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On-site Trip Planning Support System Based on Dynamic Information on Tourism Spots

Masato Hidaka [1,*], Yuki Kanaya [1,2], Shogo Kawanaka [1,2,3], Yuki Matsuda [1,2], Yugo Nakamura [1,3], Hirohiko Suwa [1,2], Manato Fujimoto [1,2] and Yutaka Arakawa [4,5] and Keiichi Yasumoto [1,2]

1 Nara Institute of Science and Technology, Nara 630-0192, Japan; yuukibb124@gmail.com (Y.K.); kawanaka.shogo.kp1@is.naist.jp (S.K.); yukimat@is.naist.jp (Y.M.); nakamura.yugo.ns0@is.naist.jp (Y.N.); h-suwa@is.naist.jp (H.S.); manato@is.naist.jp (M.F.); yasumoto@is.naist.jp (K.Y.)
2 RIKEN, Center for Advanced Intelligence Project AIP, Tokyo 103-0027, Japan
3 Research Fellowship for Young Scientists, Tokyo 102-0083, Japan
4 Faculty of Information Science and Electrical Engineering, Department of Advanced Information Technology, Kyushu University, Fukuoka 812-0053, Japan; arakawa@ait.kyushu-u.ac.jp
5 JST Presto, Saitama 332–0012, Japan
* Correspondence: hidaka.masato.hi3@is.naist.jp; Tel.: +81-743-72-5392

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Abstract: Recently, due to the drastic increase in foreign tourists coming to Japan, there has been a demand to provide smart tourism services that enable inbound tourists to comfortably enjoy sightseeing. To provide satisfactory experiences for tourists, it is desirable to provide tourist information in a timely manner by considering dynamic information, which is information that changes over time, such as current congestion information in destination spots and travel route information, in addition to static information, such as the preferences and profiles of tourists. However, in many existing systems, serious problems occur, such as (1) a lack of support for on-site use, (2) a lack of consideration of dynamic information, and (3) heavy burden on tourists. In this paper, we propose a novel system that can provide tourism plans for tourism spots in a timely manner. The proposed system consists of the following two key mechanisms: (A) A mechanism for acquiring preference information from tourists (including preference on dynamic information); (B) a curation mechanism for realizing on-site tourism. To demonstrate the effectiveness of the proposed system, we carried out evaluation experiments utilizing real tourism spots and simulations. As a result, we obtained the following primary findings: (1) On-site tourism spot recommendation is effective for tourists who do not make detailed tourism plans before sightseeing; (2) preference information for participants can be reflected in the tourism spot recommendation while massively reducing the burden on participants; (3) it is possible to obtain a higher satisfaction level than is achieved with model courses, which are often used for sightseeing.

Keywords: on-site tourism recommendation; dynamic information; acquisition of preference information; trip planning

1. Introduction

In visiting unfamiliar places within a limited timeframe, it is necessary to travel around to the tourism spots efficiently so as to achieve an optimally satisfying tourism experience [1]. There are many existing works on recommendation systems for trip planning [2], e.g., P-Tour [3], CT-Planner [4], Photo2Trip [5], and TripAdvisor [6]. Most of these systems recommend popular spots and routes before the user's tour begins. Even if sufficient information is collected before sightseeing and detailed planning is done in advance, dynamically changing information (dynamic information), such as the weather, the amount of traffic congestion, and temporary facility closures, cannot always be taken into consideration, and thus it may be necessary to change plans in an ad hoc manner.

For example, it can easily be assumed that congestion at major tourism spots results in it requiring a longer time to see them than expected, or that events scheduled on a rainy day are likely to be canceled. In such cases, tourists must spontaneously change their plans. Tourists sometimes do not acquire a detailed plan of how to get around an area's tourism spots before they begin sightseeing [7]. That is, many tourists know only the main spots that are popular. When a change is needed to select the next spot to visit, they must collect information on other spots while taking into account routes, time zones, weather, congestion, and personal preferences from the sightseeing they have experienced so far.

In our study, we examine the above-described process of "repeatedly deciding the next spot to visit during sightseeing" for on-site tour planning. It is difficult to plan an on-site tour efficiently. For example, when selecting the next spot, it takes time and effort to quickly and accurately obtain information about what kind of candidate spots are available. One way to get information on popular spots is to bring along a guidebook. This method is not reliable, as not all spots specifically match one's preferences, and it is also difficult to acquire seasonal event information. Even if the tourist is able to choose a spot to visit next, there is a possibility that he or she will be unable to reach it due to congestion, or it may be closed. Route selection in unfamiliar places also poses the risk of the tourist getting lost and needing to backtrack. Thus, there are multiple issues to solve in on-site trip planning.

In this paper, we propose an on-site trip-planning support system that efficiently recommends next spots to visit utilizing "on-site information", "tourist preferences", and "dynamic information". The proposed system consists of the following two component technologies: (1) A preference-information acquisition mechanism; (2) an on-site tourism-curation mechanism. The proposed system makes it possible to recommend tourism spots on site by compiling a tourist plan (through curation) according to individual preferences and the current situation at the tourism spot. The main contributions of this paper are summarized as follows:

- First, we propose a preference-information acquisition mechanism as the first elemental technology to build our proposed system. This mechanism shows that a tourist's preferences can be acquired with a high accuracy by combining a pair comparison method and conjoint analysis. To the best of our knowledge, there are no existing works applying a mechanism combining these methods in a trip-planning support system.
- Second, we develop an on-site tourism-curation mechanism as the second elemental technology. As far as we know, no existing system can reflect dynamic information such as time zone, weather, and congestion on site and in real time when recommending tourism spots. This mechanism provides tourist-attraction recommendations that are highly practical and result in high satisfaction for tourists by considering dynamic information, such as current location and crowdedness, from the characteristics of each tourism spot and the preference data of users. In our study, we confirm that this system can perform on-site real-time recommendation.
- Finally, to show the effectiveness of the proposed system, evaluation experiments are conducted under on-site tourism conditions and in simulated tourism situations. From these experiments, we obtain the following primary findings: (1) On-site recommendation is effective for tourists who do not usually make plans; (2) the preference-information acquisition mechanism can properly acquire the participant's preferences; (3) the on-site tourism-curation mechanism can obtain high tourist satisfaction compared with the popular model of general tourist courses.

The rest of this paper is organized as follows. Section 2 reviews the existing work related to this paper. Section 3 describes the requirements that must be fulfilled to realize our proposed system, and Section 4 presents our proposed on-site trip-planning support system. The evaluation experiment is described in Section 5. Finally, Section 6 concludes this paper.

2. Related Work

In this section, we explain the existing work related to this paper. First, we review the literature on tourism related to our research. Second, we describe an overview of previous research, focusing on existing tourism spot recommendation and planning methods for tourists. After that, we clarify the positioning of this paper.

2.1. Literature Review on Tourism

There are many studies that support tourism utilizing ICT (Information and Communication Technology). Buhalis et al. [8–10] discussed E-Tourism that adapts ICT to the travel and tourism industries. For example, Dimitrios et al. [11] discussed the role of social media in tourism. In addition, Ulrike et al. [12] discussed the role and impact of online travel reviews. Specifically, there are P-Tour [3], CT-Planner [4], Photo2Trip [5], and so on as examples of E-Tourism.

Urlike [13] focuses on the intelligent systems in tourism, takes a social science perspective, and reflects on how the social science of tourism can and should contribute to intelligent system design and evaluation. Intelligent systems in tourism include recommendation systems, context-awareness systems, search and mining of Web resources by autonomous agents, and ambient intelligence. In particular, they discuss the gaps in the literature in terms of studying tourism information searching and decision-making.

Additionally, Urlike et al. [14] discussed the difference between E-Tourism and smart tourism. They defined smart tourism as follows: "Smart tourism is defined as tourism supported by integrated efforts at a destination to collect and aggregate/harness data derived from physical infrastructure, social connections, government/organizational sources, and human bodies/minds in combination with the use of advanced technologies to transform that data into on-site experiences and business value-propositions with a clear focus on efficiency, sustainability, and experience enrichment."

That is, the difference between E-Tourism and smart tourism is that the travel phase of E-Tourism targets pre- and post-travel, while the travel phase of smart tourism is during the trip. In addition, the core technology of E-Tourism is the use of the website, while the core technology of smart tourism is the use of sensors and smartphones. In this paper, we propose a trip-planning system utilizing GPS-sensor-equipped smartphones on site (during trips), which falls under the category of smart tourism.

2.2. Existing Work on Recommendation of Tourism Spots

There are many existing works on the recommendation of tourism spots and trip planning. Shukla et al. [2] exhaustively surveyed these works and classified their recommendation systems into the following seven categories: (1) Multi-agent, (2) collaborative filtering, (3) content filtering, (4) hybrid, (5) social site, (6) social site with location information, and (7) route. In this section, we explain these seven categories in detail based on our study.

Recommendations from multiple agents (category 1) is a classical method in which agents recommend a sightseeing plan on the basis of set rules [15,16], which is also a limitation of this method. To put it simply, a rule is set to recommend a park if it is sunny and a museum if it rains. This method has disadvantages in that it takes time and effort to set rules.

Recommendation based on collaborative filtering (category 2) is a method of recommendation using information from other users whose behavior histories are similar to that of the target user [17,18]. Amazon's recommendation algorithm basically uses this algorithm. This method has the advantage of recommending spots that suit a user's preferences but are unexpected. Therefore, this method suffers from the cold start problem (cold start problem: In the recommendation algorithm represented by collaborative filtering, it is difficult to recommend items to new users who have little accumulation of evaluation [19]).

Recommendation based on content filtering (category 3) is a method that takes into consideration the degree of similarity between the candidate spot and the preferences of the user. For example, the algorithm recommends the old castle or church if a user answers "I like history", and the algorithm recommends the sea or park if a user answers "I like nature". This method has the advantage of matching the user's preferences, but also has the disadvantage of requiring time and effort for preference input and requiring follow-up when preferences change.

Hybrid recommendation (category 4) is a method of combining collaborative filtering, content-based filtering, and other approaches and aims to solve the problems of collaborative filtering recommendation methods [20,21]. This method has the advantage of reducing the impact of cold start problems, but also has the limitation of requiring time and effort to input preferences and requiring follow-up when preferences change.

Social recommendation (category 5) is a method of recommending based on data posted to a social networking service (SNS) [22]. Some social recommendations use data posted to SNSs that include location information (category 6). For example, an existing work used a photo posting site such as Flicker or a photo with a Geo-tag posted on an SNS to recommend a tourism spot by comparing the profiles of the tourists and the similarity of the spots visited in the past [5,23] using collaborative filtering. For example, the algorithm recommends similar natural spots if a user posts many mountains and sea photos, and the algorithm recommends similar historical spots if a user posts many old castle and church photos.

Furthermore, another category of existing studies proposes route recommendation methods that include multiple tourism spots [24–26] (category 7). These methods have the advantage of being less troublesome for users, but have the disadvantage of providing little diversity of tourism patterns. P-Tour [3] and CT-Planner [4], introduced in Section 2.1, are in this category.

2.3. Problem of Existing Work and Positioning of Our Work

As mentioned in Section 2.2, there is a lot of existing work on tourism spot recommendations and tourism programs, but there are still some serious problems. Table 1 shows a comparison between previous work and our work.

Table 1. Comparison with previous work related to our study.

Method	On-site		Reflects Preferences
	Current Location	Route to Current Location	
P-Tour [3]			✓
CT-Planner [4]			✓
Photo2Trip [5]			✓
TripAdvisor [6]	✓		
Google Maps [27]	✓		
This Work	✓	✓	✓

The first problem is that the existing work assumes that tourists do not use the recommendation system on site. The existing work assumes that the system is used only before the tourist goes to a tourism spot, and does not consider or reconsider recommendations while at the spot itself. However, most actual tourists collect information locally and, using that, consider where to go next, taking into consideration the route, time zone, weather, crowdedness, and their preferences from the places visited so far. Decisions are made on the spot [28,29]. Therefore, it is necessary for on-site trip-planning systems to be developed. There are services to search for the nearest tourism spot based on the GPS (Global Positioning System) information of a smartphone for on-site trip planning. However, they do not consider subsequent tourism plans and the like. For example, if a tourist performs a search again when he/she reaches the next place, there is a possibility that the spots recommended will have been previously visited or will have already been passed by. Some systems, such as P-Tour [3] and CT-Planner [4], set starting and goal points and recommend efficient routes. However, these systems also assume use before the tourist goes to the tourist area, and not use on site. Therefore, it is necessary to have on-site trip-planning methods that update the recommendation for the next spot to visit during a tour.

The second problem is unique to on-site trip planning. Most of the existing methods take into account the user's preferences, but do not take into account factors such as the route, time of day, weather, and degree of congestion. For example, it is likely that satisfaction varies depending on the opening hours and crowdedness of a spot. Moreover, there are places that can be enjoyed regardless of the weather, such as museums, but there are also places where satisfaction varies greatly depending on the weather, such as open cafes. In on-site trip planning, it is necessary to make recommendations according to the situation at that time. Therefore, it is necessary to make recommendations that take into consideration not only the preferences of tourists, but also dynamic information (information that changes dynamically with time), such as the degree of congestion or the weather at the moment.

The third problem is the burden on tourists. In on-site trip planning, since sightseeing has already begun when the tourist is at the tourism spot, it is necessary to reduce wasted time as much as possible. In the existing work, the method of acquiring information on tourist preferences from the tourism history data [17,18] and the method of direct input by tourists themselves [3] are adopted. The method of obtaining data from tourism history cannot cope with the cold start problem. The method of inputting data directly requires that the users clearly recognize their preferences themselves. Furthermore, unfamiliar tasks occur in which multiple elements are added to each other. This is a burden for the user. Therefore, it is necessary for the user's preferences to be ascertained in a more accurate manner that is less burdensome and more intuitive.

To construct an on-site trip-planning support system that efficiently recommends the next spot, the system must have the following improvements over the existing systems: (Condition 1) It must be on site; (Condition 2) it must be sensitive to the tourist's preferences and dynamic information; (Condition 3) it must acquire preferences while imposing a small burden on tourists.

3. System Requirements

In this section, we describe the requirements of the proposed system. We set six items as requirements, as shown in Table 2, based on the discussion in Section 2.

Table 2. Relationship between conditions and requirements.

Condition 1	<Requirement 1> Be a smartphone application
	<Requirement 2> Provide an efficient route
	<Requirement 3> Present multiple candidates
Condition 2	<Requirement 4> Reflect user preferences
	<Requirement 5> Consider dynamic information
Condition 3	<Requirement 6> Efficiently acquire user preferences

Since it is a condition that the system can be used on site while sightseeing (Condition 1), it is necessary that it can be used on a smartphone. Therefore, the system must be developed as a smartphone application <Requirement 1>. In addition, the recommended route must be efficient <Requirement 2>. Unlike existing methods of recommendation, which recommend a tourist destination before sightseeing, on-site tourism does not spend much time on route planning. Tourists are not familiar with the geography of tourist areas, so the route is likely to be inefficient if they try to visit the tourist areas in the desired order. A route that travels back and forth across the same place over and over again reduces the satisfaction of tourists. Therefore, in this system, it is necessary to recommend a next spot that does not have an inefficient route. Additionally, it is necessary to take into consideration that the choices made by tourists in on-site trip planning are not necessarily in line with preferences, but are dependent on the situation and mood. For example, even tourists who are usually more interested in eating and drinking than landscapes are unlikely to always want to go to restaurants throughout the day. Even if it does not suit their preferences, tourists might wish to be close to a spot where people gather. It is necessary to present multiple recommendation candidates so that tourists can choose according to the situation and mood at that time <Requirement 3>.

When making recommendations using tourist preferences and dynamic information (Condition 2), it is necessary to make recommendations according to personal preference <Requirement 4>. Under these circumstances, on-site trip planning is also required to consider dynamic information (i.e., congestion levels, weather changes, and temporary changes in business hours) <Requirement 5>. Thus, to recommend tourism spots according to personal preferences, it is necessary to acquire the preferences of each tourist.

As explained in Section 2.2, there is a cold start problem in the method of using the history of a tourism spot. Therefore, tourists need to input their preferences, but it is not easy to input preferences accurately while comparing the pros and cons of multiple attractions. Hence, to reduce the burden on tourists (Condition 3), a support method is needed to efficiently acquire the preferences of tourists <Requirement 6>.

4. Proposed System

In this section, we propose an on-site trip-planning support system that meets the six requirements mentioned in Section 3. First, we give an outline of the proposed system. Then, we explain a preference-information acquisition mechanism and an on-site sightseeing curation mechanism, which are two elemental technologies in the proposed system.

4.1. Outline

Figure 1 shows an overview of the proposed system. In the proposed system, a user preference is extracted before sightseeing using the preference-information acquisition mechanism and is stored in a user database (User DB). In addition, static and dynamic information of each tourism spot is collected using the existing system and accumulated in the spot database (Spot DB). Static information refers to the locations and features of tourism spots, opening hours, etc., and is collected by crawling tourist sites. Dynamic information refers to current crowdedness, weather, events, etc. of tourism spots, and is collected using a crowded-degree estimation system, weather APIs (application programming interface), participatory sensing, and so on. The on-site tourism curation mechanism uses the user information and tourism spot information stored in the two DBs (i.e., User DB and Spot DB) to extract tourism spots matching the preferences of tourists. After that, it recommends easily reachable tourism spots that exist on an efficient route by utilizing a distance/direction determination filter based on information of the current location and the destination. Thus, the on-site tourism curation mechanism can output multiple tourism spots according to the user's preferences, with an efficient route. We explain the preference-information acquisition mechanism and the on-site tourist curation mechanism in the following sections.

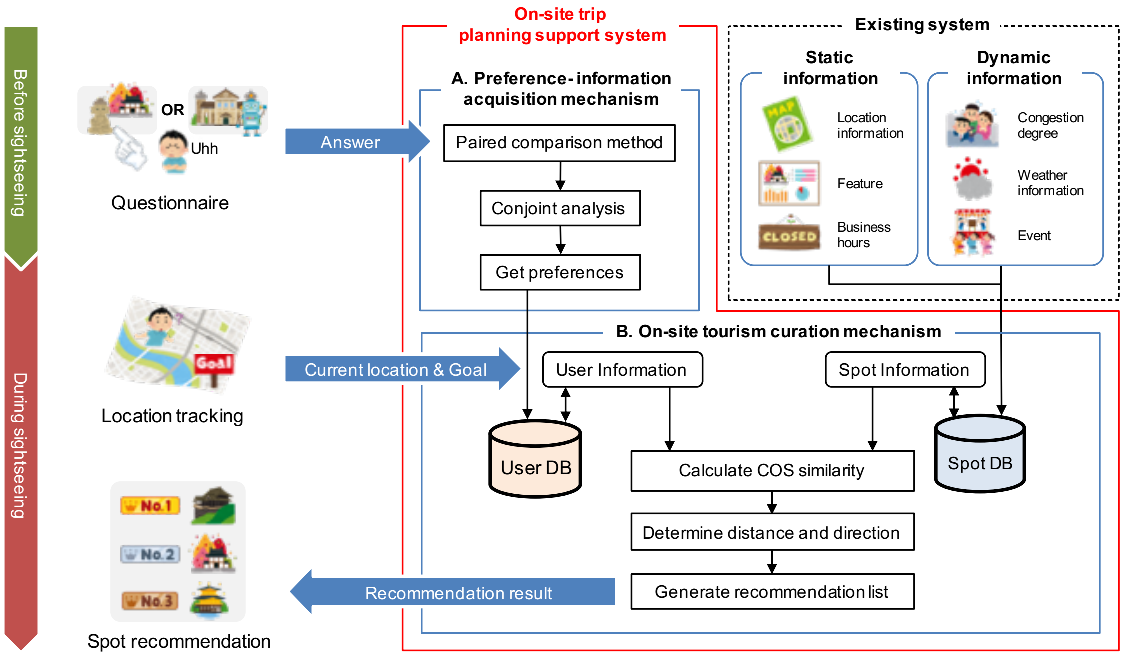

Figure 1. Overview of the proposed system.

4.2. Preference-Information Acquisition Mechanism

The preference-information acquisition mechanism acquires the user's preferences. In preference-information acquisition, it is required that the burden should be small and intuitive for the user, and the preference should be acquired accurately. This corresponds to <Requirement 6> explained in Section 3. In this paper, we propose a combination of paired comparison and conjoint analysis used in consumer questionnaire surveys. The flow of this method is as follows:

1. Prepare several tourism spots with different characteristics, such as "Japaneseness" (natural style of Japan), naturalness, and crowdedness.
2. Apply the number and type of preferences (= features of tourism spots) of tourists to the orthogonal chart, select one tourism spot with matching characteristics according to the corresponding orthogonal chart, and select a set of tourism spots. An orthogonal matrix is an array in which all combinations of the levels appear the same number of times in any two rows. The number of tests can be reduced by applying this property to the factor-level assignment table in the experimental design method.
3. Ask the user to indicate which group they like and how much they like it. This is called the paired comparison method [30], and the participant is presented with a pair of stimuli out of a plurality of stimuli to make it possible to evaluate or select the magnitude of a sensory impression or preference, etc. This is a method of quantifying value.
4. From the answers obtained in (3), we calculate the overall utility value for tourism spots. In addition, multiple regression analysis is performed using the overall utility values obtained here, and partial utility values are calculated from the features of each tourism spot. This is called conjoint analysis [31], where the utility (partial utility) for each attribute of the selection object, such as a product or service, and the preference order data for the product or service are used to obtain the overall utility for the selection object simultaneously.

In the proposed system, we selected the following five features for the tourism spots: (1) More Japanese-style or Western; (2) whether a spot is natural or artificial; (3) whether the price is expensive or reasonable; (4) whether the spot is popular or minor; (5) tolerance to crowded conditions. These items are selected from the top five things that foreign tourists who come to Japan report [7] as important in sightseeing. An orthogonal array is used in the design of the experiment, and the array shows combinations to find effective factors efficiently with the minimum number of experiments [32]. In our study, this property is used to obtain the user's preference from the answers to two levels (high or low) of five factors (Japaneseness, neutrality, price, popularity, and congestion). As a result of applying a five-factor two-level orthogonal array, it is possible to obtain a partial utility for five factors by performing eight one-pair comparisons for eight tourism spots. This partial utility is the user's preference for each factor.

4.3. On-Site Tourism Curation Mechanism

In on-site trip planning, it is required to meet <Requirement 2> to <Requirement 5> explained in Section 3. The flow of outputting the top n tourism spots is shown as follows:

1. Enter the user's preferences, current location, and destination.
2. Calculate the cosine (COS) similarity between user preferences and features of tourism spots. Then, arrange tourism spots in descending order of COS similarity and create an ordered list.
3. Exclude spots that are inefficient (spots that are far from the current location, or are not in the direction of the destination) from the list.
4. Display the top n items from the list.

The user selects one out of the top n tourism spots displayed and visits it. After sightseeing, the user can record the tourism spot visited by utilizing the check-in function. Here, we describe the method of "3. Exclude spots that are inefficient" in detail. This is to avoid going back and forth between the same places many times, and to prevent a situation where it is not possible to go from a start point to a goal point within the time limit. Specifically, spots that meet the following conditions are excluded:

1. **Already visited once during sightseeing**
   In addition to the current location and preferences of a user, there is additional information on the spots that users have already visited that day. As mentioned above, the system already has information on the tourism spots visited that day by the check-in function. With this information, spots that were visited already during sightseeing are excluded from the list.
2. **More than a certain distance from current location**
   Using the location information, calculate the spot's distance from the user and exclude from the list the tourism spots that are more than 500 m from the current location. This distance was determined based on the average distance between tourism spots in a model course used in our experiment (refer to Section 5.2).
3. **Be in a direction opposite to the direction from tourist's current location to the goal location**
   When the angle between the tourism spot, current location, and recommendation candidate goal point is obtuse (more than 90 degrees), it is regarded as a tourism spot that exists in the opposite direction of the goal point, and is excluded from the list. For example, candidates A and B shown in Figure 2 are recommended candidates, but candidate C is excluded.

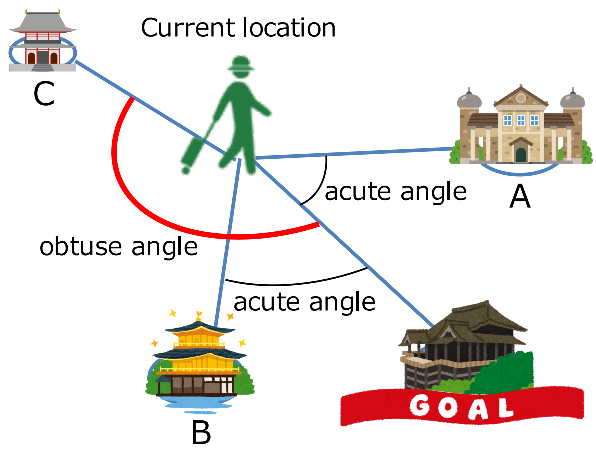

Figure 2. Algorithm for direction judgment.

5. Evaluation Experiment

In this section, we evaluate the effectiveness of the proposed system in order to show that the set conditions and requirements are fulfilled. First, to evaluate the effectiveness of the on-site recommendations, we conducted an experiment in Kyoto city, which is a famous tourist destination. Second, to evaluate the effectiveness of the two elemental technologies (i.e., the preference-information acquisition mechanism and on-site tourism curation mechanism) that compose the proposed system, a pseudo-tourism tool was constructed and participant experiments were conducted. Finally, based on these results, we confirm that the conditions and requirements set by the proposed system are fulfilled.

5.1. On-Site Tourism Recommendation Experiment

In this section, we first describe an outline of the on-site tourism recommendation experiment. Then, we describe the results and discussion of this experiment.

5.1.1. Outline

The main objective of this experiment is to evaluate whether the on-site recommendation is effective in improving the degree of user satisfaction and unexpectedness of the recommendation. The experiment was conducted using 14 participants (nine Japanese and five non-Japanese) in November 2016. All participants were in their 20s and two of them were female. For this experiment, we asked them to go sightseeing in Kyoto twice. Specifically, each participant participated in two sessions on November 20 and 27, 2016. For both days, we asked each participant to sightsee while freely taking pictures from Gion-Shijo station (start point) to Kiyomizu-dera temple (goal point). In these sessions, we set the sightseeing time to 2.5 hours. We asked each participant to move freely on their own rather than moving together with other participants. In addition, before the experiment, we divided participants into the following two groups: (Group 1) the group that usually makes a tour plan before sightseeing; (Group 2) the group that does not usually make a tour plan before sightseeing. As a criterion for grouping, we considered how frequently participants make tour plans when sightseeing on their own.

For the first session (Experiment 1), we conducted the experiment with the smartphone application developed for this experiment. For the second session (Experiment 2), we conducted the experiment without the smartphone application. We evaluated the effect of tourism spot recommendation by comparing the satisfaction level of each participant between Experiment 1 and Experiment 2. The tourism spots recommended for participants in Experiment 1 were selected based on the proximity of the distance from the current location by using the tourist information collected before the experiment. Moreover, the questionnaire used in this experiment was prepared based on the SD

(Semantic Differential) method. If participants who come to Kyoto for the first time go sightseeing without making a tour plan in an unfamiliar place, there is a risk that the experiment cannot be conducted safely because they are more likely to encounter dangers, e.g., get lost and get in a car accident. Thus, in this experiment, we first conducted Experiment 1, which is with the smartphone application, in order to avoid such a risk. Below, we explain the procedures of Experiment 1 and Experiment 2.

Experiment 1 (with tourism spot recommendation function):

1. All participants get a smartphone with the application installed at the start point.
2. Three recommended spots to visit first are shown to them in the application (Figure 3①).
3. They go to one of the recommended spots, take a picture, and upload it. This action means that they have checked in at the spot (Figure 3②).
4. When participants check in, three new spots are recommended by the application (Figure 3①). However, participants can go to spots other than the recommended ones freely.
5. Participants move toward the goal point while repeating (3) and (4) (Figure 3③).
6. Participants answer the questionnaire at the goal point (Questions 1 and 2 in Table 3).

Experiment 2 (without tourism spot recommendation function):

1. Participants who belonged to Group 1 made a tour plan before sightseeing based on information from guidebooks and the Internet. In addition, we set the creation time of the tour plan to two hours.
2. Those in the group who made tour plans beforehand (Group 1) acted according to their plan. Those in the group who did not make the tour plan beforehand (Group 2) acted freely, since there was no limitation for them.
3. Participants took pictures at an arbitrary timing.
4. Participants answered the questionnaire at the goal point (Questions 3 and 4 in Table 3).

Figure 3. Behavior state transition diagram of participants (with recommendations).

In Experiment 1, we conducted on-site tourism spot recommendation using the tourism spot recommendation system (Figure 4; the smartphone application developed for the experiment was used. The tourism spot recommendation system was implemented on our participatory sensing platform ParmoSense (Participatory Mobile Sensing Platform) [33]. This system was created for the purpose of confirming the effect of on-site tourism recommendation. Therefore, the preferences of each participant were not considered in this experiment. This is the reason why the system recommends three pre-determined tourism spots according to the participant's current location (i.e., the blue circle in the center of the screen), displaying them on a map In this experiment, we recommend three spots for the purpose of displaying recommended spots in the application., as shown in Figure 4a. Each recommended tourism spot is displayed with a black pin, and the participant taps on the pin to see detailed information of the spot (from the current location, as shown in Figure 4b, the participant can browse information such as time and distance information).

(a) Recommendation result display (b) Details of tourist spots

Figure 4. Tourism spot recommendation system built on ParmoSense (Participatory Mobile Sensing Platform) [33].

In this experiment, to evaluate the effect of on-site tourism recommendation, we had participants answer a five-step questionnaire. In addition, unexpectedness is defined as something that is unknown but recommended and of interest. The reason for evaluating not only satisfaction but also unexpectedness is that not only does the accuracy of the recommendation have a strong correlation with satisfaction, but unexpectedness is also important as an index for evaluating the recommendation [34]. Additionally, to confirm whether the effect of the proposed system depends on the style of sightseeing of the tourists, we compared the results between Group 1 and Group 2.

5.1.2. Experimental Results

Table 3 shows the content of the questionnaire and the experimental results of Group 1 and Group 2. Questions 1 and 3 show the results (mean, variance) of satisfaction. Group 1, the group that usually makes plans, has an average of 4.17 when there is a recommendation for tourism spots, and an average of 4.00 when there is no recommendation. Hence, there was not much variation in the two methods. Group 2, which consisted of those who do not make plans, has an average of 4.38 when recommendations are provided, and an average of 3.5 when there are no recommendations. Both groups show a high satisfaction when they are presented with recommendations. Questions 2 and 4 show the results for unexpectedness of tourism spots. Group 1, which usually makes plans, has an average of 4.50 when there is a recommendation for tourism spots and 3.00 when there is not. Group 2, which does not usually make plans, scored 3.88 when there is a recommendation for tourism spots, and 2.75 when there is not. From these results, it can be seen that both groups are able to more greatly enjoy unexpected spots when they appear as a recommended tourism spot.

Table 3. Questionnaires and results (on-site tourism recommendation experiment).

		Question Content	**Group 1** [1]		**Group 2** [2]	
			Avg.	**Var.**	**Avg.**	**Var.**
First session (w/ recommendation)	Q1	How satisfied were you with your sightseeing this time (first experiment)? (A scale of 1 to 5, 1: Very dissatisfied – 5: Very satisfied)	4.17	0.47	4.38	0.23
	Q2	How many spots were there that fit the description "I did not know about it, but it was surprisingly good when I went there"? (A scale of 1 to 5, 1: None at all – 5: Very many)	4.50	0.25	3.88	0.61
Second session (w/o recommendation)	Q3	How satisfied were you with your sightseeing this time (the second experiment)? (A scale of 1 to 5, 1: Very dissatisfied – 5: Very satisfied)	4.00	0.67	3.50	0.50
	Q4	How many spots were there that fit the description "I did not know about it, but it was surprisingly good when I went there"? (A scale of 1 to 5, 1: None at all – 5: Very many)	3.00	1.67	2.75	0.69

[1] The group that usually makes plans. [2] The group that does not usually make plans.

5.1.3. Discussion of On-Site Tourism Recommendation

In this section, we discuss on-site tourist recommendations. From Questions 1 and 3 in Table 3, we see that for Group 2, those who do not usually make a plan, there is a large difference in satisfaction when on-site recommendation is used. From this, it can be said that on-site recommendation is particularly effective for tourists who do not make plans. By recommending and presenting nearby tourism spots using on-site tourism recommendation, it becomes easier to discover more attractive tourism spots and it is possible to increase opportunities to visit new spots, resulting in high satisfaction results. A large difference was also found in the unexpectedness with and without the recommendation. The large difference is confirmed from Questions 2 and 4 of Table 3, especially when there is a recommendation for Group 1, those who usually make a plan, with an average of 4.50 with recommendations, and 3.00 with no recommendations. This is because tourists who usually make plans make them in advance based on major tourism spot information published in guidebooks, on the Internet, etc. By contrast, on-site tourism recommendation recommends minor sights in addition to major sights, so there are many opportunities to explore less famous sites and be satisfied with spots that were not expected.

5.2. Simulated Tourism Experiment for Elemental Technology Evaluation

In this section, we give an outline of the pseudo-tourism experiment. Then, we explain the results of the pseudo-tourism experiment for elemental technology evaluation.

5.2.1. Outline

The main objective of this experiment is to evaluate two elemental technologies (A. a preference-information acquisition mechanism, and B. an on-site tourist curation mechanism). Therefore, we conducted an experiment using a pseudo-tourism tool based on Google Maps [27]. This experiment was conducted in January 2018 with eight participants (males in their 20s).

The preferences were acquired for each participant utilizing a preference-information acquisition mechanism combining the pair comparison method shown in Figure 5 and conjoint analysis. At this time, the degree of congestion of each tourism spot is taken into consideration by including the tolerance for congestion in the preferences. For example, a crowded tourism spot will not be recommended because it will cause a decrease in satisfaction with participants who dislike crowds. Next, using the acquired preferences, we simulated pseudo-tourism on a PC from Gion-Shijo Station to Kiyomizu-dera using the pseudo-tourism tool shown in Figure 6. In the pseudo-tourism tool, on the basis of user information and spot information, tourism spots are recommended (four in this case for the convenience of implementation) according to the on-site sightseeing curation mechanism explained in Section 4.3, and they are displayed on a map. Each recommended tourism spot is indicated by a flag, and the number in the flag indicates the recommendation ranking. On the right side of the map, details of the appearance and information of each recommended tourism spot are displayed in the order of rank from highest to lowest.

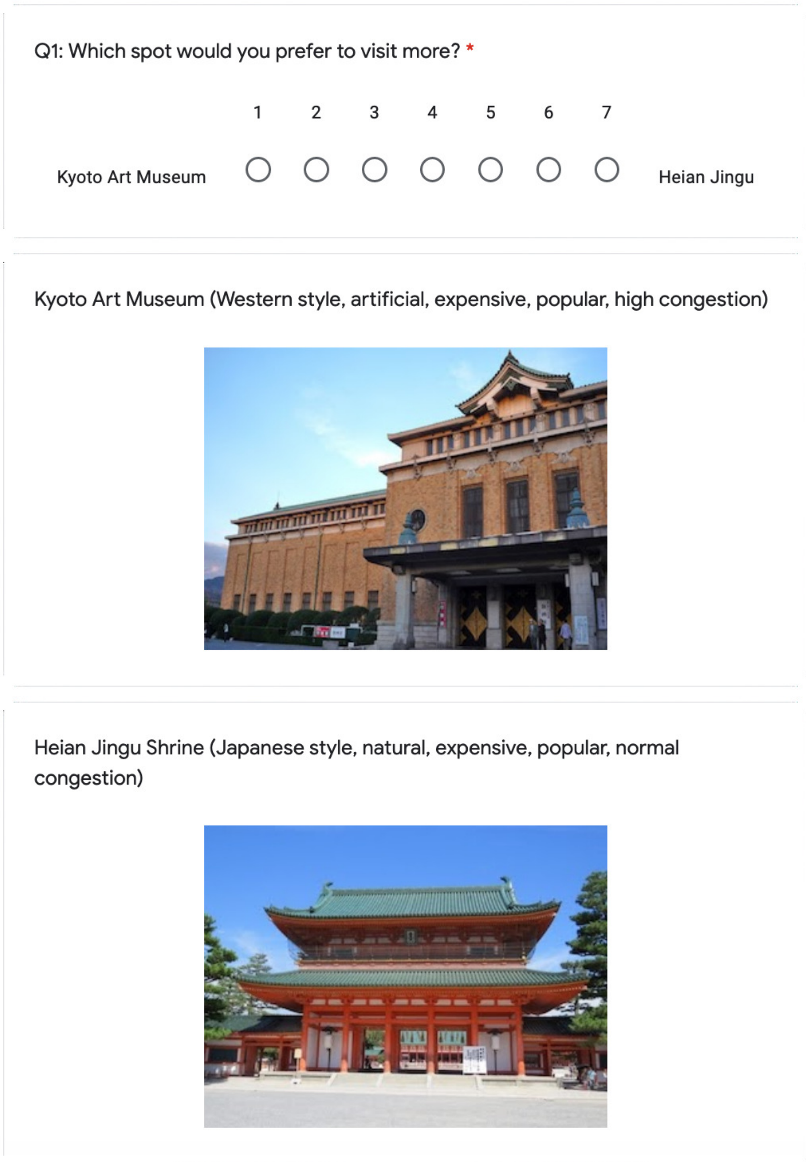

Figure 5. Example of the mechanism for acquiring preference information.

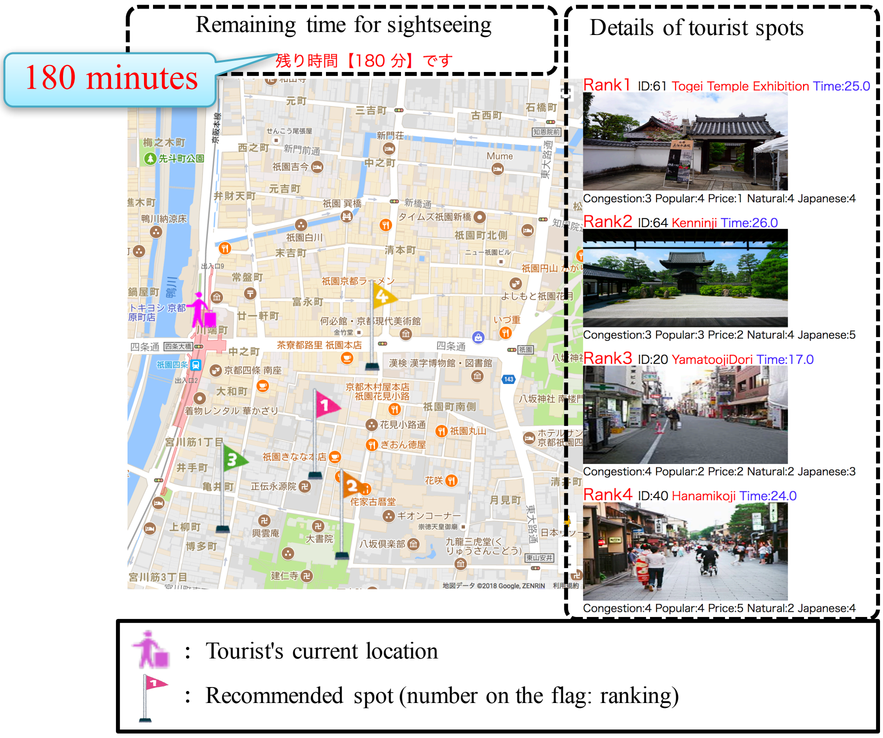

Figure 6. Tool for simulated tourism.

Each participant performed two different experiments using the pseudo-tourism tool. Specifically, the first session (Experiment 1) is to make tourism spot recommendations using the proposed system, and the second session (Experiment 2) is to develop a model course to be used in actual tourism without making recommendations. In Experiment 2, we simulated sightseeing using a model course (https://www.kyotokk.com/map2.html) that is often used in actual sightseeing. The sightseeing time is set to 180 minutes for both the first and second session, the time (i.e., consumption time) set for each tourism spot is selected, and the sightseeing is ended immediately when the sightseeing time is depleted (0 minutes left). The model course is set as a course that allows a participant to visit all spots within 180 minutes. The consumption time was determined based on the size of the tourism spots and the same values for the degree of congestion; the degree of congestion and consumption time are used for all participants. This tool allows the user to watch a route video created using Google Street View so that the route taken by the participant can be reviewed after the end of simulated sightseeing [35]. In the following, Experiment 1 and Experiment 2 are explained in detail.

Experiment 1 (with recommendations for tourism spots):

1. The preference-information acquisition mechanism is used to acquire the participant's preferences. After that, the acquisition result is shown to the participant and a map is generated using a pseudo-tourism tool.
2. The on-site tourism curation mechanism recommends four candidate tourism spots to go to next based on the acquired preferences of a participant, the participant's current location, and dynamic information.
3. The participant chooses one tourism spot that they want to visit from the recommended ones. If there are no spots that they would like to visit, they select other spot.
4. When a participant selects one tourism spot that they want to visit, time is consumed and the remaining time for sightseeing decreases.
5. Repeat steps 2, 3, and 4 while proceeding to the goal point.

6. After reaching the goal point, the participant's path (from the start point to the goal point as shown in Table 4) is displayed as a movie. The movie is created by exiting method [35].

Experiment 2 (no tourism spots recommended (model course)):

1. Generate a map with a pseudo-tourism tool.
2. Participants are presented with the next tourism spots in accordance with the model course.
3. When the participant chooses the next tourism spot presented, time is spent and the remaining time for sightseeing decreases.
4. Repeat steps 2 and 3 while proceeding to the goal point.
5. After reaching the goal point, the participant's path (from the start point to the goal point) is displayed as a movie.

After both experiments are completed, the participant answers the questionnaire shown in Table 5.

5.2.2. Experimental Results

Table 4 shows an example of the results recommended by the proposed system. Specifically, out of eight participants, we discuss the results of three participants with different preferences and describe those results in detail. According to the preference-information acquisition mechanism, participant A prefers tourism spots that have a traditional Japanese style. Therefore, the on-site tourism curation mechanism recommends spots unique to Japan, such as Kennin-ji temple and Yasui-jinja shrine. On the other hand, participant B has a preference for Western-style spots, such as Goryukaku (Higashiyama Ward, Kyoto City, architect Shichi Takeda, located beside Shimizuzaka). It was found that many Western-style spots such as this secession-style Western building were recommended and selected. While both A and B wanted to sightsee in Japan, participant A preferred uncrowded tourism spots. Moreover, participant C preferred crowded spots. Therefore, the on-site tourism curation mechanism recommends that participant A avoid crowded spots, such as the five-storied tower and Shimizuzaka, while it recommends to participant C a crowded spot, such as the five-story tower. From the above results, it was confirmed that the recommendations by the proposed system reflect the preference of the participants and that the degree of congestion can be considered.

Table 4. Examples of tourist routes.

Participant	Recommended/Selected Route
A	S ⇒ Gion Shopping Street ⇒ Kennin-ji ⇒ Yasui-jinja ⇒ Yasaka Street ⇒ Ninen-saka ⇒ Sannei-saka ⇒ G
B	S ⇒ Gion Shopping Street ⇒ Hanamikoji Street ⇒ Yasui-jinja ⇒ Craft Ichi Nenzaka ⇒ Yumemi-saka ⇒ Ninen-saka ⇒ Goryukaku ⇒ G
C	S ⇒ Kennin-ji ⇒ Yasaka Street ⇒ Nittai-ji ⇒ Ninen-saka ⇒ Kodai-ji ⇒ Goju Tower ⇒ G

S = Gion-Shijo Station (start point), G = Kiyomizu-dera (goal point).

Next, Table 5 shows the contents of the questionnaire and the experimental results. Question 1 indicates the burden of the preference-information acquisition mechanism of the proposed system. The average value between participants is 3.75, and shows that the burden on the participants is small. Question 2 shows the validity of the preference-information acquisition mechanism. The average value between participants is 4.13, indicating that this mechanism can properly obtain the participant's preferences. Question 3 compares which better reflected the participant's sightseeing preferences, the model course or the one created by the proposed system. The average value between participants is 4.00, indicating that this mechanism can create a course that can fully reflect the preferences of the participants. Question 4 compares the degree of satisfaction of the model course with the course created by the proposed system. The mean value between participants is 3.88, indicating that this mechanism is more satisfactory.

Table 5. Questionnaire and results (simulated tourism experiment).

	Question Content	Average	Variance
Q1	Did you find it difficult to answer the preference-information acquisition mechanism questions (8 questions)? (1: Very much so – 5: Not at all)	3.75	1.20
Q2	How close was the preference predicted by the proposed system to your actual preferences? (1: Pretty far – 5: Pretty close)	4.13	0.33
Q3	In the courses created with the model course and the proposed system, which one did you feel better reflected your preferences? (1: Model course – 5: Proposed system)	4.00	0.87
Q4	Of the model course and the course created by the proposed system, which is better overall? (1: Model course – 5: Proposed system)	3.88	0.93

5.2.3. Discussion on Each Elemental Technology

In this section, we discuss each elemental technology. From Questions 1 and 2 in Table 5, it was found that the preference-information acquisition mechanism can basically properly acquire the participant's preference with minimal burden. From Questions 3 and 4 in Table 5, it is considered that the on-site tourism curation mechanism is effective as a mechanism for recommending tourism spots reflecting the preference of tourists. However, the variance of Question 1 is a little high. One of the participants felt the proposed method imposed a high burden. The reason for this low evaluation was due to dissatisfaction with the interface in this experiment. An improvement in the interface is a task for future work.

5.3. Achievement Confirmation and Future Challenge

In this section, in order to draw conclusions more clearly, the confirmation of the achievement of the conditions and requirements is explained, as well as future issues. We first describe whether all of the requirements of the proposed system mentioned in Section 4.3 have been fulfilled. Then, we describe future challenges for the proposed system.

5.3.1. Achievement Confirmation of Conditions and Requirements

- The proposed system needs to be usable on-site during sightseeing (Condition 1), so it is necessary to fulfill <Requirement 1>, <Requirement 2>, and <Requirement 3> described in Section 3. To fulfill the above requirements, we implemented the proposed system as a smartphone application. In addition, we newly introduced an algorithm that excludes tourism spots that are in the opposite direction of the destination in accordance with the current location of the participant (tourist). As a result, we realized a system that can display/recommend multiple candidates for tourism spots to visit next on site. Hence, as shown in the evaluation results of the on-site tourism recommendation experiment in Section 5.1, it can be concluded that <Requirement 1>, <Requirement 2>, and <Requirement 3> are fulfilled sufficiently.
- The proposed system needs to be tailored to tourist preferences and dynamic information (Condition 2). Therefore, it is necessary to fulfill <Requirement 4> and <Requirement 5> mentioned in Section 3. To fulfill the above requirements, we developed an on-site tourism curation mechanism that can recommend multiple sightseeing spots that are close to the current location and that match the tourist's preferences. From the evaluation results of the pseudo-tourism experiment in Section 5.2, it is shown that this mechanism can make

recommendations that can fully reflect the tourist's preferences and dynamic information. Hence, it can be concluded that <Requirement 4> and <Requirement 5> are sufficiently fulfilled.

- The proposed system needs to acquire tourist's preferences while imposing a small burden on them (Condition 3). Therefore, it is necessary to fulfill <Requirement 6> mentioned in Section 3. To fulfill this requirement, we newly developed a preference-information acquisition mechanism that combines paired comparison and conjoint analysis. From the evaluation results of Section 5.2, it is shown that the proposed mechanism imposes a small burden and is intuitive for tourists, and it can efficiently acquire preferences. Hence, it can be concluded that it fulfills <Requirement 6> sufficiently.

5.3.2. Future Challenge

Through the evaluation experiments in Sections 5.1 and 5.2, we confirmed the effectiveness of the proposed system. However, regarding the design of the experiment in Section 5.1, for safety reasons, we first conducted Experiment 1 (with recommendations for tourism spots) and then conducted Experiment 2 (no recommendations for tourism spots). Therefore, in this experiment, we did not consider the bias due to the experimental order. To consider such a bias, we need to improve the experiment plan, such as by changing the order of experiments according to each participant. In addition, because all of the participants are students, the participants in this experiment are not representative of all tourists. Thus, in the future, we need to conduct the experiment with a greater number of people, with tourists with different attributes as participants. Furthermore, to further improve our system, we think that it will be necessary to propose not only tourism spots to be visited next, but also a method for creating a sightseeing plan that takes into consideration the balance of the sightseeing schedule. Specifically, rather than simply providing a set of tourism spots that are highly recommended for tourists, it will be more useful if temporal constraints, such as user schedule and venue closing times, are considered. For example, it is not realistic to always go to a restaurant during a day's sightseeing, even for tourists who are usually more interested in eating and drinking than landscapes. It is necessary to consider satisfaction tradeoffs for tourists when choosing between multiple tourism spots. Hence, we think that it is necessary to collect data for predicting the next possible action of a tourist (e.g., satisfaction of the tourist [36,37], congestion status of tourism spots [38]) and construct a concrete model from this data to solve this problem.

Additionally, because the proposed system is set for Japan (especially, Kyoto), it cannot be used in other tourism areas immediately. In the case of adaptation to other tourism areas, we must modify a part of the preference-information acquisition mechanism. Specifically, it is necessary to re-create the questionnaire of getting the user's preference according to the characteristics of the tourism spots. Here, the characteristics of the tourism spots must be based on the viewpoints that the user emphasizes when selecting a tourism spot. In selecting viewpoints, it is necessary to consider the characteristics of each tourism area and the attributes of tourists.

6. Conclusions

In this paper, we have proposed an on-site trip-planning support system that recommends tourism spots efficiently according to on-site information, tourist preferences, and dynamic information. Specifically, our system consists of the following two key mechanisms: (A) A mechanism for acquiring preference information of tourists, and (B) a curation mechanism for realizing on-site tourism. The proposed system makes it possible to recommend tourism spots on site by compiling (curating) a tourist plan according to the individual preferences of the user and the current situation of the tourism spot. To verify the effectiveness of the proposed system, we conducted evaluations of on-site tourism and simulated tourism experiments. As a result, the following primary findings were obtained:

- For tourists who do not usually make plans, there is a large difference in satisfaction results between scenarios with recommendations and those without recommendations. Therefore, on-site recommendations are effective for tourists who do not usually make plans.
- The preference-information acquisition mechanism, which is the first elemental technology of our proposed system, can reduce the burden on tourists and acquire a tourist's preferences with a high accuracy by effectively combining the pair comparison method and the conjoint analysis.
- The on-site tourism curation mechanism, which is the second elemental technology of our proposed system, can create a course that can sufficiently reflect the preferences of tourists. Therefore, it is possible to obtain a higher level of satisfaction compared to the model courses that are often used for sightseeing.

In future work, we will try to implement the preference-information acquisition mechanism and the on-site tourism curation mechanism used in the pseudo-tourism experiment on the mobile application. In addition, we think that the system should not only consider tourism spots, but also generate a sightseeing plan that balances the user's sightseeing schedule [35].

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