1}^{N} x_{if} = 1, \; f \in \{2, 3, \dots, N-1\} \qquad (7)$$

Equation 7 satisfies the constraint that the user visits the desired tourist spot *f*.

$$\sum_{j=1}^{N} x_{ij} = \sum_{j=1}^{N} x_{ji}, \quad i = 2, 3, \dots, N-1 \qquad (8)$$

Equation 8 satisfies the constraint that the number of movements to and from the tourist spot *i* are equal.

$$q_i - q_j + 1 \leq (N-1)(1 - x_{ij}) \qquad (9)$$

Equation 9 satisfies the Miller-Tucker-Zemlin (MTZ) formulation constraint [10]. Here, q_i denotes the order of visiting the tourist spot i $(1 \leq i \leq N)$ desired by the user. This is often used in the traveling salesman problem to prevent the selection of routes that include loops [11].

Unlike the traveling salesman problem, the optimal route found in this study does not require visiting all vertices. Therefore, the following constraint is further added.

$$\sum_{i=0}^{N}\sum_{j=0}^{N} x_{ij} = q_N - 1 \qquad (10)$$

Equation 10 satisfies the constraint that the number of movements between tourist spots is one less than the number of tourist spots that the user intends to visit.

IV. SYSTEM OPERATION EXPERIMENT

This section verifies the performance of the proposed system and the accuracy of the derived solution. In this experiment, 100 tourist spots were assumed in the eastern Hokkaido area, and attractiveness was set for each tourist spot. The map data were created using Google Directions API [8] and travel time between tourist spots acquired.

The input data used in this experiment are presented in Table 2. In this experiment, it was assumed that congestion did not occur in any case.

The output results obtained for the three input cases are listed in Tables 3, 4, and 5.

Table 6 shows the satisfaction and calculation time of each output result. The calculation time may be very long, depending on the input. Therefore, we verified the accuracy of the approximate solution obtained when processing was interrupted for a certain period. We compared the satisfaction of the approximate and optimum solutions obtained when the calculation time was cut off at 10, 20, and 30 s for the processing of Case 1 [12].

The results of the experiment are presented in Table 7. The results show that the tourist route obtained by limiting the processing time had the same degree of satisfaction as the optimum route.

Table 2: Input items in the operation test

Input	Case 1	Case 2	Case 3
Departure point	Kushiro Station	Kushiro Station	Shibecha City
Arrival point	Ainu village	Meiji Park (Nemuro)	Shiretoko Five Lakes
Number of people	1	4	2
Budget	5,000 yen	10,000 yen	10,000 yen
Purpose of travel	Nature, Activity	Nature, Food	Food, Activity, Culture
Departure time	9:00	10:00	10:00
Arrival time	16:00	14:00	15:00
Weather	Sunny	Sunny	Cloudy
Desired tourist spot	None	None	Shibetsu Salmon Museum

Table 3: Output for case 1

Arrival time	Departure time	Tourist spot
-	9:00	Kushiro Station
9:56	10:56	Kottaro Marsh Viewpoints
11:20	11:30	Tancho Sanctuary
11:48	11:58	Tsurumidai Plain
12:29	13:02	Japanese Crane Reserve
13:15	14:15	Akan International Crane Center
13:48	13:58	Yuzuru Station
14:50	15:50	Akan Bokke
15:54	-	Ainu village

Table 4: Output for case 2

Arrival time	Departure time	Tourist spot
-	10:00	Kushiro Station
10:38	10:48	Kottaro Marsh Viewpoints
10:52	11:12	Tancho Sanctuary
12:25	12:45	Tsurumidai Plain
13:14	13:14	Japanese Crane Reserve
13:56	-	Akan International Crane Center

Table 5: Output for case 3

Arrival time	Departure time	Tourist spot
-	10:00	Shibecha City
10:54	11:19	Shibetsu Salmon Museum
11:26	11:56	Shibetsu Local Museum
12:43	12:43	Road to heaven (via)
13:16	13:26	Oronko Rock
13:36	13:56	Waterfall of Oshinkoshin
14:09	14:24	Furepe Falls
14:26	14:46	Shiretoko Nature Center
14:58	-	Shiretoko Five Lakes

Table 6: Satisfaction and processing time

Case	Satisfaction	Processing time [s]
Case 1	33.76	561.2
Case 2	19.86	17.1
Case 3	30.56	18.2

Table 7: Satisfaction with optimal and approximate solutions

Processing time [s]	Satisfaction
561.2	33.76 (Optimal)
10.0	31.86
20.0	32.96
30.0	32.70

V. CONCLUSION

We confirmed that the proposed system could recommend optimal sightseeing routes using real-time information from tourist spots. However, some challenges need to be addressed before the system can be operational.

First, considerable computational time was needed even when the tourist spot was not far from the departure point, which can be problematic when tourists face sudden problems. Though it can be resolved to some extent through approximate solutions, it is necessary to reduce the computation time to improve real-time practical applications.

The second challenge concerns improving the constraints involving meals. We expect the improved system can propose a plan that allows users to arrive at their preferred eatery at the desired time.

Finally, the model should be further developed to allow real-time information from actual sensors. It is necessary to address these challenges to achieve the final goal of operating this system at actual tourist spots.

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