DEVELOPMENT AND EVALUATION OF SIGHTSEEING SUPPORT APPLICATION USING ICT AND PSYCHOLOGICAL EFFECTS

Utsunomiya University graduate school
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Doctoral thesis

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Introduction

1.1 Introduction

With the spread of the Internet, the methods of obtaining and distributing information at tourist destinations are changing dramatically. The widespread use of smartphones has made it possible to obtain tourist information and adjust schedules at tourist destinations, and there is a need for tourist sites themselves to evolve their own methods of distributing information. The Internet is overflowing with information from major portal sites, making it difficult to find what you are looking for. In addition, information about famous tourist attractions that have become the talk of the social network spreads instantly, while the opportunity to come into contact with customs and unique sights that only the locals know is decreasing. Local guides have been responsible for distributing information that is rooted in the local community, but as travel becomes more personalized and diversified, it is becoming more difficult for local guides to respond.

In this study, we proposed a new method of information distribution in such tourist areas by applying psychological effects. For Nikko, which is experiencing sluggish tourist growth, BLE Beacons have been installed throughout the city since 2014 to set up a location-based infrastructure. In 2014-2016, we implemented and evaluated an application that applied the Zeigarnik effect to attract repeat customers.

In 2017, we designed a user interface based on Maslow's hierarchy needs and designed solar BLE Beacon. In 2018-2019, we implemented and evaluated an application for optimal information distribution based on prospect theory, a behavioral economics approach, and demonstrated its effectiveness. In 2019, in order to support information distribution in a wide area, we developed hardware for evaluation of LPWA and conducted its evaluation.

1.2 The Structure of the Thesis

The purpose of this research is to attract new tourists from Japan and abroad and to establish a methodology to increase the number of repeat visitors to Nikko tourism. Our research is separated into seven parts, as described in Fig. 1.1.

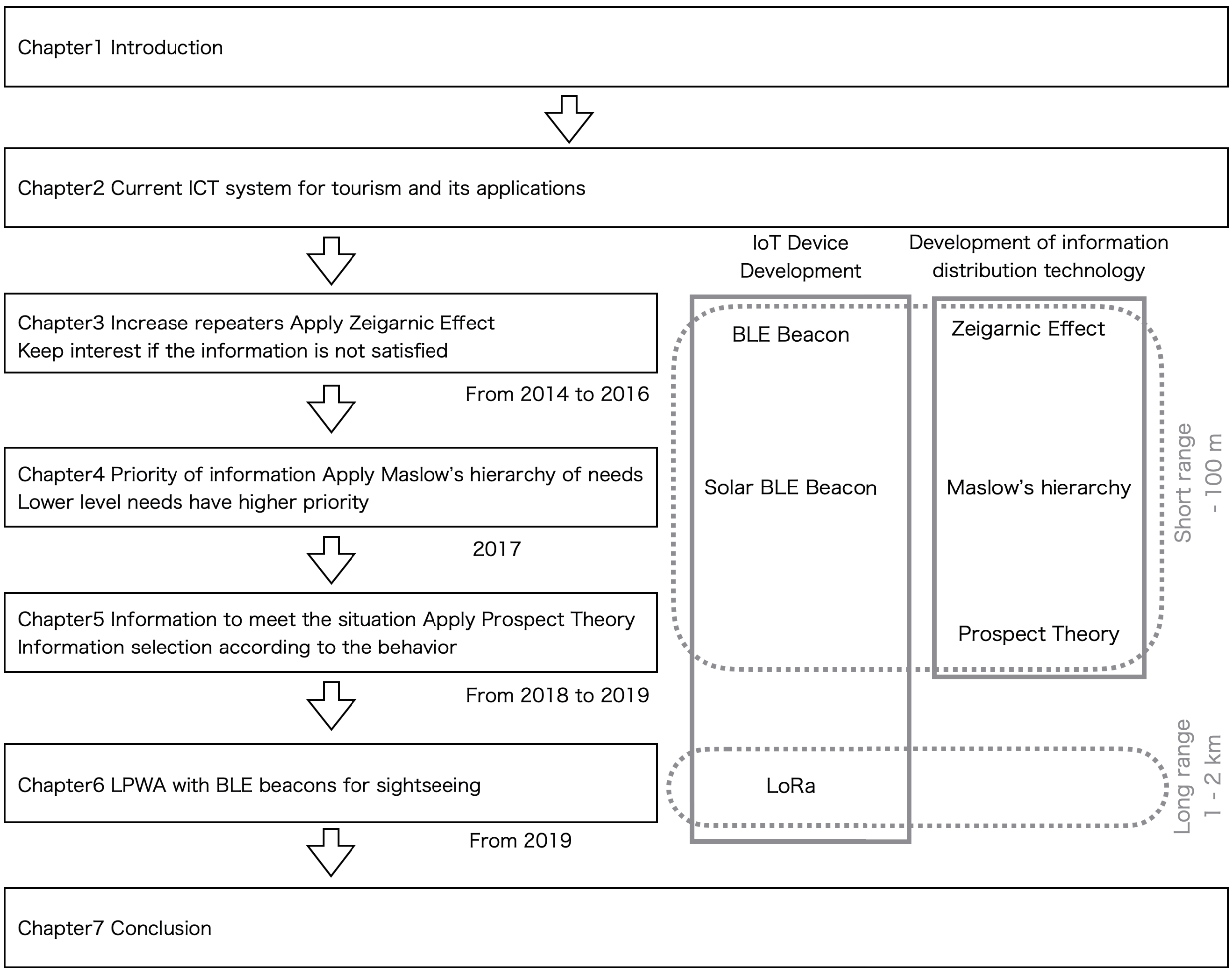


Fig. 1.1: Objectives of this research

There are seven sections. In section 1, the background and motivation of this research are explained. In section 2, some related work including research about the relationship between tourism and psychology, and tourism support by ICT are introduced and the research problems are described.

In section 3, between 2014 and 2016, we implemented and evaluated an application of the Zeigarnik effect to increase repeat customers. The research on a sightseeing support mobile application using the Zeigarnik Effect and newly developed the cognitive model for sightseeing to increase repeaters. A survey of tourist's images of Nikko and verification of the effectiveness of using the application revealed that a large amount of information is not effective to increase the number of tourists. Therefore, the Zeigarnik Effect is focused on and construct a cognitive model of travel. This model is extended based on the memory of a trip. A trip starts with expectations before the trip. If there is an element which has been "forgotten" or left a feeling of "unsatisfaction" in the awareness during the trip and in the memories after the trip, it will be kept in the memory for a long time and trigger a revisit. Following this idea, this model of sightseeing has an "unknown" part. The Zeigarnik Effect is used to produce something "forgotten" or related with "unsatisfaction". We also designed the circuit of BLE Beacon and the box to put it and installed it on the streets of Nikko.

In section 4, from 2017 to 2018, we implemented and evaluated a user interface designed with Maslow's hierarchy of needs. The design method of a sightseeing support mobile application uses Maslow's hierarchy of needs to meet the intention of travelers. What kind of information is required when traveling for sightseeing purposes? The mental model of sightseeing does not answer this question. The information required for sightseeing was diverse, and in the result of analysis, it covered ten categories and 50 items. The Maslow's hierarchy of needs is used to design the user interface of the sightseeing application. Next, the information is mapped onto Maslow's hierarchy of needs. We also designed the solar BLE Beacon and the case of it and installed it in Oku-Nikko.

In section 5, from 2018, we implemented and evaluated an application of the prospect theory to provide the information according to the behavior of traveler. One critical issue in using a smartphone for sightseeing is that there is too much information. Too much information not only makes selection difficult but also denies or complicates access to the information. This is a phenomenon called overload of clue. In the information delivery using the BLE Beacon, one beacon provides one information. However, it is necessary to link various information to the beacon for practical use. For example, around a BLE Beacon, there are not only shrines and temples but also souvenir shops and restaurants. However, all that information, what is the most relevant for tourists? For example, it is conceivable to obtain the user's profile and send the most appropriate information in consideration of triggers such as position and time. However, it is difficult to formulate a strategy for providing information that also assumes the user's psychological and physical conditions. As a result, it is expected that similar information will be provided to tourists in the same pattern. It is essential to select and provide the most appropriate and in-demand information from the uncountable bits of information to increase tourists' satisfaction. The calculation method of the information value using the Analytic Hierarchy Process (AHP) to calculate value factors based on the Prospect Theory is defined. The effectiveness of this idea is proved through experiments.

In section 6, the possibility to use LPWA with BLE Beacons for sightseeing is discussed. Utilizing the advantages of LPWA's low power consumption and long-distance communication, we discuss the possibility of a tourism support system that links BLE Beacon and LPWA. In order to conduct the experiment, we also designed the the circuit of LoRa device and developed an application for evaluation.

Finally, a summary of this studies is given in Section 7.

Chapter 2

Current ICT system for tourism and its applications

This chapter describes previous studies related to this research. It describes e-WOM, Sharing Economy, and Psychology of Tourism as research on ICT in tourism, and BLE Beacon and Nikko as the base of the experiment.

2.1 e-WOM

Tourism has long been recognized to be an asymmetric information market [1, 2]. In other words, it can be said that tourists may not know word-of-mouth information that is known by local residents and tourist agencies. Traditional word of mouth has evolved into a new form of communication called electronic word of mouth (e-WOM) with the evolution of the Internet. e-WOM was defined by R. E. Goldsmith and D. Horowitz [3] as diffused Internet communication on online platforms such as SNS, blogs and review site. E. Manes have stated that e-WOM is effective in reducing information asymmetry [4]. According to R. Minazzi, as the exchange of e-WOM has become more and more popular, it has been reported that people who have experienced travel have made it a part of their enjoyment of travel to share their experiences on the Internet [5]. TripAdvisor's hotel reviews are a prime examples of e-WOM for tourism. Yelp is the leading provider of restaurant reviews globally. In Japan, there are famous review sites, such as 4Travel, Gurunabi and Tabelog (Table 2.1).

Table 2.1: eWOM

Service name	**e-WOM**
TripAdviser	hotel reviews
4Travel	travel reviews
Yelp	restaurant reviews
Gurunavi	restaurant reviews
Tabelog	restaurant reviews

e-Wom is becoming an important indicator in deciding where to visit. e-WOM is flooded with popular spots, but on the other hand, it is difficult for e-WOM to accumulate information that only local people know.

2.2 Sharing economy

K. Tomiyama states that guided tourism has the effect of increasing the attractiveness through tourism resources [6]. As a result, it became clear that the effect of guided sightseeing was particularly high for shrines and temples and for combined natural and human resources.

The features of the guided tour are as follows.

- People communicate with words.
- There is a two-way communication between the guide and the tour participants.
- The content and method of guidance can be adjusted by observing the tour participants.

- The guide can draw out the interests and senses of the tour participants through his or her actions.

Guided tours are more effective in communicating the content of the guidance to the tour participants compared to self-guided tours. In the case of a highly specialized trip such as a tour, the guide can help you learn things that you might not have noticed or known if you were just passive [7].

It is becoming more and more common to use sharing services like Airbnb to stay in tourist destinations. In 2016, Airbnb released "Airbnb Experiences" [8], a matching service for local guides. The "Airbnb Experience" broadens the possibilities of guided tours in tourist destinations.

While these approaches are effective, there is a limited number of guide matching in the sharing economy. The emergence of ICT systems equipped with AI and next-generation recommendation engines is expected.

2.3 Psychology of Tourism

There are several works about environmental psychology and tourism. P. L. Pearce and P. F. Stringer [9] studied the viewpoint of physiology, cognition and individual variation. J. D. Fridgen [10], V. Raaij [11], T. Sasaki also studied this field. In particular, T. Sasaki mentioned that we can categorize a trip into 3 scenes: before the trip, during the trip, and after the trip [12] (Fig. 2.1). It means that a trip is not only the enjoyment of the trip but also planning to increase expectation before the trip and remembering the memory of the trip after returning home.

M. Masaki proposed for a system to create repeat visitors by making tourists feel that their trip is not complete [13], as an example of applying psychological effects to tourism.

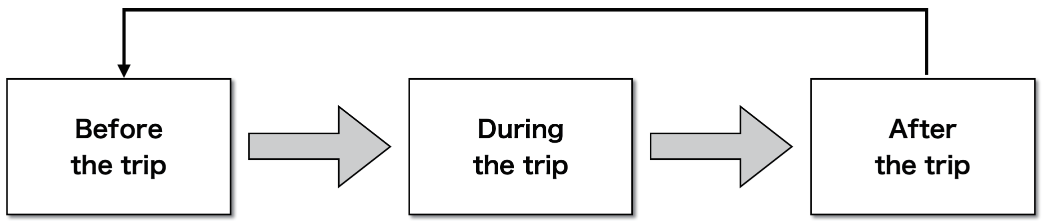


Fig. 2.1: Mental model

2.4 Smart Tourism

“Smart tourism” is a word that describes a foundation of ICT-based tourism. Its definition is described in “to describe the increasing reliance of tourism destinations, their industries and their tourists on emerging forms of ICT that allow for massive amounts of data to be transformed into value propositions” [14].

A similar word is “Smart Tourism Ecosystem (STE)” [15], which is a “digital ecosystems and smart business networks as conceptual building blocks.” Furthermore, “Smart Tourism Destination (STD)” [16] is a scenario for destination management. B. Neuhofer [17] described the importance to provide “personalized experiences.” P. M. da Costa Liberato [18] described how the use of technology “before, during, and after” the visit influences the tourist experience. There are also new ideas such as “Ambient Intelligence (AmI) Touris” [19] to restructure the tourism ecosystem. “Smart Tourism Technology (STT)” is an idea that supports the process of deciding the destination. C. W. Yoo [20] described which information is useful to increase the satisfaction.

These research provide a good idea of frameworks of tourism support by ICT; however, they do not mention evaluating the tourism support applications.

2.5 BLE Beacon

IoT is now becoming popular, and there are research using IoT for sightseeing. One of the most popular technologies of IoT is a beacon using Bluetooth Low Energy (BLE) [21]. BLE is part of the Bluetooth standard and was added in Bluetooth 4.0 released in 2009. The most important feature of BLE is its ultra-low power consumption. A BLE device can operate for about a year on a single button battery. The first attempt to use BLE as location information was iBeacon for iOS, which was announced by Apple in 2013. When the iPhone approaches the iBeacon, the application can get the iBeacon's UUID, Major, and Minor. The application can identify the location by comparing the UUID, Major, Minor with the location information registered in the database in advance. In 2015, Google released EddyStone for Android. The general term for technology that identifies location information with BLE is read as BLE Beacon.

BLE has a function to send an "advertising message" to notice a BLE device's existence (Advertising IND). The outline of the behavior of BLE advertising is described in Fig. 2.2.

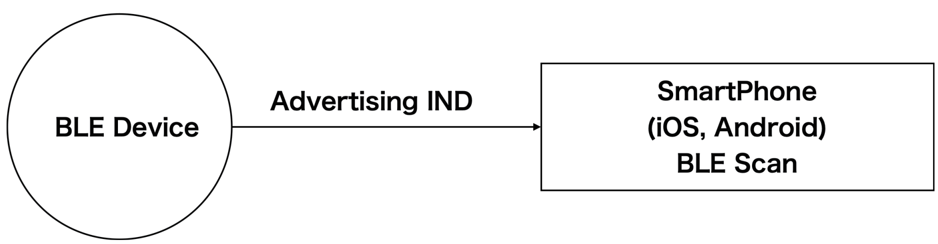


Fig. 2.2: advertising ind

BLE and Wifi use the same 2.4 GHz band. Therefore, if BLE uses this radio band as it is, radio interference will occur, and the communication capability of BLE will be reduced. Therefore, instead of using the entire frequency band, BLE divides the channels into 40 channels and communicates between devices while switching the channels. Advertising IND uses three of them (channel 37, 38, 39) to send an advertising message in the prefixed interval (Fig. 2.3). The other 37 channels are called data channels and are used for actual data exchange. An advertising message can reach about 100m on the street and 20m in a forest in summer.

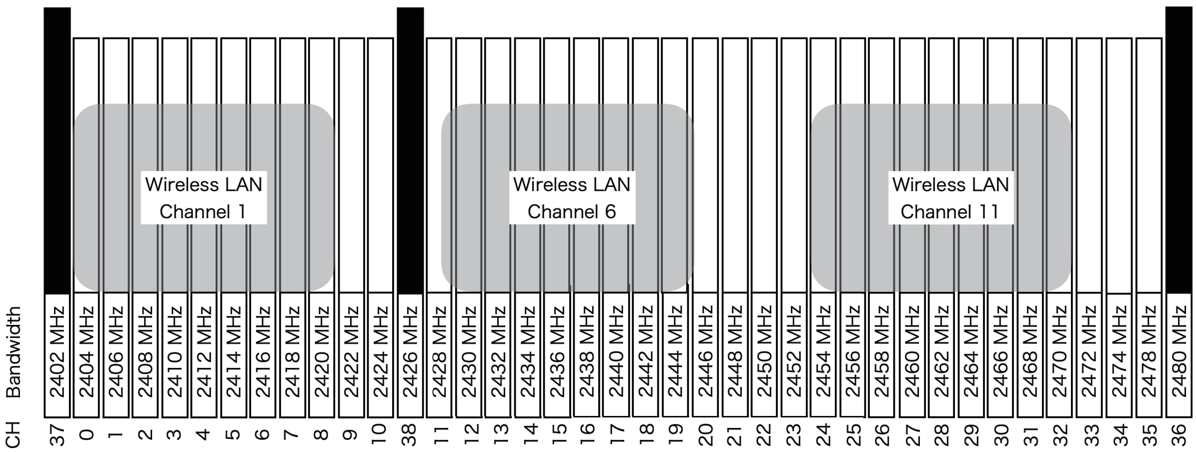


Fig. 2.3: BLE Channels

For the case of iBeacon, in an advertising message, there is two information. One is UUID that is a unique id of a BLE device (16 octets), and the other is Major/Minor flags (2 octets each) (Table 2.2). Such information is used to indicate the location of a beacon. In iOS, the iBeacon scan API (Core Location API) cannot be customized by calling from the program, but in Android, the BLE Scan API can be customized by calling from the program, so the iBeacon format is often used for BLE Beacon as a common format.

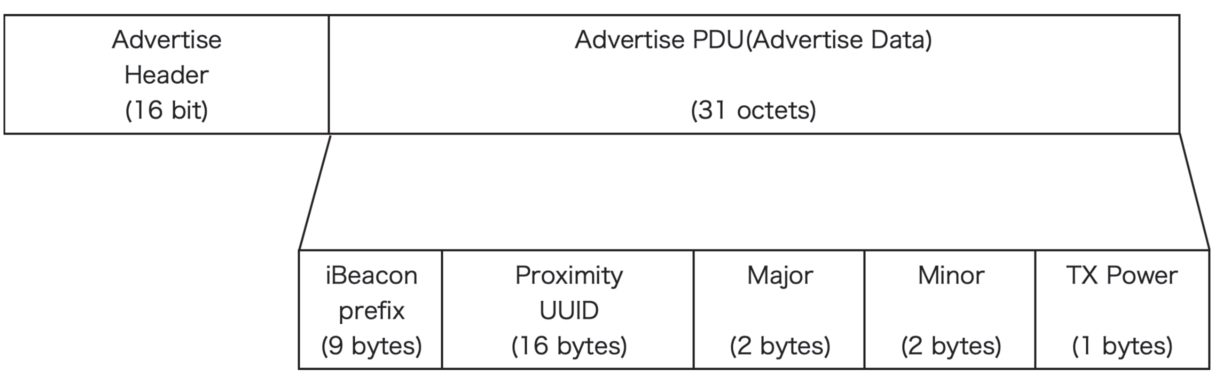


Fig. 2.4: iBeacon format

Table 2.2: iBeacon Format Example

Item	**Size**	**Data**
iBeacon Prefix	9	Pre fixed 02 01 1A 1A FF 4C 00 02 15
Proximity UUID	16	User define (CB 86 BC 31 05 BD 40 CC 90 3D 1C 9B D1 3D 96 6B)
Major	2	User define (00 01)
Minor	2	User define (00 10)
TX Power	1	User define (0C)

For iOS, the Core Location API gives your applications the ability to determine proximity to iBeacon. When you discover an iBeacon, depending on its proximity, your application can get one of the values Far, Immidiate, Near, or Unknown and RSSI as a system event via the Core Location API (Fig. 2.5). Since these processes are done at the OS System level, this allows for reduced power consumption by the application.

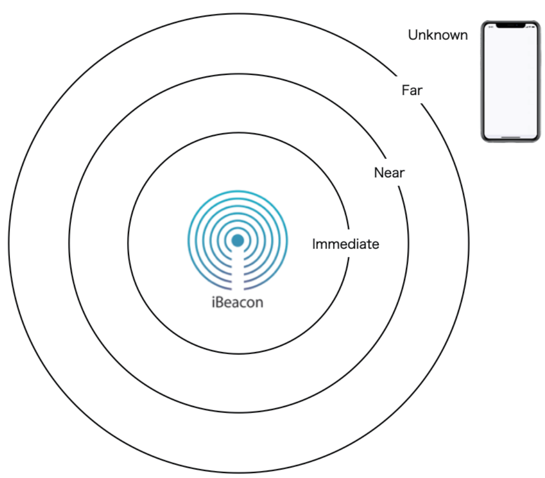


Fig. 2.5: iBeacon Event

There are many types of research that use BLE Beacon for indoor navigation [22, 23]. In the iBeacon Mile Project, the iBeacon Living Lab in Amsterdam installed iBeacons on a 3400 meter long section stretching from Amsterdam Central Station to the naval base. At the SAIL Amsterdam 2015 festival, 223 iBeacons were installed and are being tested to deliver information to visitors [24]. They have also recently released a LoRaWAN Beacon concept that works with LoRaWAN (Fig. 2.6). LoRaWAN Beacon is a system that can adjust BLE Beacon's UUID, Major, Minor and transmitting power through LoRa communication. By making communication possible with LoRa, they are building a network that can be controlled in a wide area.

Fig. 2.6: LoRaWAN Beacon

Schiphol Airport in Amsterdam installed 2,000 beacons in the terminal to make it easier for passengers to reach the appropriate gate and to inform them about their flight details. They were used to make it easier for customers to arrive at the right gate and inform them of their flight details [25]. Hong Kong, Hamad, Gatwick, Dallas, and Houston International Airports are also trying to do the same.

In addition, M. Macik discusses on ubiquitous indoor navigation without a smartphone[26]. In Europe, there are some projects that use IoT for sightseeing. One example was TAG CLOUD (Technologies lead to Adaptability and lifelong engagement with culture throughout the CLOUD) [27]. This is an information providing service that combines a smartphone with a QR code or IC tag at famous places in Europe (Alhambra in Spain, Trendaim in Norway, The Barber Institute of Fine Arts in the United Kingdom, etc.). However, the TAG CLOUD requires access to the cloud, and its usability is limited in suburbs and buildings where such access is difficult.

2.6 About Nikko

Nikko was registered as one of the world cultural heritage on December 2, 1999. Traditionally, traveling signifies getting away from daily life. Visiting unknown places is one of the great pleasures. We can discover many things such as a hidden history of a village, original culture, and wild nature. The origin of the word "discover" is come from the negative of cover by dis, so a travel gives us new information. The dream to discover unknown parts of the world brings us to unknown places. The satisfaction is not proportional to the amount of information.

We started a study to investigate the most attractive aspect of travel and how to increase expectation and satisfaction of travel in Nikko. The number of tourist overnight stays in Nikko city has been declining in recent years. Comparing the total number of guests in 2010, before the earthquake, with the total number of guests in 2018, before the COVID-19 pandemic, using the tourism statistics of Nikko city, Kyoto city, and Takayama city [28, 29, 30, 31], Kyoto and Takayama cities showed an increasing trend, while Nikko showed a decreasing trend.

Table 2.3: The number of tourist overnight in million

Area	2010	2018	Comparison with 2010
Nikko city	3.61	3.29	91%
Kyoto city	13.10	15.82	120%
Takayama city	2.05	2.21	107%

A comparison of the number of foreign guests shows that areas with successful inbound strategies have seen a dramatic increase in the number of foreign guests, while Nikko has seen only a slight increase.

The overall number of tourists staying overnight in Nikko is declining, and furthermore, Nikko is struggling to attract inbound tourists. Nikko has not been successful in discovering "novelty" as a tourism resource for Japanese people, and lacks the ability to disseminate information on its "attractions" for foreigners. Nikko City has failed to make effective use of its location within a two-hour radius of the

Table 2.4: The number of foreign tourist overnight in thousand

Area	2010	2018	Comparison with 2010
Nikko city	73	119	160%
Kyoto city	984	4,503	450%
Takayama city	187	552	295%

Tokyo metropolitan area and the numerous tourism resources it retains related to its history. One of the main reasons for this is that the use of ICT in tourism has not been successful. With this background, we started our research targeting Nikko, a local tourist destination.

Chapter 3

Increase Repeaters Apply Zeigarnik Effect

Between 2014 and 2016, we designed BLE Beacon, installed it in Nikko street, and implemented and evaluated an application of the Zeigarnik effect to increase repeat customers.

3.1 BLE Beacon Design

In 2014, we designed the circuit and manufactured the board (Fig. 3.1). The design was aimed to meet the following conditions.

- Keep it running for one year
- Radio waves reach about 30m-100m
- Waterproof case

The first step was to select the BLE module. We compared the power level and radio wave strength of BLE Modules in Table 3.1. In terms of power consumption, Type ZY is the best choice, but the distance is not enough because Max TX Power is 0 dbm. We chose raytac's mdbt42 [32], which consumes less power and has a TX Max power of +4 dbm of reaching for 100 m.

Table 3.1: Comparison of BLE Module

Module	Manufacture	BLE chip	TX current(0 dBm)	TX Power(MAX)
mdbt42	Raytac	NR52832	5.3 mA	+4 dBm
Type ZY	Murata	DA14580	4.8 mA	0 dBm
CYBLE-022001-00	Cypress	CYBL10X6X	15.6 mA	+3 dBm
BLE113	Bluegiga	CC2541	14.3 mA	0 dBm

Next, we designed the circuit of BLE Beacon. In order to improve battery life and make it compact, it was constructed with a minimum of components: an LED, a capacitor for noise reduction, a reset switch, and a battery folder.

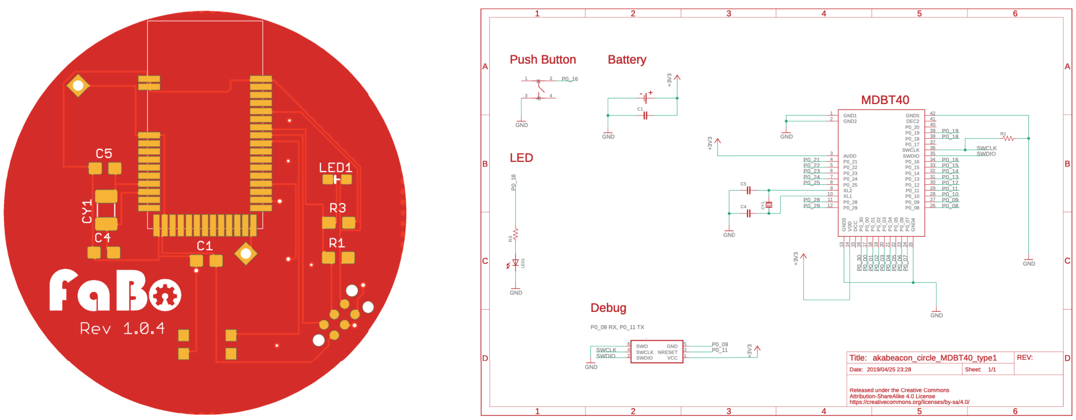


Fig. 3.1: PCB Design

Especially important is the power supply mechanism. We decided to use button cell battery, which can stably operate BLE Beacon for a long time. Among the many button batteries available, we decided to use CR2477 because of its size and battery capacity in Table 3.2. The CR2477 has a capacity of 950 mAh, which allow the BLE Beacon to operate for over a year.

BLE Beacon transmits radio waves in a cycle of once every 100 ms. Therefore, in order to keep the BLE Beacon running for a long time, it is necessary to minimize the power consumption when it is not transmitting. In MTBT42's Advertising IND, 37ch, 38ch, and 39ch can be used to transmit within 1.5 ms. Then it switches to sleep

Table 3.2: Button Cell Battery

Type	**Voltage**	**Capacity**	**Width**	**Height**
CR2032	3 V	200 mAh	20.0 mm	3.2 mm
CR2430	3 V	300 mAh	24.5 mm	3.0 mm
CR2450	3 V	600 mAh	24.5 mm	5.0 mm
CR2477	3 V	950 mAh	24.5 mm	7.7 mm

mode for 100 ms (Fig. 3.2). In sleep mode, it spend only 0.44 uA of power (Table 3.3). This makes it possible to run for nearly a year on a single button battery.

Table 3.3: Power consumption

Advertising(0 dBm)	5.3 mA
System sleep	0.44 uA

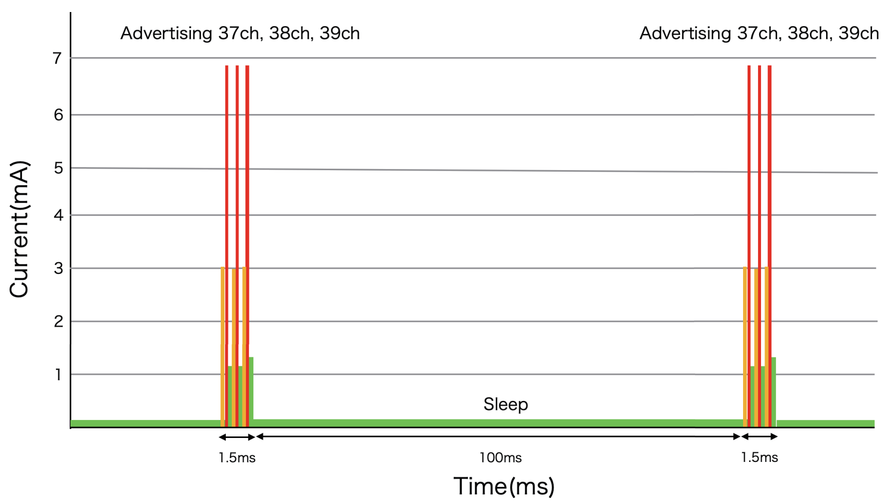


Fig. 3.2: Power Consumption of BLE

We also designed a case for the Beacon (Fig. 3.3). We used a 3D printer to print it (Fig. 3.4). When we designed the case, we tried to keep the size as small and inconspicuous as possible, and we also added a water-resistant feature.

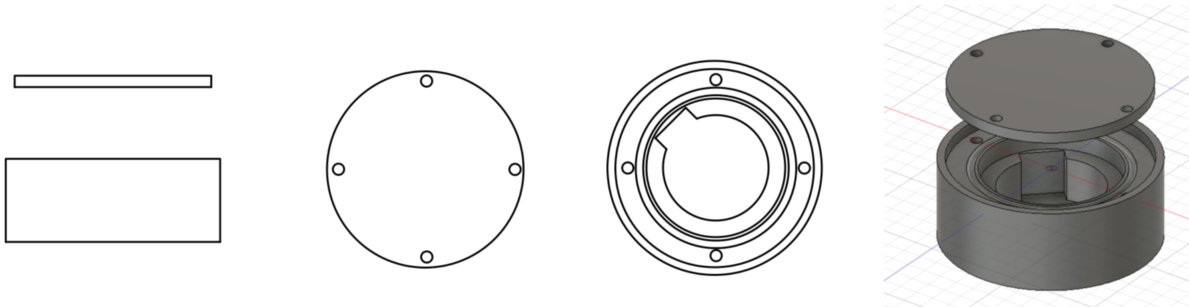


Fig. 3.3: Case Design

Fig. 3.4: Build beacon

3.2 BLE Beacon Installation

We installed 15 BLE Beacons in Nikko main street (Fig. 3.5). The BLE Beacon was fixed to a tourist information sign with double-sided tape (Fig. 3.6). Each Beacon was assigned a different UUID and Major and Minor. As for iOS, even if the app is not running, you can launch the app from the BLE Beacon discovery event. Since the event is triggered when an BLE Beacon with a different UUID is discovered, we assigned different UUIDs to the BLE Beacons that are next to each other (Table 3.4).

Fig. 3.5: Installed Beacon

Fig. 3.6: BLE Beacons on the street in Nikko (in a white dotted circle).

Table 3.4: Beacon UUID, Major, Minor

Beacon ID	UUID	Major	Minor
1	CB86BC31-05BD-40CC-903D-1C9BD13D966A	1	1
2	CB86BC31-05BD-40CC-904D-1C9BD13D966A	1	2
3	CB86BC31-05BD-40CC-905D-1C9BD13D966A	1	3
4	CB86BC31-05BD-40CC-906D-1C9BD13D966A	1	4
5	CB86BC31-05BD-40CC-907D-1C9BD13D966A	1	5
6	CB86BC31-05BD-40CC-903D-1C9BD13D966A	1	6
7	CB86BC31-05BD-40CC-904D-1C9BD13D966A	1	7
8	CB86BC31-05BD-40CC-905D-1C9BD13D966A	1	8
9	CB86BC31-05BD-40CC-906D-1C9BD13D966A	1	9
10	CB86BC31-05BD-40CC-907D-1C9BD13D966A	1	10
11	CB86BC31-05BD-40CC-903D-1C9BD13D966A	1	11
12	CB86BC31-05BD-40CC-904D-1C9BD13D966A	1	12
13	CB86BC31-05BD-40CC-905D-1C9BD13D966A	1	13
14	CB86BC31-05BD-40CC-906D-1C9BD13D966A	1	14
15	CB86BC31-05BD-40CC-907D-1C9BD13D966A	1	15

3.3 Development of the Base Application

We developed Nikko Kamen Navi application that is supported iOS and Android (Fig. 3.7). NikkoKamen Navi has a menu structure as shown below. Basic functions were implemented to provide tourist information that for each area.

- Town navi
  Information of BLE Beacon spot
- Shop navi
  Information of shop and restaurant
- Spot navi
  Information of tourist attractions
- Timetable of bus
  Timetable of local bus
- Beacon collection
  Display the collected BLE Beacons as stamps
- Information
  News and Announcements

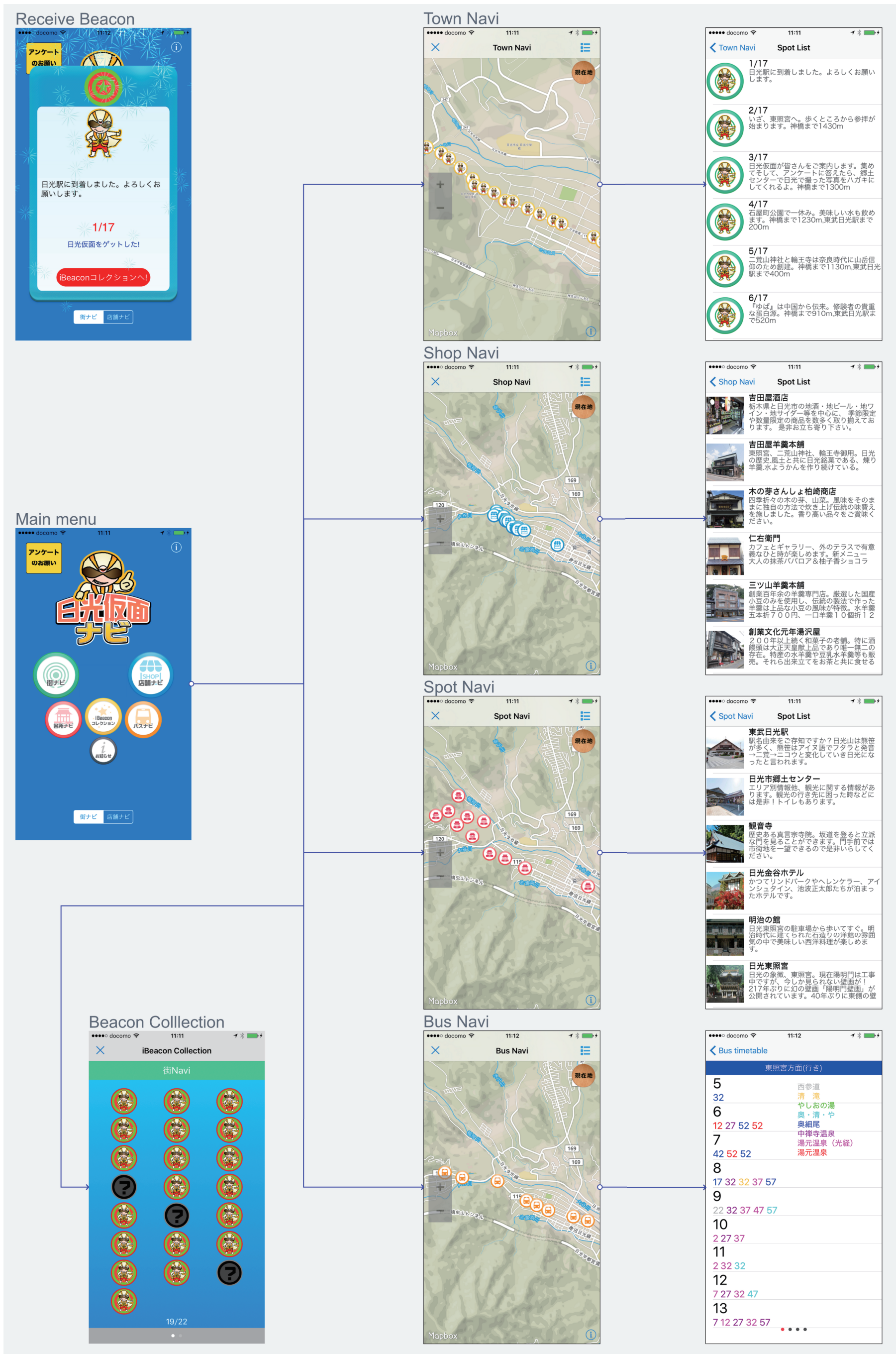


Fig. 3.7: NikkoKamen Navi.

3.4 Information Distribution Using Beacon as a Starting Point

Nikko Kamen Navi is an application that delivers information about the surrounding area when it receives a BLE Beacon signal. When you get close to an iBeacon, iOS receives the UUID, Major, and Minor and notifies the application. Using the UUID, Major and Minor as keys, the application will retrieve and display the information from a local database (Fig. 3.8).

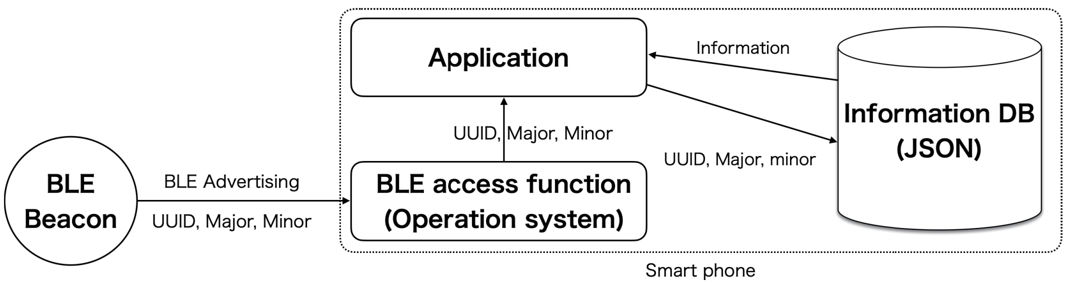


Fig. 3.8: Delivering sightseeing information by BLE beacon.

The application shows the message of the location when a tourist approaches a BLE Beacon with a smartphone.

Fig. 3.9: Receive beacon's signal and show message.

3.5 Our Cognitive Model of Sightseeing

We studied the system to realize how to provide information to make people feel and understand the culture and history of the Nikko region, and how to increase the number of visitors and repeat visitors. We focused on Zeigarnik Effect [33] for that purpose. Zeigarnik Effect carries the name of Bluma Zeigarnik, a Lithuanian-born psychologist. This effect explains that completed tasks are less recalled than uncompleted tasks. For the Zeigarnik Effect, a study made by N. Schiffman and S. Greist-Bousquet in 1992 [34] provided evidence. Zeigarnik Effect explains that a desire or stress to complete uncompleted part can keep memory longer. In other words, Zeigarnik tasks that have been completed are recalled less well than tasks that have not been completed. Nowadays, all the applications provide detailed navigation functions for trips; however, we thought to create the incomplete experience based on the Zeigarnik Effect.

In the ordinary cognitive model of sightseeing, simple loop of three stages, Expectation (before travel) => Notice (during travel) => Memory (after travel), is used (Fig. 3.10).

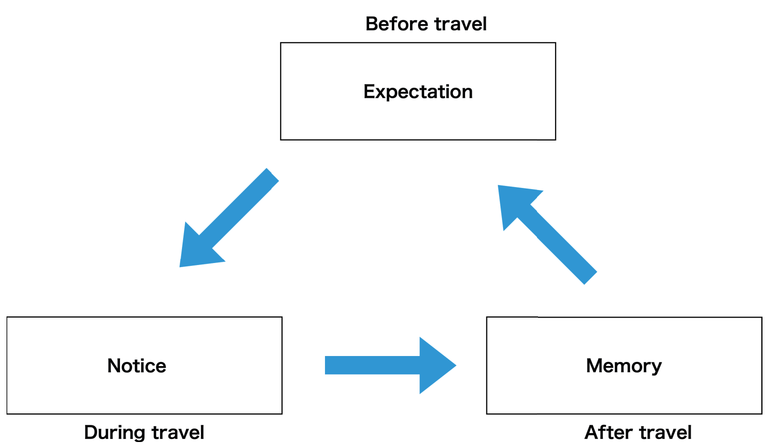


Fig. 3.10: Cognitive model of sightseeing

We developed this model based on the Zeigarnik Effect and our research on modeling of expectation (Fig. 3.11).

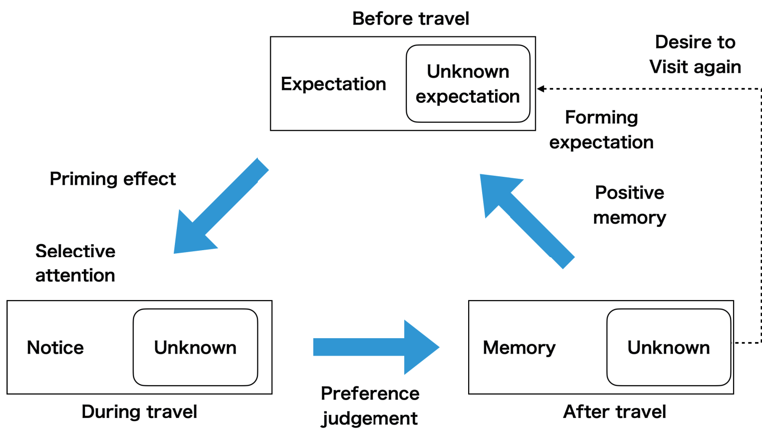


Fig. 3.11: Our cognitive model for sightseeing

In our model of sightseeing (Fig. 3.11), if a visitor finds unknown part of the visited area, Zeigarnik Effect causes strong memory that remains after the travel. Then the memory extended and emphasized by unknown part causes unknown expectation and generate a desire to visit there again. We evaluated and proved the effect of quizzes to make an unknown part. For example, perhaps I do not know the answer to the question about Toshogu shrine: "The roof of hall of worship of Toshogu shrine has 100 pictures of dragons. How many fingers do they have?". This is not an easy question. It is difficult to answer at first so that the image of "pictures of dragons" may be kept in my memory, making me want to see the picture again.

3.6 Extending the Application of Zeigarnik

We developed application implemented in our cognitive model for sightseeing. This was achieved by extending the functions to Nikko Kamen Navi. When the application receives a BLE Beacon signal, it triggers a quiz on the screen (Fig. 3.12). The content of the quiz is related to the history of Nikko, such as "The roof of the hall of worship of Toshogu shrine has 100 pictures of dragons. How many fingers do they have?"(Fig. 3.13). In this application, we apply the Zeigarnik Effect by displaying a quiz and presenting incomplete information to tourists.

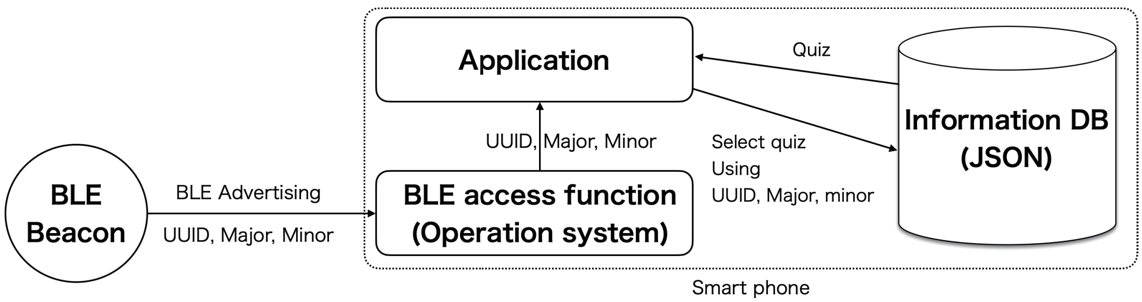


Fig. 3.12: Application

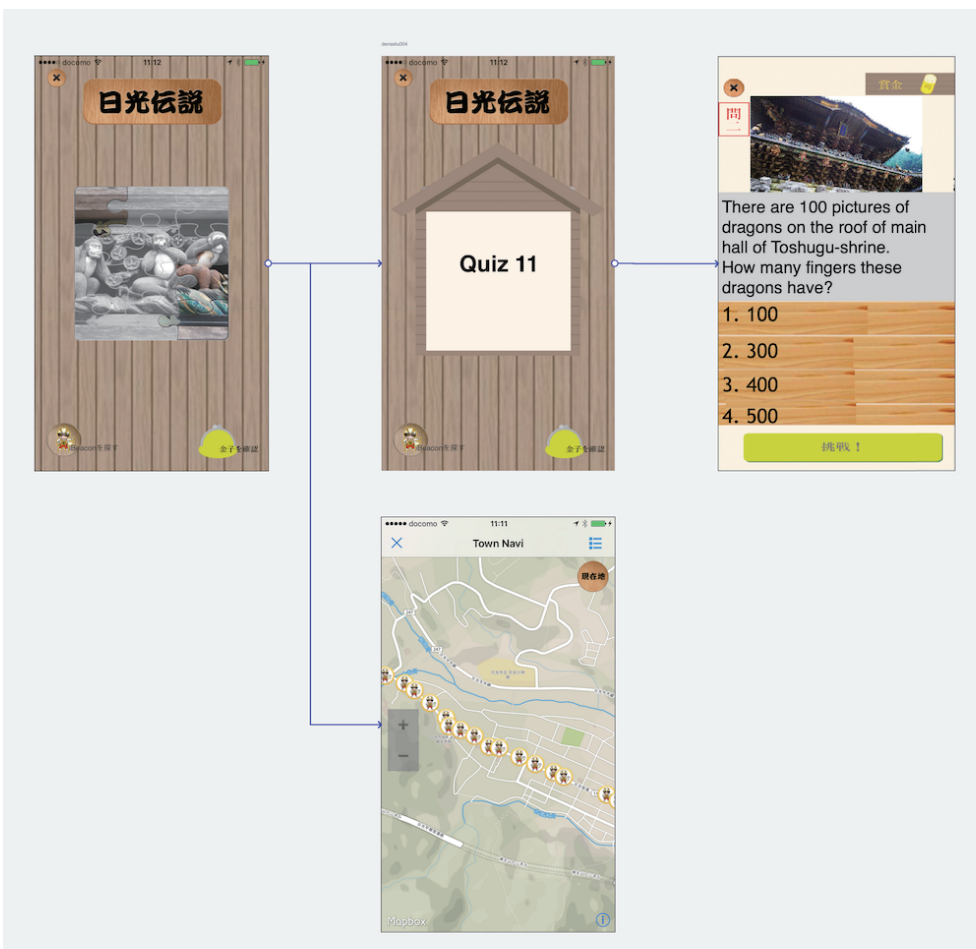


Fig. 3.13: Extending the application of Zeigarnik

3.7 Experimental results

In 2016, we tried to evaluate the effectiveness of our cognitive model from a different viewpoint, in other words, how this model increases impression of Nikko. For that purpose, we performed these trials from Sep. 2016 to Dec. 2016. Eighteen students cooperated in this trial. Students visited Nikko when they could find the time. When they arrived at Nikko station, they started to walk toward Toshogu shrine following navigation of the application and answering quizzes.

Just after they finished sightseeing, we asked them to answer two questionnaires, one on impression about the application (5 levels Liker scale) and another on impression of Nikko (5 levels Liker scale). Then two months later, we asked them to answer the same questions on impression of Nikko to check the effect of using application, especially trying quizzes, to remain and emphasize the memory of Nikko. Outline of this trial is described in Fig. 3.14. After we received answers from students, we analyzed them to classify the impression of Nikko Kamen Navi by using principal component analysis and cluster analysis (Ward's method) in SPSS v23. We got 3 clusters. Cluster 1 (n=7) were persons who appreciated sound, color, and expression. Cluster 2 (n=7) appreciated overall impression and UX. Cluster 3 (n=4) appreciated quiz contents and visibility of the map.

Table 3.5 shows the average of the score as the result of this step. Two months later, we compared answers of the impression of Nikko. One is the answer of just after trial and another is that of two months later. Table 3.6 shows the comparison of the two results. Each cell shows the average of the score in each cluster. A cell with color is the question that scores increased. In Cluster 1, the score of two questions increased and in Cluster 2, the score of only one question increased. On the other hand, in Cluster 3, the score of nine questions increased. In Table 3.6, there are two colors in the cells, one is light and another is dark. The dark color means that the difference of score is +1 or larger. The light color means the difference is less than +1. Cluster 1 and 2 do not have a dark colored cell and only Cluster 3 has such cells. This result means that Cluster 3 has a better impression in Nikko than other two clusters. This result means that those who appreciated contents had the strong memory of Nikko, especially culture and history. We can conclude that this is one of the evidence to prove the effectiveness of our cognitive model for sightseeing. If it is possible to generate satisfaction and expectation by quizzes, it may also be possible to increase a positive impression of Nikko.

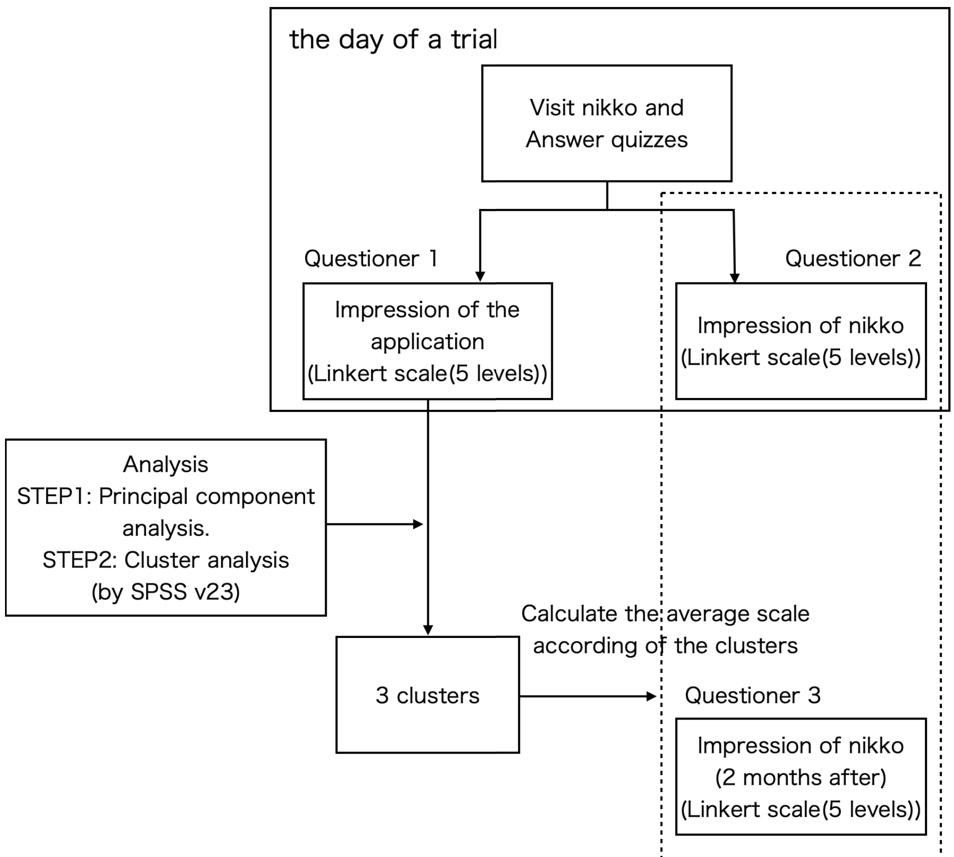


Fig. 3.14: Outline of the trial and Analysis

Table 3.5: Result of cluster analysis

Evaluation point	Cluser1	Cluster2	Cluster3
Impression	3.29	4.57	3.25
Interface	4.00	4.14	3.25
Usability	3.00	3.71	3.25
Character size	4.14	4.00	4.00
Sound	4.43	3.29	3.25
Color	4.57	4.29	3.25
Expression	4.29	3.86	3.25
Contents(Quiz)	3.14	4.14	4.25
Visibility of the map	3.43	3.29	5.00

Table 3.6: Comparison of the results between two months

Just after visit				2 months after			
Questions	Cluser1	Cluser2	Cluser3	Questions	Cluser1	Cluser2	Cluser3
Nature	4.57	4.86	4.00	Nature	4.43	4.83	4.50
History culture	4.29	5.00	3.50	History culture	4.43	4.80	4.75
City scope	4.14	3.86	4.00	City scope	4.00	3.83	4.00
Hot spring	4.00	3.71	3.50	Hot spring	3.57	3.50	3.25
Traditional culture	3.43	3.86	3.00	Traditional culture	3.71	3.83	4.00
Food	3.86	4.00	3.50	Food	3.71	3.83	4.75
Activity	3.00	3.43	2.25	Activity	3.00	2.83	3.75
Night spots	2.86	2.71	3.50	Night spots	3.00	2.67	3.00
Interaction with local people	3.00	3.43	2.25	Interaction with local people	3.37	3.33	3.00
Reservation of accommodation	3.14	3.29	3.50	Reservation of accommodation	3.00	3.17	3.00
Price/quality of accommodation	3.43	3.71	3.25	Price/quality of accommodation	3.00	3.17	3.50
Convenience of access	3.86	4.43	2.75	Convenience of access	3.29	3.50	1.75
Price	3.14	3.43	2.25	Night spots	3.00	3.83	3.25

Chapter 4

Apply Maslow's Hierarchy of Needs to Prioritize Information

In 2017, we designed the Solar BLE Beacon and installed it in Oku-Nikko, and we implemented and evaluated an application of UI designed with Maslow's hierarchy of needs.

4.1 About Oku-Nikko

Oku-Nikko is in the west part where is world heritage area with beautiful the marsh registered under the Ramsar Convention [35]. This area is famous for great nature such as forest, lake, mountain, river, waterfall and large marshland called Senjyo-gahara. We can see different kinds of flowers, birds, and animals in Oku-Nikko. We can also enjoy hiking, mountain climbing, fishing, bird watching, etc. in this area, and many people visit this area in all season from many countries.

Many tourists visit Nikko, over 10 million people per year, to see Toshogu shrine. However, almost all of them do not visit Oku-Nikko. One of the reasons is that access to Oku-Nikko is difficult to understand.

4.2 Design of Solar BLE Beacon

The Solar BLE Beacon consists of a solar panel, charging circuit, BLE Beacon, and battery (Fig. 4.1). The Solar Panel uses a small panel capable of charging at 5V / 40 mA. A board with MCP73871 was used to manage the charging process. The battery was a 400 mAh lithium-ion battery.

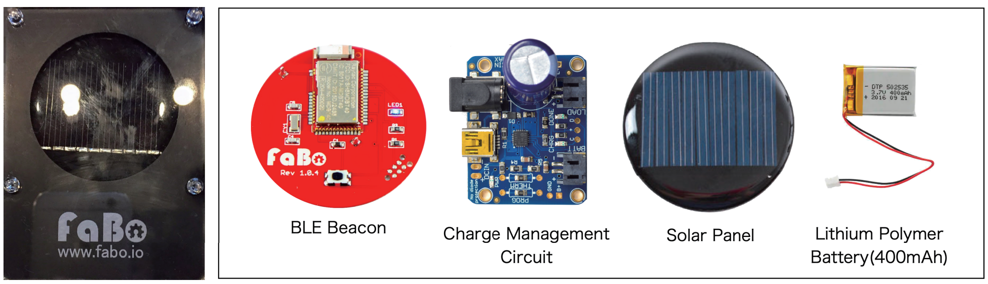


Fig. 4.1: Solar BLE Beacon

The balance between charging and consumption is shown in Fig. 4.2. If it's daytime, when the BLE Beacon is in sleep mode, it is mostly charged and only consumes heavily when the BLE Beacon is transmitting a signal. During the night, it is constantly consumed.

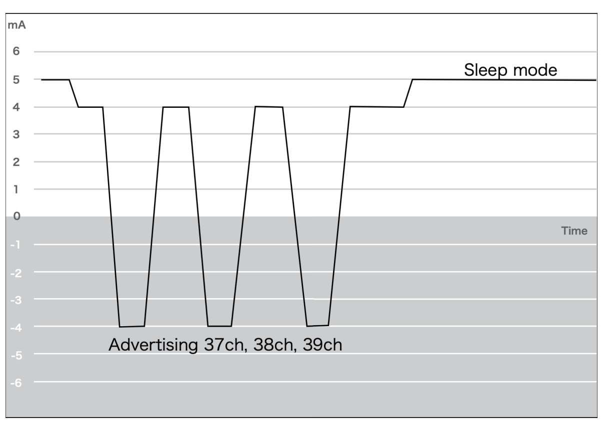


Fig. 4.2: Power Charging (Day time)

If we can create a balance where the lithium-ion battery is charged when the sun is shining, the Solar BLE Beacon will be able to operate for multiple years. Fig. 4.3 shows a dialog diagram of the Solar BLE Beacon. The Power Management Circuit manages the charging and consumption of the lithium-ion battery.

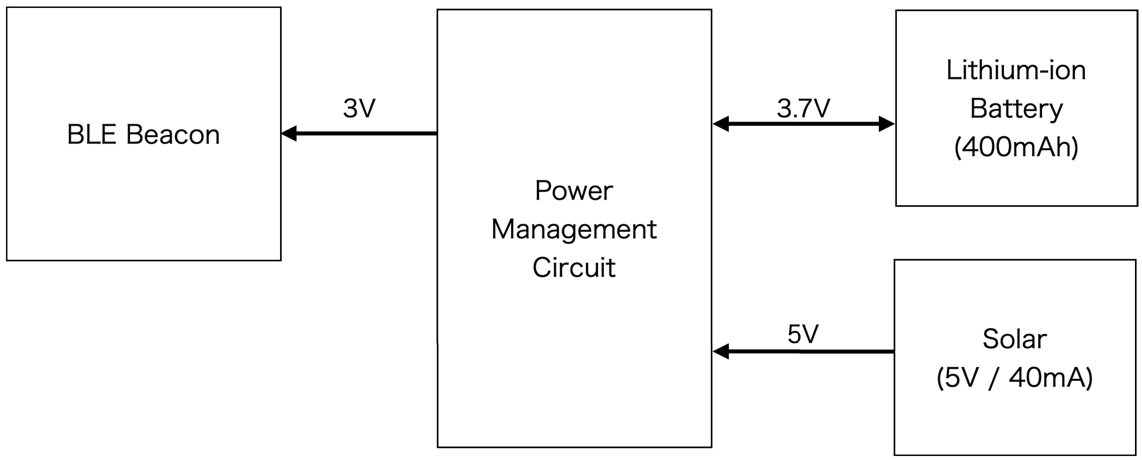


Fig. 4.3: Dialog Diagram

To be installed and operated outdoors, we have designed the case in Fig. 4.4. The case design features a solar panel and water resistance, beacons are designed to keep running all the time with no one to manage them in mountain side.

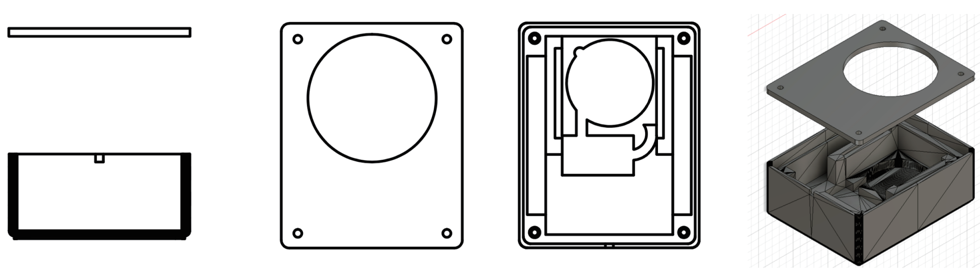


Fig. 4.4: Solar Beacon case

4.3 Installed Solar BLE Beacons in Oku-Nikko

We installed 11 BLE Beacons from Akanuma to Yudaki in Oku-Nikko in Fig. 4.5. We also installed BLE Beacon on the promenade of Senjo-Gahara. BLE Beacons were attached to tourist signs in Fig. 4.6.

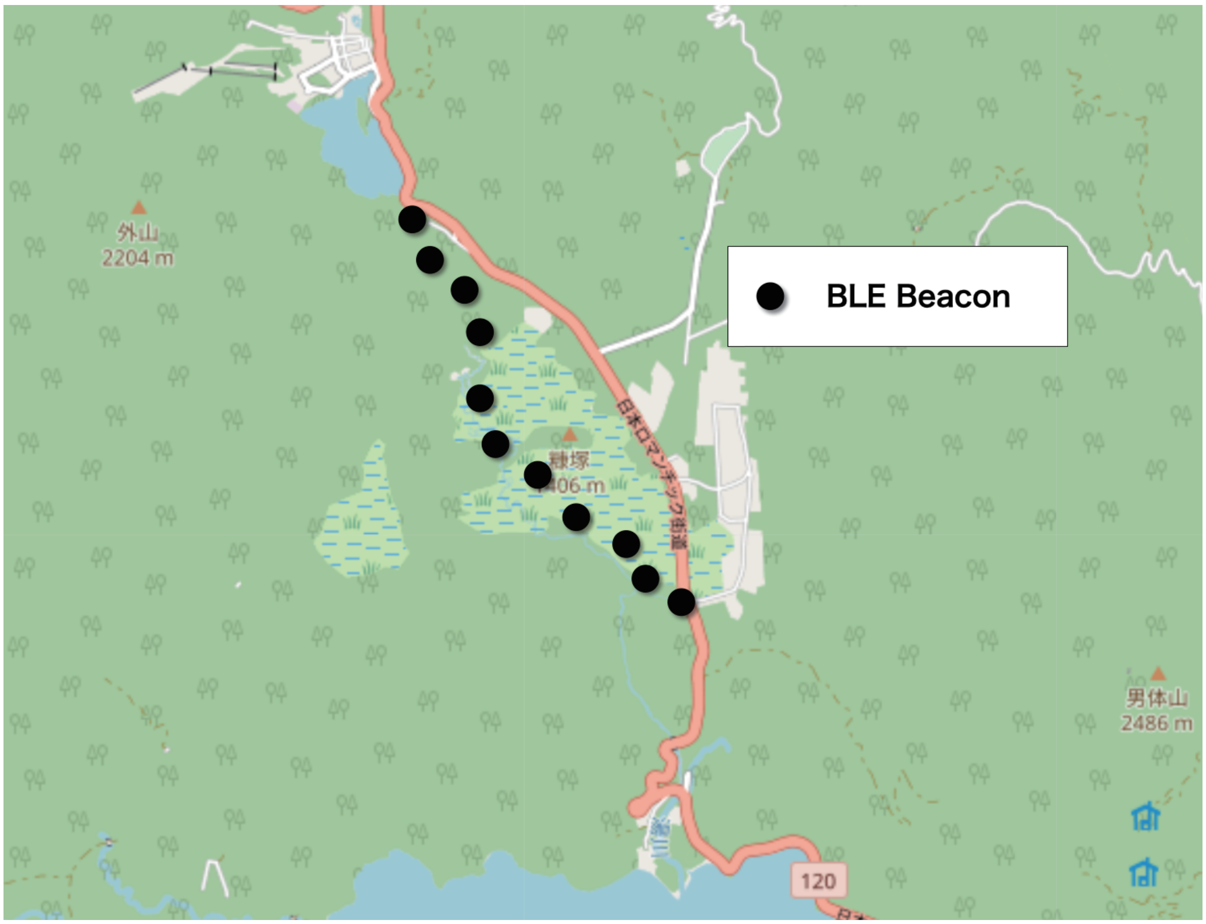


Fig. 4.5: Solar BLE Beacon in Oku-Nikko

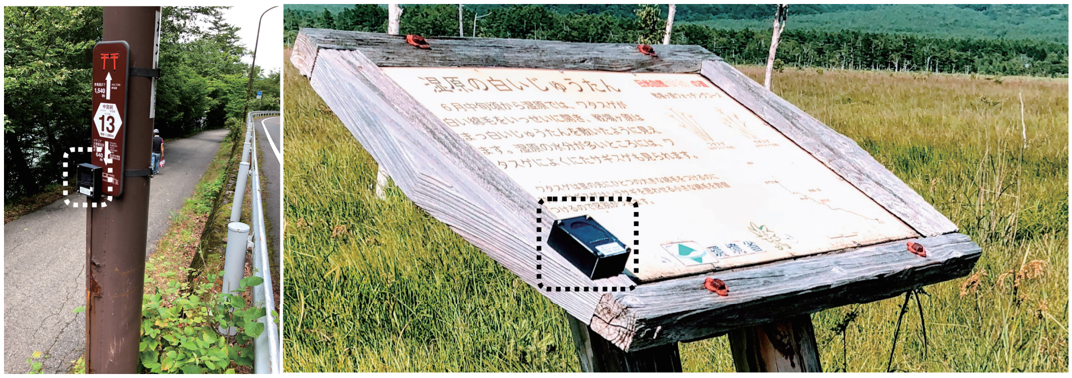


Fig. 4.6: Installed Solar BLE Beacon in Oku-Nikko

4.4 Categories of elements of a Travel

Traditionally, the psychology of sightseeing separates travel in three stages, such as before travel, during travel, and after travel. According to Fig. 2.1, the trigger of travel is a desire for novelty. However, these studies do not contain the analysis of required information during sightseeing. Our research is focusing on this part and propose a design method for an application for sightseeing based on psychology. We firstly classified the information required for sightseeing into ten categories (Fig. 4.7).

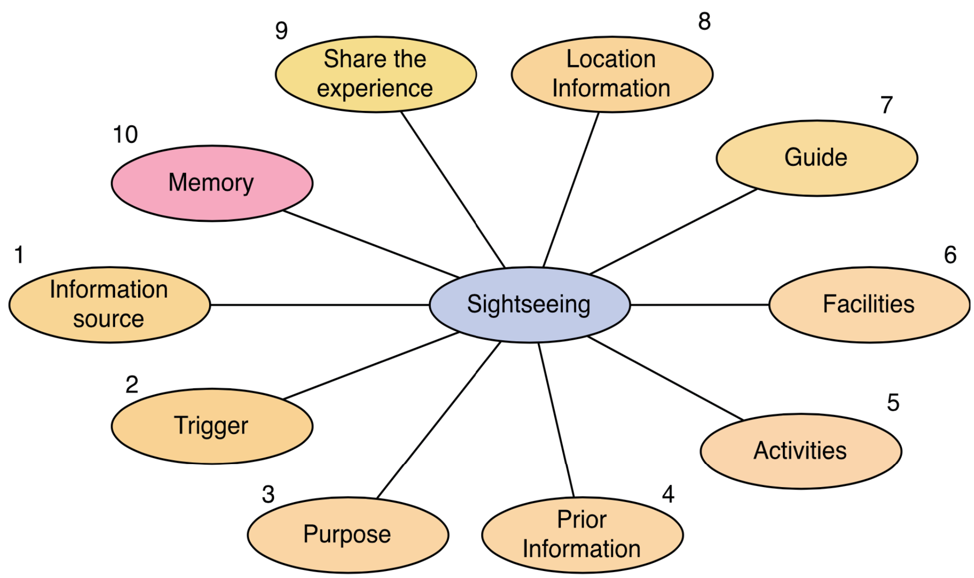


Fig. 4.7: Categories of information required for a sightseeing

One to 4 in Fig. 4.7 are related to motivation for sightseeing.

1. **Information source:**

   Tools used to find information relating to the destination before and during a sightseeing. (web page, book, magazine, travel agency, information from friends, SNS, direct mail (DM), etc.)

2. **Purpose:**

   The purpose of sightseeing. (hot spring, gourmet, nature, scenery, shopping, festival, event, attraction, theme park, etc.)

3. **Trigger:**

   Cue to go to sightseeing. (information source, purpose)

4. **Memory:**

   Positive memory to be a repeater based on the previous trip

Five to 7 are related to logistics of sightseeing.

5. **Prior information:**

Information relating to the destination area. (accommodation, WiFi, model course, weather, price, regional products, activity, etc.)

6. **Activities:**
   Something to see or to do in the destination area. (Gourmet, event, attraction, high light, model course, facilities, etc.)

7. **Facilities:**
   Information on facilities in the destination. (museums, parking lot, restroom, fee, opening hour, reservation, congestion, etc.)

Eight to 10 are related to information required during sightseeing.

8. **Guide:**
   Information to look around the destination. (Guidance of the area, model route, history, information of origin, effect of hot spring, etc.)

9. **Location information:**
   Information on navigation and maps and spot. (Map, route search, store location information)

10. **Share the experience:**
    Activity to share the impression of the destination. (SNS, blog, comments, postcard, letter, email, etc.)

Fig. 4.8 shows the related among information relating to sightseeing and category of the information. These items are summarized in Fig. 4.8.

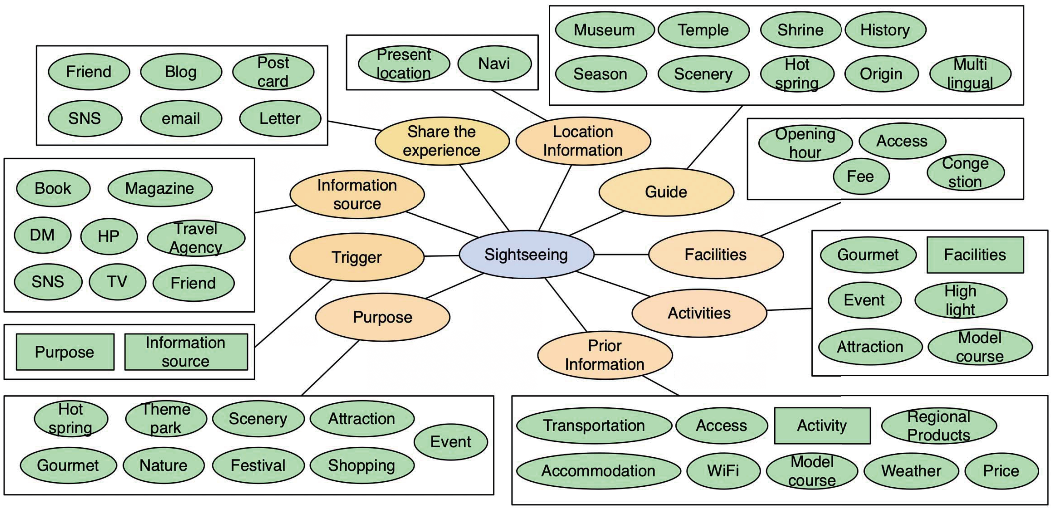


Fig. 4.8: Categories of information of sightseeing.

4.5 Maslow's Hierarchy of Needs

We used Maslow's hierarchy of needs [36, 37] to design the UI of the sightseeing application. We mapped the information into Maslow's hierarchy of needs, as shown in Fig. 4.9. We did not use the 7th layer, "Self-actualization needs", as this need is not directly related to sightseeing.

Maslow stated that people are motivated to achieve certain needs and that some needs take precedence over others [36, 37]. Our most basic need is for physical survival, and this will be the first thing that motivates our behavior. Once that level is fulfilled the next level up is what motivates us, and so on. The lower need is more important and has higher priority. He developed different types of the hierarchy of need such as 5 layers model and 8 layers model. In our research, we used the 7 layers model (Fig. 4.9) since this model meets the classification of information required for sightseeing.

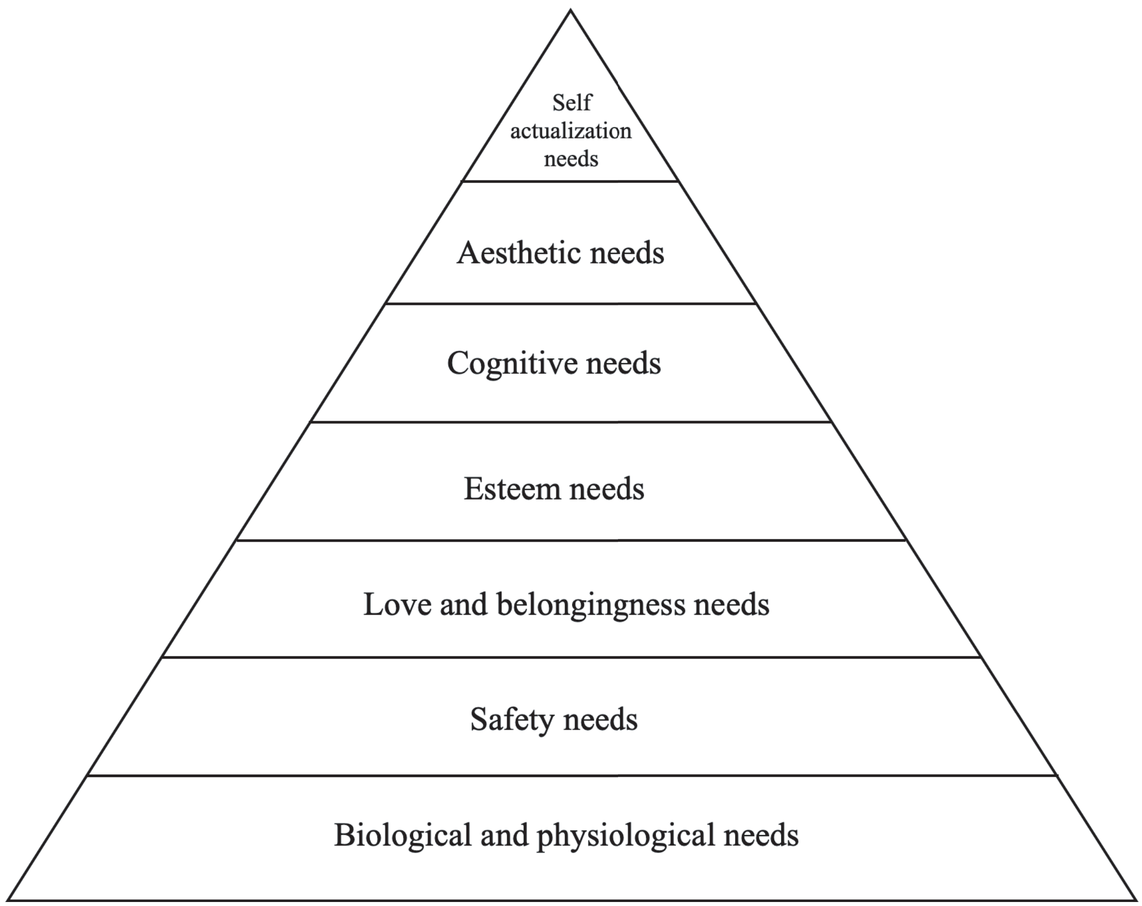


Fig. 4.9: Maslow's hierarchy of needs

- **Level 1. Biological and physiological needs**
  air, food, drink, shelter, warmth, sex, sleep, etc.
- **Level 2. Safety needs**
  protection from elements, security, order, law, stability, etc.
- **Level 3. Love and belongingness needs**
  friendship, intimacy, trust, and acceptance, receiving and giving affection and love. affiliating, being part of a group (family, friends, work).
- **Level 4. Esteem needs**
  esteem for oneself (dignity, achievement, mastery, independence) and the desire for reputation or respect from others (e.g., status, prestige).
- **Level 5. Cognitive needs**
  knowledge and understanding, curiosity, exploration, need for meaning and predictability.
- **Level 6. Aesthetic needs**
  appreciation and search for beauty, balance, form, etc.
- **Level 7. Self-actualization needs**
  realizing personal potential, self-fulfillment, seeking personal growth and peak experiences.

We applied this idea to the design of our application for sightseeing in Oku-Nikko.

4.6 Mapping between Maslow's Hierarchy of Needs and Elements of Sightseeing

Table 4.1 shows the mapping between Maslow's hierarchy of needs and elements of sightseeing.

Table 4.1: Mapping between Maslow's hierarchy of needs and elements of sightseeing

Level	Hierarchy of needs	Elements of sightseeing
1	Biological and physiological	Food(stores), Restroom
2	Protection from elements, security etc.	Transportation, Access, Accommodation, WiFi, Price, Weather, Congestion, Disaster relief, Alert of risk, Map, Multi lingual assist
3	Love and belongingness needs	SNS, Blog, email, Letter, Post card
4	Esteemneeds	"like", Reaction for the articles, Reply for mail
5	Cognitive needs	Guidance, Model course, Event, High light
6	Aestheticneeds	History, Origin, Hidden knowledge Photo and explanation of scenery, animals and flowers
7	Self-actualizationneeds	Coincidence of expectation and experience Achievement of purpose

4.7 Analysis of elements of sightseeing and their priority

We performed an interview with visitors in Nikko area and Oku-Nikko area on September 2nd and 3rd, 2017 to investigate images and impression on Oku-Nikko. We performed the interview at Nikko station (Tobu and JR), Nikko Natural Science Museum, Visitor center in Yumoto and Akanuma, and rest area in Senjyo-gahara. The target was both Japanese (125) and foreigners (24). Typical answers were as follows.

Have image of Oku-Nikko: 70 persons (56%) ⇔ No idea: 14 persons (11.2%)

If they answered to have an image of Oku-Nikko, their images were "nature", "beautiful" and "quiet". From the result of the interview, we thought that many visitors in Nikko may have an unclear image of Oku-Nikko. However, they may have no idea of famous sightseeing spots and access to Oku-Nikko. We also asked them what kind of information is required if they use an application to guide Oku-Nikko. The answers were as follows.

- Restroom
- Spring water
- Name and photo of birds
- Seasonal information
- Information of bus route and timetable
- Opinion and recommendation from specialists
- Guide walking tour

4.8 Priority of Information for Sightseeing in Oku-Nikko

Based on the elements of sightseeing, we listed up the following functions that should be implemented in an application of Oku-Nikko.

- Weather
- Information
- Bus time table
- Map (present location, visitor center, restroom, restaurant)
- Information (nature, sign board, shops, etc.)
- Photos in different seasons (Spring, Summer, Autumn, Winter)
- Picture book (birds, flowers, mountains)
- Stamp rally
- Pop up information according to location of a beacon
- SNS

- Setting

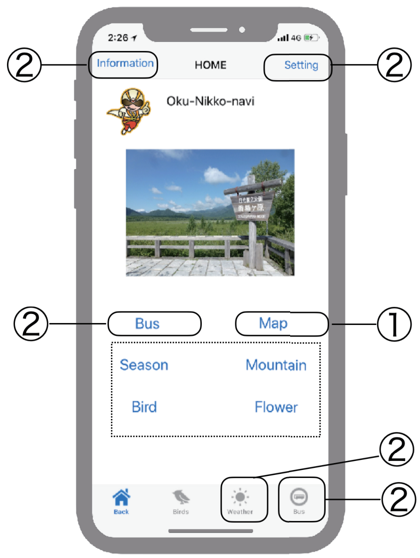
Table 4.8 shows mapping among elements of information, Maslow's hierarchy of needs, and functions of the application. In the next section, we would like to explain how we designed the application based on the analysis described in this section.

Table 4.2: Mapping among elements of information, Maslowś hierarchy of needs and functions of application

Elements of sightseeing (Oku-Nikko)	**Levels of needs**						**Function of App**
	1	**2**	**3**	**4**	**5**	**6**	
Weather		o					Weather
New Information (Weather, Disaster, Bear, Event etc.)		o			o	o	Information
Transportation, Access		o					Bus (Timetable and route)
Restroom, Present location, Model courses	o	o					Map
Transportation, High light, Guidance, Food (Shops)	o	o			o		Pop-up
High light, Photos of seasons						o	Seasons Photo
Guidance, Photos of animals, Origin, flowers, mountains					o	o	Photobooks
Event					o		Stamp rally
SNS,"Like"			o	o			SNS
Multi lingual		o					Setting

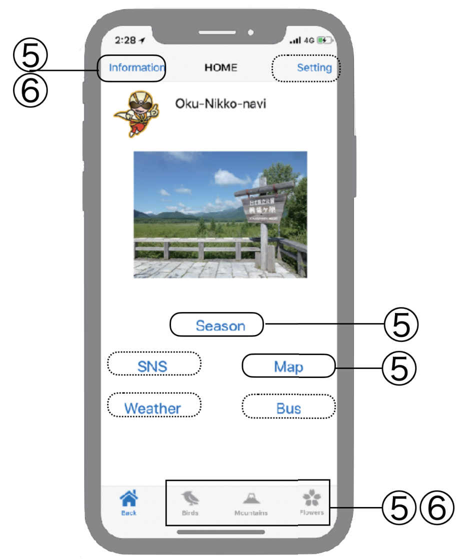
4.9 Develop Application

We designed the user interface based on the mapping among sightseeing information elements and Maslow's hierarchy of needs. The user interface contains some buttons, Weather, Information, Timetable of a bus, Map (current position, restroom, visitor center, rest house), Information on the area (nature guide, shops), Photos of seasons, Guidebook of birds, flowers and mountains, Stamp Rally, Pop-up information according to the received beacon signal, SNS, and Setting. We tested two patterns: In the first pattern, levels 1 and 2 had higher priority (Fig. 4.10), while in the second one, levels 5 and 6 had higher priority (Fig. 4.11). The application was developed for iOS.



Level						Function of application. (SmartPhone)
①	②	③	④	⑤	⑥	
	○					Weather
	○			○	○	Information
	○					Bus(Timetables and route)
○	○			○		Map
○	○			○		Pop-up
					○	Season photo
				○	○	Photo books
				○		Stamp ralley
		○	○			SNS
	○					Setting

Fig. 4.10: Layout1



Level						Function of application. (SmartPhone)
①	②	③	④	⑤	⑥	
	○					Weather
	○			○	○	Information
	○					Bus(Timetables and route)
○	○			○		Map
○	○			○		Pop-up
					○	Season photo
				○	○	Photo books
				○		Stamp ralley
		○	○			SNS
	○					Setting

Fig. 4.11: Layout2

The two user interface designs are shown in Fig. 4.10 and Fig. 4.11. Also, we introduced buttons to access seasonal photos and photo books of nature (mountain, flower, bird) on the home screen. The outline of the experiment is described in Fig. 4.12. We performed an experiment to compare these applications.

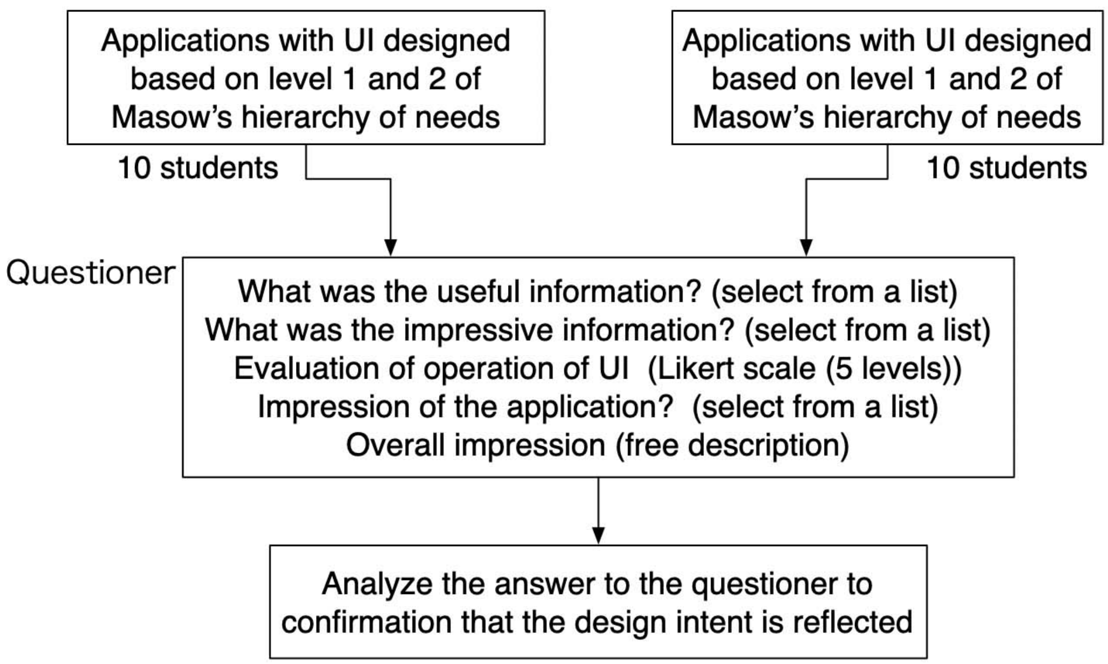


Fig. 4.12: Two different designs of user interface. Left one was designed based on layer 1 and 2, right one was designed based on layer 5 and 6

4.10 Experimental results

The experiment was held from February 19, 2018 to February 21, 2018. Twenty students (eighteen male and two female) joined the experiment. After using the application, we asked them about the impression of the application by having them answer a questionnaire. Some of the questions are listed below.

- What was the useful information? (multiple selections are possible)
- What was the impressive information? (multiple selections are possible)
- The following ten items are evaluated on a scale of 1 (not good) to 5 (very good).
  1. Easy to operate.
  2. The characters are easy to read.
  3. The amount of information is appropriate.
  4. Good design.
  5. Easy to read map.
  6. Ease of use of bus timetable.
  7. The button layout is correct.
  8. The pop-up is easy to see.
  9. The pop-up information is appropriate
- Impression of the app. (multiple selections allowed)
- Impressions using the app. (free description)

The impression of information is summarized in Fig. 4.13 As a result, when Layout-1 was used, information on surrounding areas and information on the time required to reach the bus stops and major sightseeing spots included in restroom information and pop-ups using beacons were highly evaluated. When Layout-2 was used, the guidebook of birds, flowers, and mountains was highly evaluated. We think that the user interface design based on the mapping among sightseeing information elements and Maslow's hierarchy of needs is valuable.

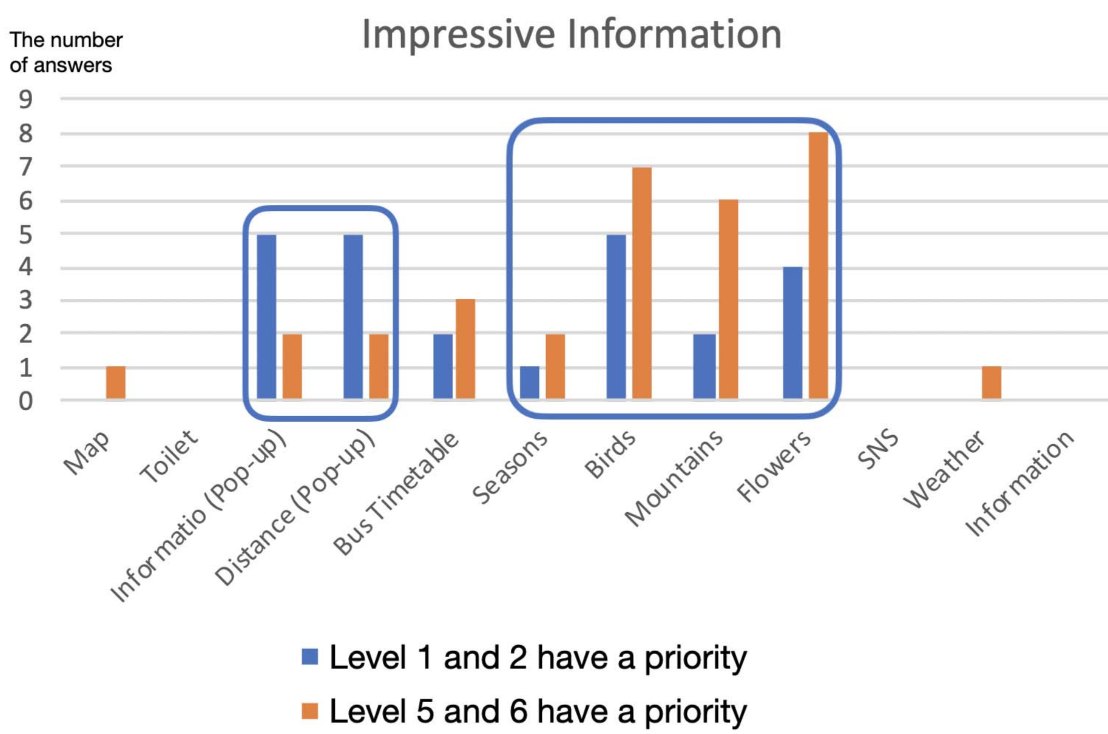


Fig. 4.13: Two different designs of UI, left one was designed based on layer 1 and 2, right one was designed based on layer 5 and 6,

Chapter 5

Information Tailored to the Situation by Applying Prospect Theory

In 2018, we implemented and evaluated an application of the prospect theory to provide the information according to the behavior.

5.1 Providing information based on Prospect Theory

5.1.1 Optimization of Delivered Information

One critical issue in using a smartphone for sightseeing is that there is too much information. Too much information not only makes selection difficult but also denies or complicates access to the information.

This is a phenomenon called overload of clue [38]. In the information delivery using the BLE Beacon that we are developing, one beacon provides one information. However, it is necessary to link various information to the beacon for practical use. For example, around a BLE Beacon, there are not only shrines and temples but also souvenir shops and restaurants.

In addition, there is an information asymmetry in tourist destinations. It is difficult for tourists to find out about local word-of-mouth information in tourist areas that they do not normally live in. For tourists, it is very difficult to get the information they really need in a tourist area where there is a lot of and asymmetry of information.

However, of all that information, what is the most relevant for tourists? For example, it is conceivable to obtain the user's profile and send the most appropriate information in consideration of triggers such as position and time.However, it is difficult to formulate a strategy for providing information that also assumes the user's psychological and physical conditions. As a result, it is expected that similar information will be provided to tourists in the same pattern. It is essential to select and provide the most appropriate and in-demand information from the uncountable bits of information to increase tourists' satisfaction.

As shown in Fig. 5.1, sightseeing information is to be provided following the change of user requirements. To implement a function to realize such a procedure, we first consider the value of information for each tourist and situation.

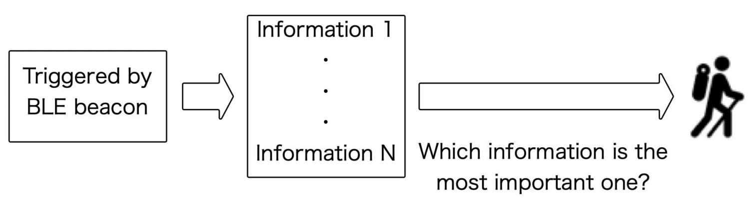


Fig. 5.1: A model to provide information.

Prospect Theory [39, 40] is an important theory in behavioral economics. This theory has the following three features.

- **Reference Point is used for evaluation**
- **Diminishing Sensitivity**
- **Loss Aversion**

Fig. 5.2 shows a graph that explains the Prospect Theory [41]. This graph explains that the loss gives larger mental damage rather than gain. We tried to apply this idea to our sightseeing support application. It means deciding the information to be delivered based on the psychological value. According to Fig. 5.2, if the value of the information is left as the reference point (the origin of the graph), the psychological value should be considered lower. The reference point is also changed by many reasons such as the knowledge and experiences, history of the daily behavior of a day of a tourist. If we can follow the change of the reference point, or the mental state of a tourist, we think that it is possible to provide sightseeing information that increases travel expectation of the travel and satisfaction of the tourist.

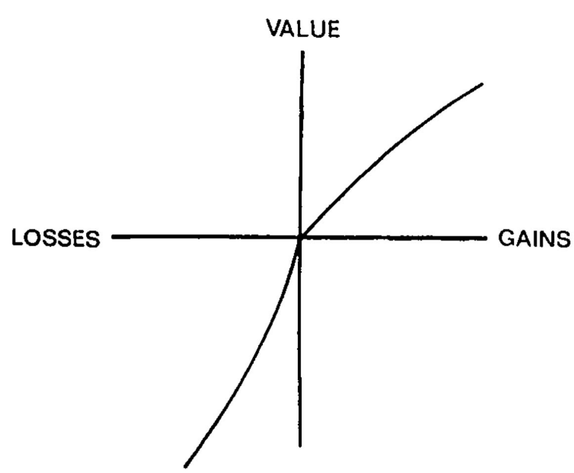


Fig. 5.2: Prospect theory

5.1.2 Outline of the Technology for Providing Sightseeing Information

In this section, we explain our idea regarding the method of providing appropriate information to a tourist. Original Prospect Theory is used to describe the value or impression according to an input such as earned money. In the field of marketing, it is also used in limited-time campaigns and refund campaigns that apply the loss-avoidance theory of prospect theory. However, in our sightseeing support system, the value of information varies according to the situation.

For example, information regarding restaurants is valuable if it is provided when a tourist is hungry. However, this information is not valuable just after lunch. Therefore, it is important to change the value of the information in real-time, which can be carried out in two ways. The first way is to change the value of the information itself, and the other is to change the baseline of the evaluation.

In the application, according to the limited calculation and storage resources, it is difficult to calculate the value while considering additional surrounding information. Therefore, we explained value as the difference between the predefined information value and the baseline of the evaluation. If a tourist is satisfied with the provided information, the baseline is up, and if they receive the information again, the value is slightly lower than the original value. According to the psychological state, if the information is not useful for a tourist, the value becomes poor, and the dissatisfaction level and mental damage increases. We tried to reflect the difference between positive and negative mental reaction in the information value evaluation algorithm that is based on the Prospect Theory.

5.1.3 Calculation of the Initial Value of Information

To calculate the value of information based on Prospect Theory, we classified information for sightseeing into four categories based on Maslow's hierarchy of needs as described in Table 5.1.

As the basis of the classification of sightseeing information, we used levels 1, 3,

Table 5.1: Classification of information based on the idea of Maslow's hierarchy of needs.

Level of Needs	**Contents**
(1) Biological and physiological needs	Sweets
	Restaurant
(3) Love and belongingness needs	Post office
	Souvenier
(5) Cognitive needs	Musium
	Information center
	Event/Attraction
(6) Aesthetic needs	Nature/Scenery
	History/Culture
	Landmark

5, and 6 of Maslow's hierarchy of needs. The reasons why we did not use levels 2, 4, and 7 are as follows. Level 2 is a "safety" need. Between Nikko Station and Toshogu Shrine located in central Nikko and the area is very safe place. Therefore, there is no need to provide safety information to a tourist. Level 4 is "esteem" needs such as posting information to SNS. Such information is not needed to be provided by sightseeing application. Level 7 is "self-actualization" needs, and there is no need to provide such information.

5.1.4 Category and Value factor

We set some value factors that should affect the value of sightseeing information, which are based on the characteristics of the categories. Table 5.2 shows an example of the value factors of sightseeing information. The value factor index (I) was set in five stages, which ranged from 1 (lowest) to 5 (highest).

For example, based on a restaurant's information included in Maslow's biological and physiological needs, three information, i.e., "interest", "rareness", "environment", and "location" are set. At the start of the application, the "interest" is the information provided in the questionnaire. The "rareness", "environment", and "location" are obtained when the information is added in the application's database. For example,

Table 5.2: Category and value factors.

Category	**Value Factors**
(1) Biological and physiological needs	Interest, Rarity, Environment, Location
(3) Love and belongingness needs	Interest, Rarity, Location
(5) Cognitive needs	Interest, Complexity, Rarity
(6) Aesthetic needs	Interest, Rarity, Attraction

"JR Nikko Station" has the following information, as described in Table 5.3.

- Maslow's hierarchy of needs: Aesthetic needs
- Category of information: Landmark
- Value factors: Rarity:3, Attraction:2

Name of information	Explanation	Maslow's hierarchy of needs	Category of information	Value factors		
				Rarity	Attraction	Interest
JR Nikko starion	History	Aesthetic	Landmakr	3	2	Set by user

Fig. 5.3: Details of sightseeing information.

5.2 Modification of Prospect Theory

In this subsection, we explain the formula for evaluating the value of information based on the modified Prospect Theory.

$$U = \sum_{i=1}^{n} W_i \cdot V(\Delta I_i) \tag{5.1}$$

$$V(\Delta I_i) = \begin{cases} \Delta I_i^{\alpha}, \Delta I_i \geq 0 \\ -\lambda(-\Delta I_i)^{\beta}, \Delta I_i < 0 \end{cases} \tag{5.2}$$

$$\Delta I_i = I_i - I_0 \tag{5.3}$$

$$[a_{ij}] = \frac{W_i}{W_j} \tag{5.4}$$

$$A \begin{bmatrix} W_1 \\ W_2 \\ \cdots \\ W_n \end{bmatrix} = \begin{bmatrix} \frac{W_1}{W_1} & \frac{W_1}{W_2} & \cdots & \frac{W_1}{W_n} \\ \frac{W_2}{W_1} & \frac{W_2}{W_2} & \cdots & \frac{W_2}{W_n} \\ \cdots & & & \\ \frac{W_n}{W_1} & \frac{W_n}{W_2} & \cdots & \frac{W_n}{W_n} \end{bmatrix} \times \begin{bmatrix} W_1 \\ W_2 \\ \cdots \\ W_n \end{bmatrix}$$

$$= n \begin{bmatrix} W_1 \\ W_2 \\ \cdots \\ W_n \end{bmatrix} \tag{5.5}$$

The meaning of each parameter is as follows.

Table 5.3: Parameter of Formula

U	Utility (=overall value)
W_i	Probability weighting function
I_i	Value factor
$V(\Delta I_i)$	Value function

Formula (5.1) is used to calculate the value of information based on the Prospect Theory. Value function $V(\Delta I_i)$ is defined as Formula (5.2), where $\alpha = \beta = 0.88, \lambda = 2.25$ as described in [40]. ΔI_i in (5.1) and (5.2) is a value between the current value and the value of the reference point. Using this parameter, we tried to control the change of value according to the situation.

There are several ways to calculate the probability weighting function W_i. We used the Analytic Hierarchy Process (AHP) to calculate value factors [42] because it is possible to use the structure of the information value. AHP can be used to determine the importance between the whole and items from a paired comparison using the ratio of importance of each evaluation item. This is shown in Formula (5.4), where W is the importance of information and i, j are the numbers relating to value factors. Paired comparison matrix A = $[a_{ij}]$ is shown in Formula (5.5), n is the eigenvalue of matrix A. By finding the eigenvector for the maximum eigenvalue, the probability of each value factor W_i can be calculated, and the value U of sightseeing information can be calculated.

A reference point is set to each category that is classified by using Maslow's hierarchy of needs. As explained in Fig. 5.7, after the proposed information is evaluated by a tourist, the value of the relating reference point is recalculated. The rule of changing reference point is described in Table 5.4. Sometimes the value of the reference point increases or decreases monotonously. To prevent the difficulty of calculating the value, we set the range of the reference point from 1 to N (odd number) and the initial value is $\left\lceil \frac{N}{2} \right\rceil$. If the value of the reference point reaches 1 or N, the value returns to $\left\lceil \frac{N}{2} \right\rceil$.

Table 5.4: Change of reference point.

Change of Reference Point		**Information**	
		Responded	**Not Responded**
Evaluation	Good	0.5	1
	Not Good	−2	−1

5.3 Example of Calculation of the Value of Information

We assume that the value factor $I_1 = 5$, value factor $I_2 = 4$, and value factor $I_3 = 3$ are set and the reference points range from 1 to 5 (Table 5.5).

Table 5.5: Value of I and Reference point

	I_1	I_2	I_3	Reference point
value	5	4	3	1-5

By using the Formula (5.3), the original information value is $\Delta I_i = I_i$ because $I_0 = 0$. For the Formula (5.2), the value of α and β and λ is used by Table 5.6.

Table 5.6: α, β, λ

param	value
α	0.88
β	0.88
λ	2.25

The decision matrix is calculated by using Formulas (5.4). Value factor I_1 is $I_1/I_1 = 1$, $I_1/I_2 = 1.25$, $I_1/I_3 = 1.67$. Similarly, value factor I_2 is $I_2/I_1 = 0.8$, $I_2/I_2 = 1$, $I_2/I_3 = 1.33$. Value factor I_3 is $I_3/I_1 = 0.6$, $I_3/I_2 = 0.75$, $I_3/I_3 = 1$ (Table 5.7).

Table 5.7: Decision matrix of I_0.

	Value Factor I_1	Value Factor I_2	Value Factor I_3
Value factor I_1	1	1.25	1.67
Value factor I_2	0.8	1	1.33
Value factor I_3	0.6	0.75	1

Then, the probability weighting function W_i is calculated by using Formulas (5.5), and the decision matrix is shown in Table 5.7. The result is shown in Table 5.8.

As a result, $W_1\ is$ 0.4167, $W_2\ is$ 0.333, and $W_3\ is$ 0.2500. Then, from the Formula (5.1), $U = \sum_{i=1}^{n} W_i \cdot V(\Delta I_i)$, the original information value is calculated as $U = 5^{0.88} * 0.4167 + 4^{0.88} * 0.3333 + 3^{0.88} * 0.25 = 3.5038$.

Table 5.8: The result of calculation of W_1 from I_0.

Item	Eigenvector	Weight
Value factor I_1	1.25	0.4167
Value factor I_2	1	0.3333
Value factor I_3	0.75	0.2500

Calculation of Value Factor I_0 Relating to a Reference Point

First, we assume $I_1 = I_2 = \ldots = I_n$. The probability weighting function W_i is calculated by applying AHP, as explained in Formulas (5.4) and (5.5). The initial value of the decision matrix is described in Table 5.9. The result is shown in Table 5.10.

Table 5.9: Decision matrix of I_0 relating to a reference point.

	Value Factor I_1	Value Factor I_2	Value Factor I_3
Value factor I_1	1	1	1
Value factor I_2	1	1	1
Value factor I_3	1	1	1

Table 5.10: Calculation of W_i from I_0

Item	Eigenvector	Weight
Value factor I_1	1	0.3333
Value factor I_2	1	0.3333
Value factor I_3	1	0.3333

As a result, $W_1 = W_2 = W_3 = 0.3333$ is obtained. If the value of a reference point is 3, $U = W_1 * V(\Delta I_1) + W_2 * V(\Delta I_2) + W_3 * V(\Delta I_3) = 3$ is obtained. Then, $V(\Delta I_i) = \Delta {I_i}^{\alpha}$, $\Delta I_i = 3.484$, and $I_1 = I_2 = I_3 = 3.484$ are obtained.

5.3.1 Calculation of Information Value U

Finally, we can calculate the information value U when the case of the value of a reference point is three. By using the value factor $I_0 = 3.484$ and Formula (5.3), $\Delta I_1 = 1.516, \Delta I_2 = 0.516, \Delta I_3 = -0.484$ is obtained. Then, using (5.1) and (5.2)

$\Delta I_1 = 1.516, \Delta I_2 = 0.516, \Delta I_3 = -0.484$ and $W_1 = 0.4167$, $W_2 = 0.3333, W_3 = 0.25$ is calculated. The result of information value $U = 0.49$ (Table 5.11).

Table 5.11: Calculation results

I_1	I_2	I_3	Reference point	I_0	U
5	4	3	3	3.484	0.49

5.3.2 Outline of the Behavior of the Application

Fig. 5.4 shows the outline of the behavior of the application. The application consists of a smartphone application and a watch application. The smartphone application does the main processing, while the watch application displays information to tourists and handles feedback.

At first, the smartphone OS scans for BLE Beacons in the vicinity and, if found, notifies the application the UUID, Major, and Minor. The application finds the Beacon ID by searching the local database based on the UUID, Major, and Minor.

Using the Beacon ID as a key, the smartphone application calculates the information value of spots in the vicinity. Then, the list of information based on the information value is generated in descending order.

Finally, the list is sent to a watch application. High-priority information is displayed on the watch application, and at the same time, audio information is provided.

A tourist can add “Good” or “Not Good” to the presented information as a feedback. A tourist can also see other information of the point on a list and can do it the same way. If “Good” or “Not Good” is provided, a reference point of information is updated based on a tourist’s action. A reference point is also calculated for each category classified by Maslow’s hierarchy of needs in a location near a BLE Beacon.

Fig. 5.5 shows the screen of the watch application.

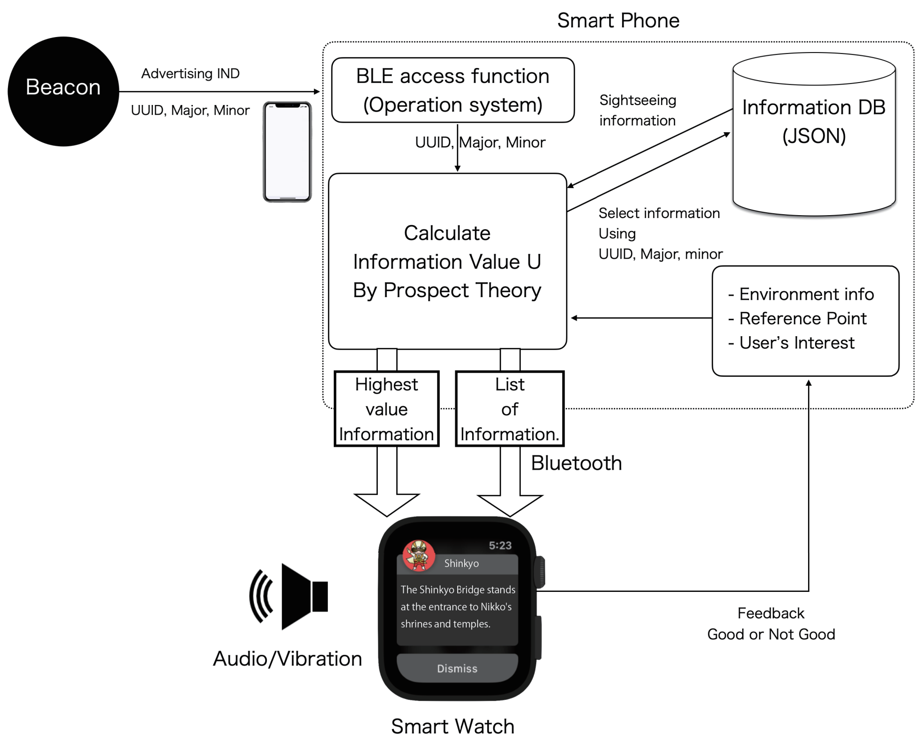


Fig. 5.4: Outline of the behavior of the application.

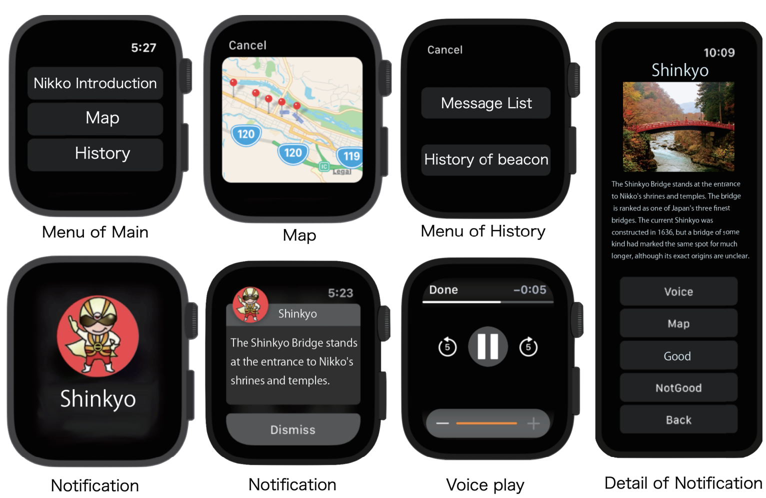


Fig. 5.5: Watch application

5.3.3 User's Interests

Users' interests and preferences are collected in the form of questionnaires by the application (Fig. 5.6). Each question is associated with the Maslow's hierarchy of needs. The result of this questionnaire is used as the value of User's Interest in value factor (Table 5.12).

Table 5.12: User interest

User Profile	Age	Enter the year of birth
	Sex	Enter Male or Female
	Who come with	Alone , Family, Friends
User Interest	Delicious food	Select a number from 1-5
	Sweets	
	Souvenir	
	Postcard	
	Experience, Event	
	Information desk	
	Museums	
	History,Culture	
	Nature	
	Landmark	

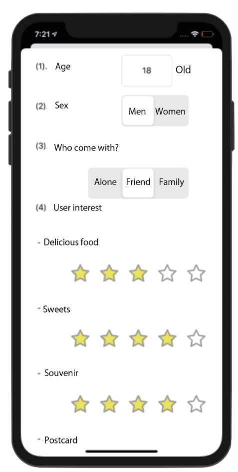


Fig. 5.6: Questionnaire of user interest.

5.3.4 Reference Point

Reference points are maintained as user states for each level of the Maslow's hierarchy. In other words, the reference point will change with the division into Level 2, Level 3, Level 5 and Level 6. The increase or decrease of the reference point depends on the user's action after the information is delivered (Fig. 5.7). When tourists open the delivered information, a "Good", "Not Good" button appears at the screen, and they can give feedback by pressing that button (Fig. 5.8).

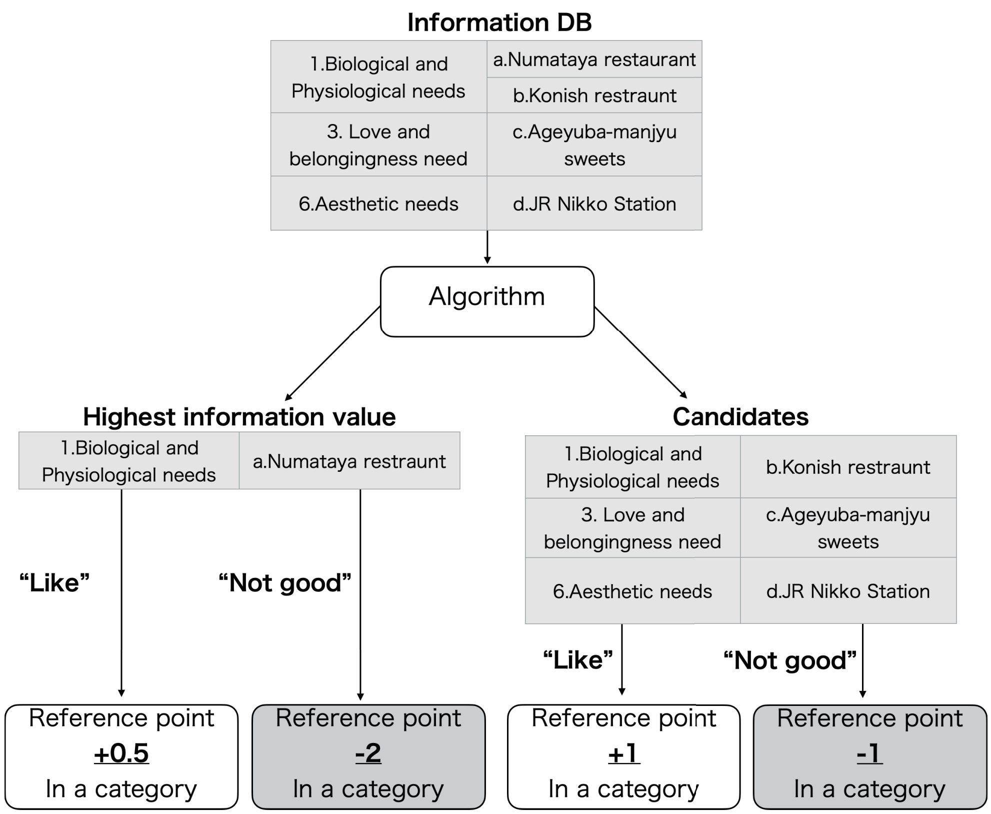


Fig. 5.7: Evaluation of information and update of the reference point.

Fig. 5.8: Flow of feedback.

5.3.5 BLE Beacon Installation Points

BLE Beacons were installed at 13 points (Fig. 5.9), and the points were linked to tourist information. Each BLE Beacon was tied to multiple tourism information and assigned a number (Table 5.13). Fifty three pieces of information about tourist attractions associated with BLE Beacon.

5.3.6 Value of factor at each point

For each BLE Beacon installation point, we defined the Value of Factor for that location. As explained in Table 5.2, each hierarchy consists of a different number of Value of Factors. Level 1 “Biological and physiological needs” has 4 factors, level 3 “Love and belongingness needs” has 3 factors, level 5 “Cognitive needs” has 3 factors, Level 6 “Aesthetic needs” has 3 factors. Interest was collected from the user questionnaire, and the other values were defined by us based on the surrounding circumstances. Level 1 “Biological and physiological needs” are shown in Table 5.14. Level 3 “Love and belongingness needs” are shown in Table 5.15. Level 5 “Cognitive needs” are shown in Table 5.16. Level 6 “Aesthetic needs” are shown in Table 5.17.

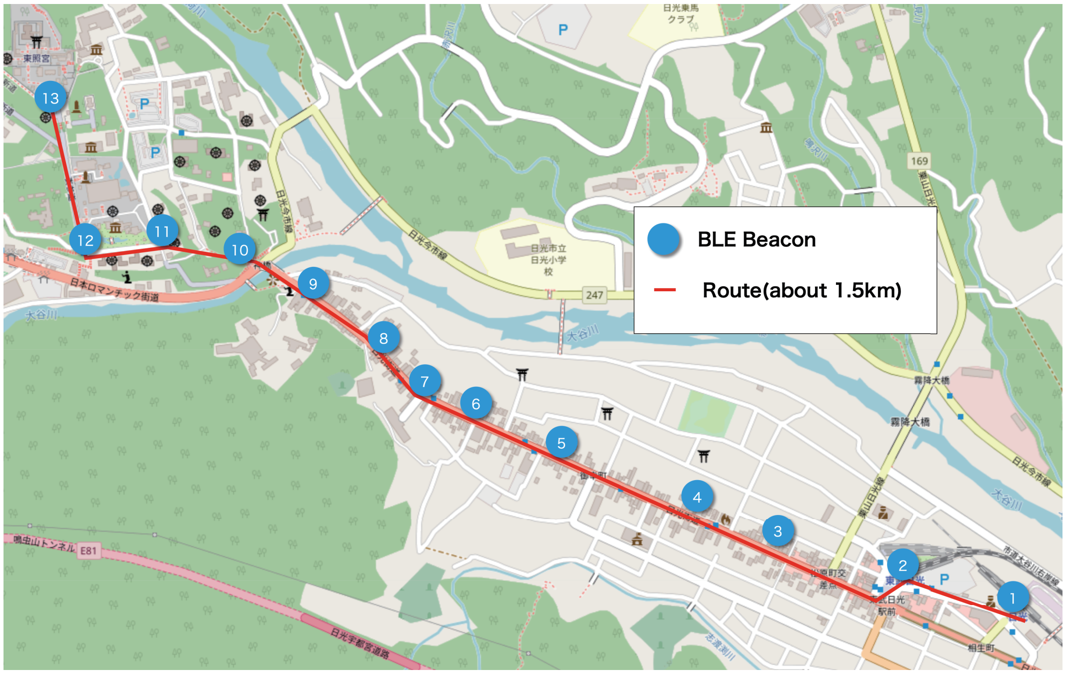


Fig. 5.9: Experiment route.

Table 5.13: Number of information linked to BLE Beacon

Bescon ID	Location name	Number of information
1	JR Nikko station	4
2	Tobu Nikko station	6
3	Nikko community house	2
4	Nikko fire station	5
5	Nikko information center	4
6	Spring water	2
7	Hatsuishi	4
8	Kannonji temple	6
9	Shinkyo bridge	4
10	Entrance of world heritage	3
11	Rinnoji bus stop	1
12	Nikkoden info. center	3
13	Entrance of toshogu shrine	9

Table 5.14: Value of Factors, Level 1

Point Name	BLE beacon ID	BLE Beacon Point Name	Rarity	Environment	Location
Konishi	1	JR Nikko Station	1	2	4
Numataya	1	JR Nikko Station	1	4	3
Restraunt “Mako”	2	Tobu Nikko Station	1	3	2
Niemon Cafe	3	Nikko community house	2	5	4
Yubatei “Masudaya”	4	Nikko fire station	3	4	3
cafe Karin	4	Nikko fire station	2	5	2
Restaurant “suzuki”	5	Nikko information center	1	3	2
Miyamae dango	5	Nikko information center	1	2	4
Nikko Yuba restraunt	5	Nikko information center	4	3	4
Nikko Sprint water	6	Sprint water	5	4	5
Yoshidaya yokan	7	Hatsuishi	3	2	4
Yasai cafe meguru	7	Hatsuishi	3	4	4
Mitsuyama yokan	8	Kannonji temple	5	2	4
izu	8	Kannonji temple	4	2	2
Hippari-Dako	8	Kannonji temple	1	3	4
Nisshodo	8	Kannonji temple	4	2	4
Iwasaku Shrine	9	Shinkyo	4	5	4
Asaya Rest house	9	Shinkyo	2	4	4
Motomiya Cafe	10	Entrance of world heritag	2	5	4
Ueshima Cafe shop	13	Entrance of toshogu shrine	2	5	4
Meiji no Yakata	13	Entrance of toshogu shrine	3	4	2

Table 5.15: Value of Factors, Level 3

Point Name	BLE beacon ID	BLE Beacon Point Name	Rarity	Location
Age Yuba Manjyu	1	JR Nikko Station	4	4
Toko Bussan	2	Tobu Nikko Station	3	4
Yuba Matsubaya	3	Nikko information center	4	3
Fudaraku Honpo	4	Nikko fire station	4	4
Nikko Post Office	6	Spring water	3	4
Warakudo	8	Kannonji temple	2	3

Table 5.16: Value of Factors, Level 5

Point Name	BLE beacon ID	BLE Beacon Point Name	Rarity	Complexity
Bike Share Service	2	Tobu Nikko Station	1	3
Igarashi lacquerware	2	Tobu Nikko Station	3	4
Nikko Wood Carving Workshop Erudite Center	2	Tobu Nikko Station	4	1
Urushi Museum	2	Tobu Nikko Station	3	1
COCON NIKKO	4	Nikko fire station	4	2
Nikko Ippitsuryu Takase	4	Nikko fire station	3	4
Nikko information center	5	Nikko information center	3	4
Nikko Kimono Rental Utakata	7	Hatsuishi	5	2
Nikkoden info. Center	11	Rinnoji bus stop	3	3
Kanaya Hotel Urushi Museum	12	Nikkoden info. center	3	1
Nikko Toshogu Museum	13	Entrance of toshogu shrine	4	3
Nikko Toshogu Art Museum	13	Entrance of toshogu shrine	4	4

Table 5.17: Value of Factors, Level 6

Point Name	BLE beacon ID	BLE point name	Rarity	Attraction
JR Nikko Starion	1	JR Nikko Starion	3	2
Hatuishi	7	Hatuishi	3	2
Kannonji temple	8	Kannonji temple	3	3
Inagaki Taisuke Statue	9	Shinkyo Bridge	3	2
Shinkyo Bridge	9	Shinkyo Bridge	5	5
Ooya River	10	Entrance of world heritage	3	3
Tarosugi Cedar	10	Entrance of world heritage	5	3
Sannai Garden	12	Nikkoden info. center	4	5
Rinnoji Temple	12	Nikkoden info. center	3	3
Gojyunoto	13	Entrance of toshogu shrine	5	5
Kaizando	13	Entrance of toshogu shrine	2	3
Nikko Niarayama Temple	13	Entrance of toshogu shrine	3	3
Nikko Toshogu	13	Entrance of toshogu shrine	5	5
Nikkosanrinnoji Taiyuin	13	Entrance of toshogu shrine	2	3

5.3.7 Calculation of the Information Value

We calculate the U for all points. U depends on user interest and reference point. In this study, we fixed user interest at 3 and calculated U at reference points of 2, 3, and 4. Fig. 5.10 is distribution chart of the information Value U.

Table 5.18: Information Value

ID	Point Name	Ref.2	Ref.3	Ref.4	ID	Point Name	Ref.2	Ref.3	Ref.4
1	Konishi	0.546360	-1.272299	-3.774710	28	Mitsuyama yokan	1.462957	-0.035950	-2.097830
2	Numataya	0.819712	-0.901861	-3.454531	29	izu	0.638038	-1.280257	-3.786989
3	Age Yuba Manjyu	1.445504	0.081180	-2.437950	30	Hippari-Dako	0.819712	-0.901861	-3.454531
4	JR Nikko Starion	0.482038	-1.688956	-4.281453	31	Nisshodo	1.139781	-0.421481	-2.928167
5	Restraunt “Mako”	0.135344	-2.058228	-4.621173	32	Warakudo	0.482038	-1.688956	-4.281453
6	Toko Bussan	1.165504	-0.490808	-3.066091	33	Kannonji temple	0.823282	-1.189903	-3.833819
7	Bike Share Service	0.328784	-1.735974	-4.334549	34	Iwasaku Shrine	1.767508	0.506268	-1.611182
8	Igarashi lacquerware	1.165504	-0.490808	-3.066091	35	Asaya Rest house	1.139781	-0.421481	-2.928167
9	Nikko Wood Carving Workshop Erudite Center	0.818374	-0.793846	-3.312298	36	Inagaki Taisuke Statue	0.482038	-1.688956	-4.281453
10	Urushi Museum	0.328784	-1.735974	-4.334549	37	Shinkyo Bridge	2.094540	0.834222	-0.724950
11	Niemon Cafe	1.462957	-0.035950	-2.097830	38	Motomiya Cafe	1.462957	-0.035950	-2.097830
12	Yuba Matsubaya	1.165504	-0.490808	-3.066091	39	Ooya River	0.823282	-1.189903	-3.833819
13	Yubatei “Masudaya”	1.086529	-0.652137	-3.243259	40	Tarosugi Cedar	1.574480	0.006171	-1.996760
14	cafe Karin	1.056888	-0.758906	-2.746694	41	Nikkoden info. Center	0.823282	-1.189903	-3.833819
15	Fudaraku Honpo	1.445504	0.081180	-2.437950	42	Kanaya Hotel Urushi Museum	0.328784	-1.735974	-4.334549
16	COCON NIKKO	0.900201	-0.856733	-3.378685	43	Sannai Garden	1.797065	0.489078	-1.510075
17	Nikko Ippitsuryu Takase	1.165504	-0.490808	-3.066091	44	Rinnoji Temple	0.823282	-1.189903	-3.833819
18	Restaurant “suzuki”	0.135344	-2.058228	-4.621173	45	Ueshima Cafe shop	1.462957	-0.035950	-2.097830
19	Miyamae dango	0.546360	-1.272299	-3.774710	46	Meiji no Yakata	0.880971	-0.940025	-3.492469
20	Nikko Yuba restraunt	1.312170	-0.191195	-2.737065	47	Nikko Toshogu Museum	1.165504	-0.490808	-3.066091
21	Nikko information center	1.165504	-0.49080	-3.066091	48	Nikko Toshogu Art Museum	1.445504	0.081180	-2.437950
22	Nikko Sprint water	1.996727	0.769190	-1.004844	49	Gojyunoto	2.094540	0.834222	-0.724950
23	Nikko Post Office	1.165504	-0.490808	-3.066091	50	Kaizando	0.482038	-1.688956	-4.281453
24	Yoshidaya yokan	0.880971	-0.940025	-3.492469	51	Nikko Niarayama Temple	0.823282	-1.189903	-3.833819
25	Yasai cafe meguru	1.312170	-0.191195	-2.737065	52	Nikko Toshogu	2.094540	0.834222	-0.724950
26	Nikko Kimono Rental Utakata	1.376604	-0.273464	-2.171162	53	Nikkosanrinnoji Taiyuin	0.482038	-1.688956	-4.281453
27	Hatuishi	0.482038	-1.688956	-4.281453					

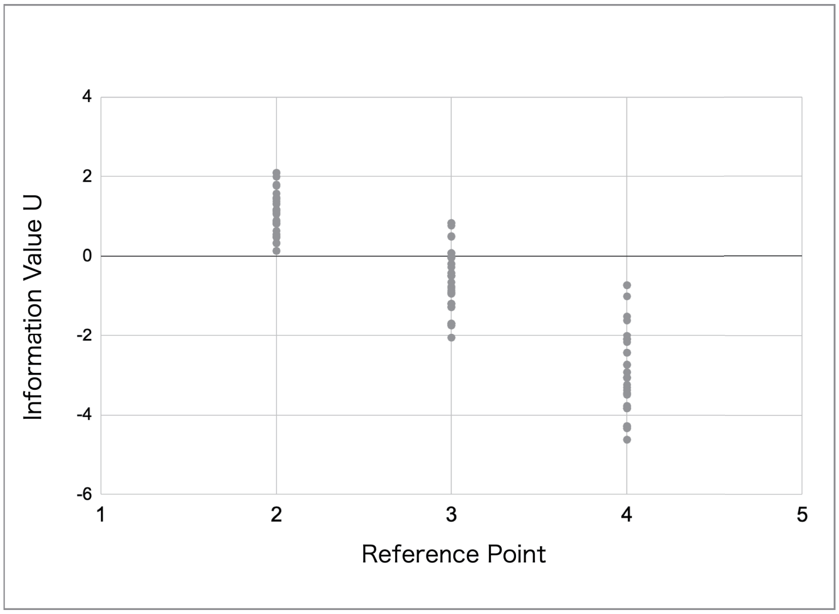


Fig. 5.10: Distribution chart of Information Value U

5.3.8 Simulation of Calculation of the Information Value

We will explain the simulation result of changing information value. We assume that the location of the BLE Beacon is Hatsuishi, which is a round rock where Shodo-Shonin, the founder of Nikko, performed Buddhism training. BLE Beacon ID of Hatsuishi is 3 that 4 tourist information is linked to it (Table 5.13). The rock is located close to the main road, and people visit there regularly. We set four critical pieces of sightseeing information near Hatsuishi, as described in Table 5.19.

Table 5.19: Parameters of simulation.

Level of Needs	**Contents**
(1) Biological and physiological needs	Yoshida-ya “yokan” sweets shop, Natural food restaurant “Kai”
(3) Love and belongingness needs	Kimono rental shop “Utakat”
(6) Aesthetic needs	Hatsuishi

User interests and reference points change depending on the user of the application. User's interest is entered before using the app, and reference point changes its value by taking user's feedback during sightseeing.

The original value change according to the user interest point. In this case, the value of the user interest points 2, 3, and 4 at reference point 3 are shown in Table 5.20 and Fig. 5.11.

Table 5.20: Information value at user interest 2, 3, and 4 at reference point 3.

Level of needs	Information	User Interest point 2	User Interest point 3	User Interest point 4
1	Yoshida-ya "yokan" sweets shop	-1.280257	-0.940025	-0.421481
1	Natural food restaurant "Kai"	-0.421481	-0.191195	0.208288
3	Kimono rental shop "Utakata"	-0.273464	-0.273464	-0.273464
6	Hatsuishi	-1.688956	-1.688956	-1.688956

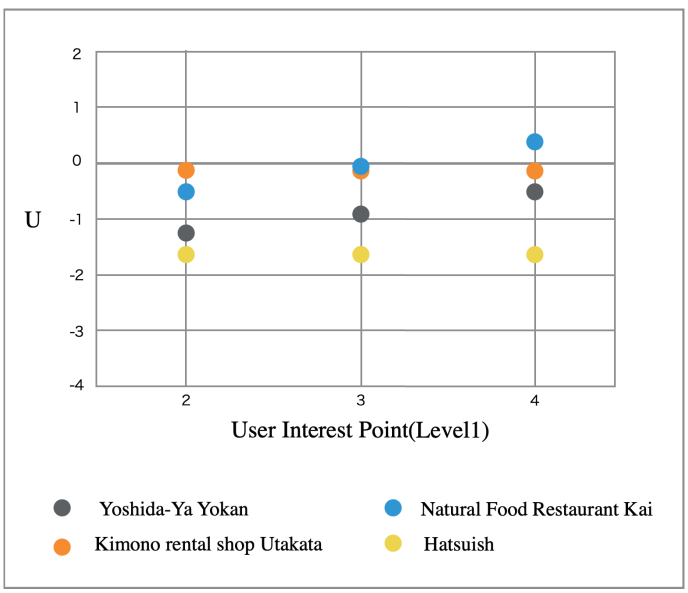


Fig. 5.11: Simulation of Information Value U for interest point

The original value change according to the user reference point. In the case where interest point is 3, the value of the reference points, i.e., 2, 3, and 4 of level 1, are shown in Table 5.21 and Fig. 5.12

Table 5.21: Information value at reference points 2, 3, and 4.

Level of needs	Information	Original information value	Level1 Reference point 2	Level1 Reference point 3	Level1 Reference point 4
1	Yoshida-ya “yokan” sweets shop	2.75	0.881	−0.94	−3.492
1	Natural food restaurant “Kai”	3.062	1.312	−0.191	−2.736
3	Kimono rental shop “Utakata”	3.218	−0.274	−0.274	−0.274
6	Hatsuishi	2.432	−1.689	−1.689	−1.689

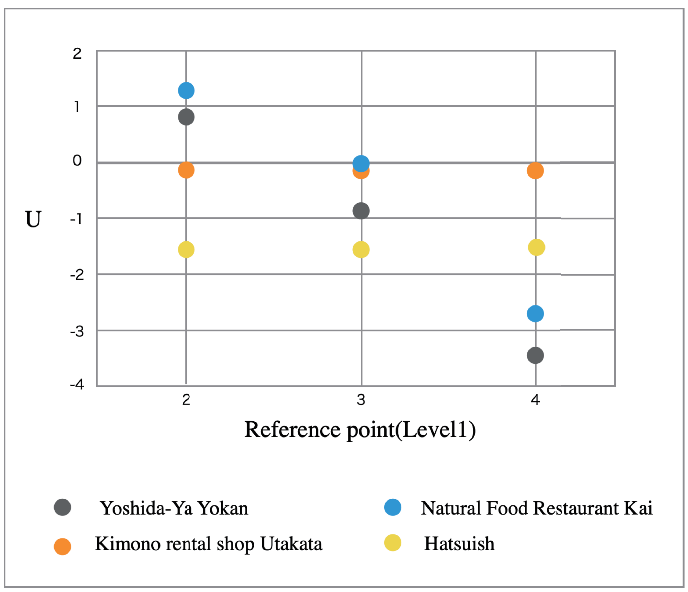


Fig. 5.12: Simulation of Information Value U for reference point

Table 5.22 shows the log of information value during the experiment. At this location, we did not set information in the category of "Love and belongingness needs". The maximum information value is different for each tester (indicated by * in the table). Each tester received different information based on their interest, desire, and behavior.

Table 5.22: Some personalized information values (some of them). * means the highest value.

Tester ID		Yoshida-Ya "Yokan" Sweets Shop	Natural Food Restaurant "Kai"	Kimono rental shop "Utakata"	Hatsuishi
A	Reference point	2	2	4	4
	Value	0.881	1.312 *	−2.171	−3.378
B	Reference point	3	3	3	3
	Value	−0.422	0.208	0.279 *	−0.857
C	Reference point	5	5	3	3
	Value	−2.376	−1.901	−0.274 *	−1.689
D	Reference point	3	3	3	3
	Value	−0.036	0.506 *	−0.522	−0.857
E	Reference point	5	5	3	3
	Value	−3.25	−2.628	−0.615	−0.274 *

5.4 Experiment of Application Using Prospect Theory

5.4.1 Outline of the Experiment

This experiment aimed to conform to the effectiveness to provide appropriate sightseeing information to meet the traveler's situation. We performed two experiments to evaluate the sightseeing application. The outline is described in Fig. 5.13.

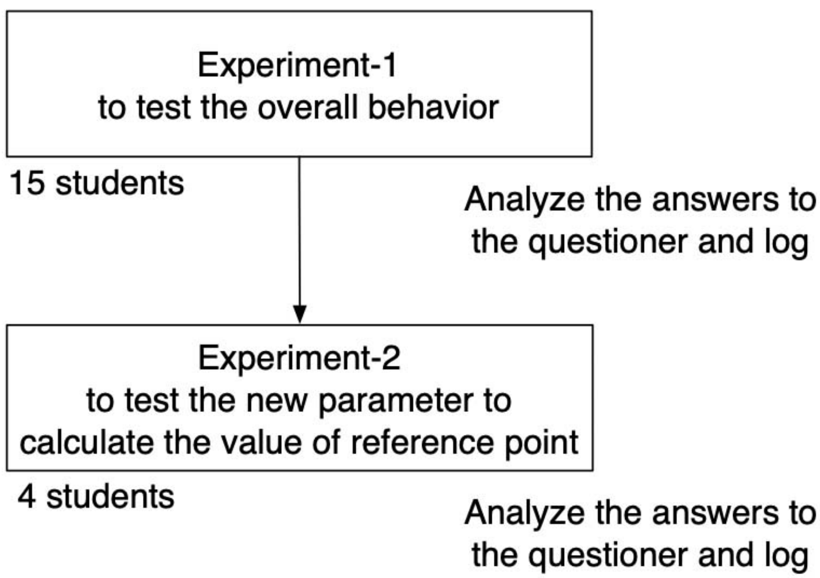


Fig. 5.13: Outline of the experiment.

The first experiment was carried out on December 9 and 10, 2019. Fifteen students from Utsunomiya University participated in this experiment. Nine examinees used smartwatches (Apple Watch), and six examinees did not use them. The second experiment was carried out on March 18, 2020. Four students from Utsunomiya University joined this experiment, and all of them wore smartwatches (Apple Watch). Because of COVID-19 pandemic, the large-scale experiment was not allowed by the university and government. Therefore, experimented to confirm the parameters' effect to calculate the information value using the Prospect Theory. We evaluated the application by the following points.

- Awareness of BLE Beacon
- Change of value of the reference point
- Distribution of information value
- Evaluation of the delivered information
- Change of image of Nikko

Fig. 5.9 shows the route of experiments from Nikko Station to Toshogu Shrine. There were 13 BLE Beacons on the route, and the distance between two beacons was about 100 m.

5.4.2 Awareness of BLE Beacon

Figure 5.14 shows the number of noticed BLE Beacons by the smartwatch users in the trials. The average number of noticed BLE Beacons was 10.3 (79.2%) in experiment 1, and 11.9 (91.5%) in experiment 2. Many subjects could notice many Beacons. The BLE Beacon was installed every 100 m so that if a traveler missed receiving a signal from a BLE Beacon, he/she could recover to get sightseeing information.

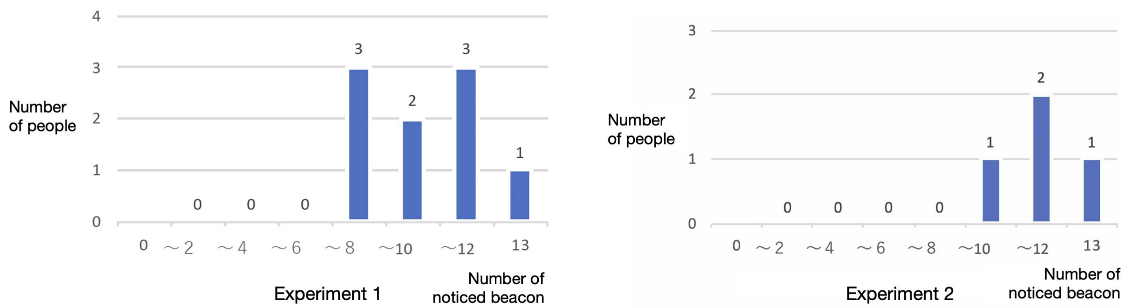


Fig. 5.14: The number of noticed BLE Beacons

5.4.3 Change of Value of the Reference Point

The reference point was changed according to the rule (Table 5.23). Fig. 5.15 and 5.16 shows the history of changing the value of reference points by the responses of the testers in experiment 1 and 2, respectively. Each tester shows a different trend. The calculated information value differs according based on the reaction of the presented information. This result displays that each tester received personalized and optimal sightseeing information according to their needs.

However, the shape of graphs are a little different. In experiment 1, the graphs become flat because we used parameter different from Table 5.4 as described in Table 5.23. After modifying the parameter, the value of the reference point followed the tester's responses.

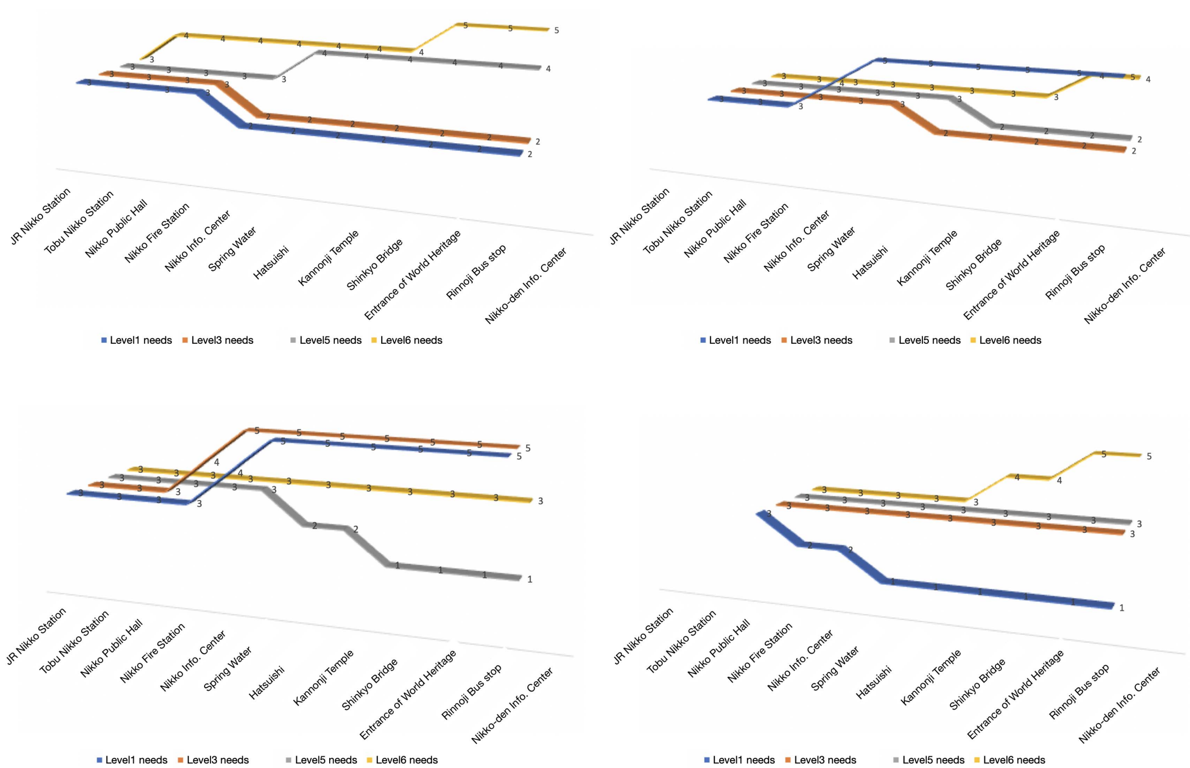


Fig. 5.15: History of changing the value of the reference points: Experiment 1.

Table 5.23: Old parameters to change the value of reference point.

Change of Reference Point		**Information**	
		Responded	**Not Responded**
Evaluation	Good	0	1
	Not Good	−1	0

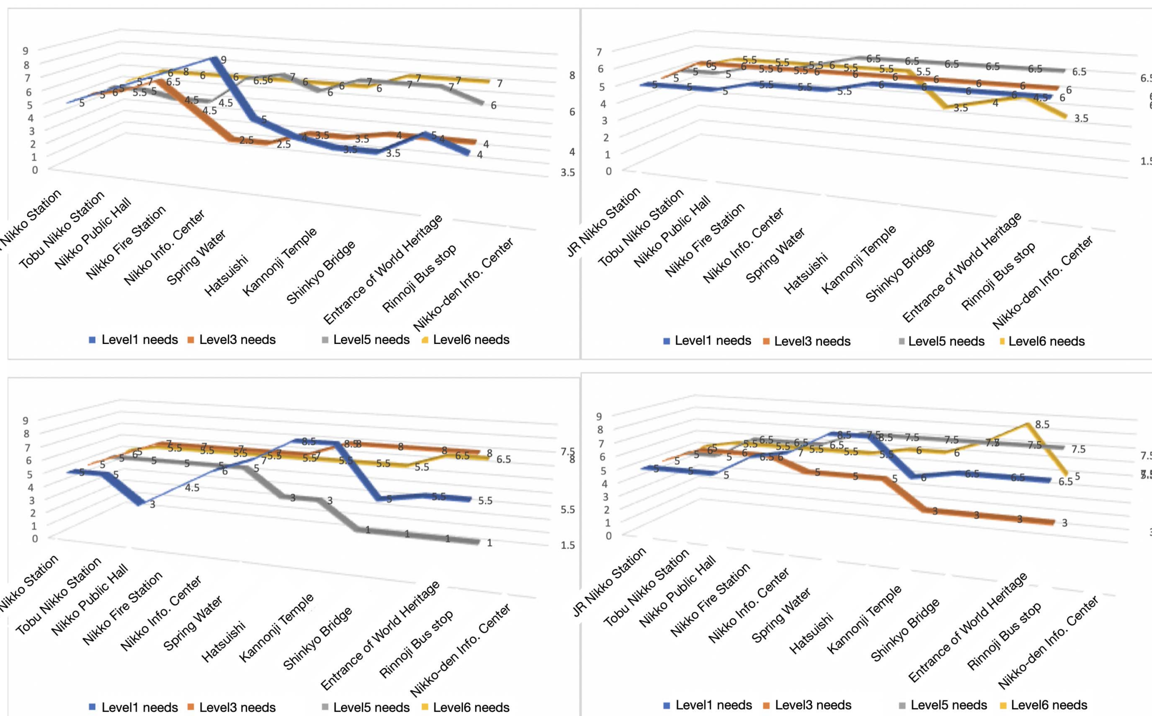


Fig. 5.16: History of changing the value of the reference points: Experiment 2.

5.4.4 Distribution of Information Value

Figure 5.17 shows the average of each category's information value. The largest circle category has a higher value in this area.

In experiment 1, just after starting from Nikko station, *love and belongingness needs* were dominant, then *biological and physiological needs* were dominant. However, near the Kannonji Temple and Shinkyo Bridge, the value of *information relating to cognitive needs* and *aesthetic needs* became dominant.

In experiment 2, the result shows that the average information value is higher between the JR Nikko Station and the fire station. On the other hand, the average information value decreased between the the fire Station and Toshogu Shrine. This experiment's weather condition was cold and windy, so the testers required information on the *biological and physiological needs* and not *aesthetic needs*.

Therefore, we think this application can provide appropriate information by following the intention of a user.

5.4.5 Evaluation of the Delivered Information

Figure 5.18 shows the result of evaluation of the delivered information. In experiment 1, 90 sets of information were received from the testers. Out of those, 48 pressed "Like" (53%), 19 pressed "Not Good" (21%), and 23 with no action. Also, in 58 sets of information, they pressed "Like". In total, they pressed "Like" 106 times. If they pressed "Not Good", it worked to change the value of the reference point actively.

In experiment 2, 48 sets of information were received from the testers. Out of those, 32 pressed "Like" (67%), 13 pressed "Not Good" (27%), and three with no action. Moreover, in 55 sets of information they pressed "Like". In total, they pressed "Like" 87 times.

After changing the parameter to change the reference point's value, the information value was better, and the testers would like to respond to the delivered information.

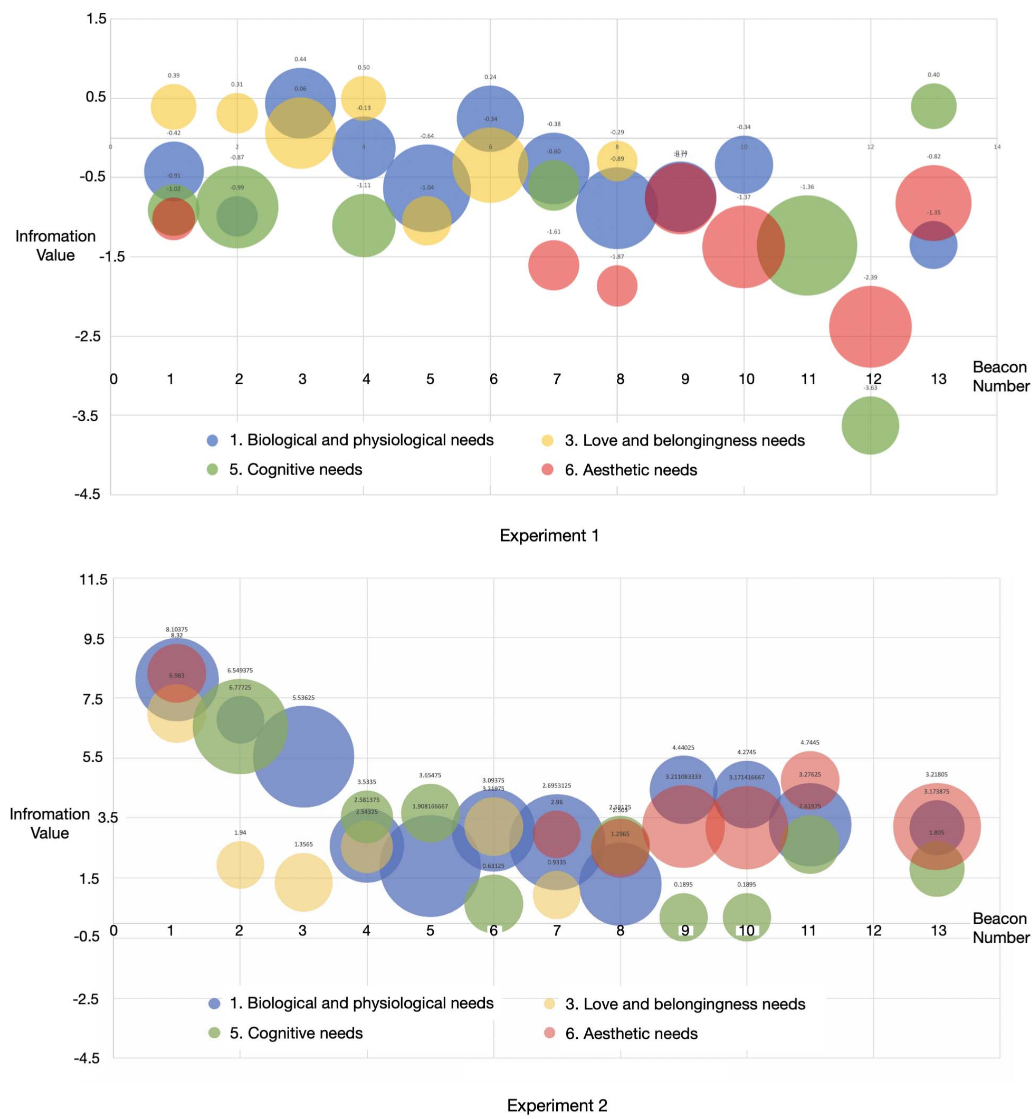


Fig. 5.17: Bubble chart of the information value.

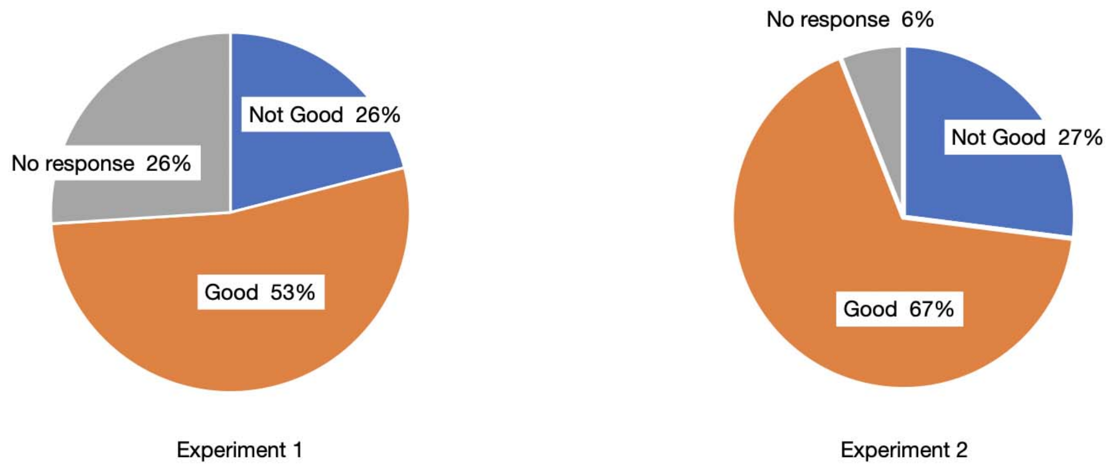


Fig. 5.18: The result of evaluation of the delivered information.

5.4.6 Change of Image of Nikko

We asked the testers to answer a questionnaire about the image of Nikko before and after the experiment. The questionnaire is shown in Fig. 5.19. Each tester makes a check on the line between two words. Figure 5.20 shows the result of the questionnaire. A dotted square represents positive feelings, and a solid square represents negative feelings.

In experiment 1, after using this application, they answered positively to the positive items and negatively to the negative items, except *silent* whether they used a smartwatch or not. The reason why the results differed only for *silence* may be that the smartwatch users were delivered audio information in addition to the screen information.

In experiment 2, the response was similar. The difference was *global*. We intended to design this application to provide information to inbound travelers. After refining the parameters, the application could provide a variety of information that reflects Nikko's tradition.

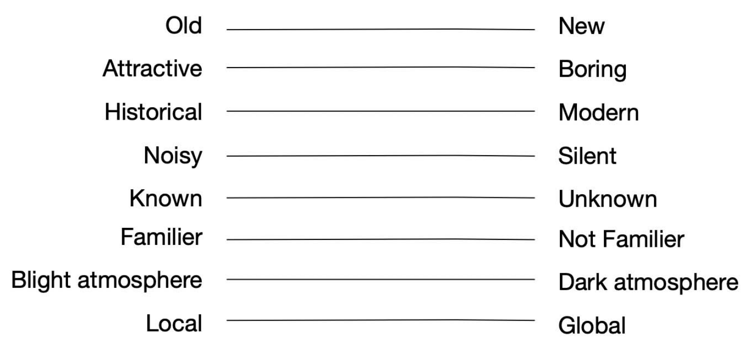


Fig. 5.19: Questionnaire about the image of Nikko.

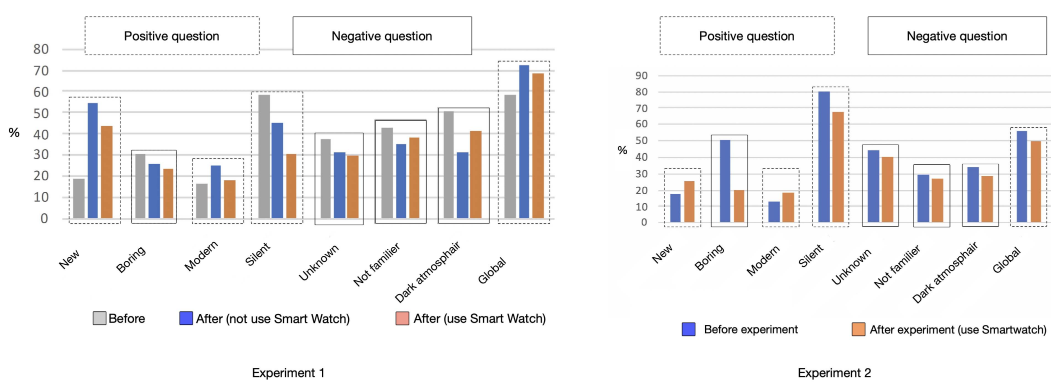


Fig. 5.20: Change of image of Nikko.

Chapter 6

LPWA with BLE Beacons for sightseeing

In 2019, we implemented LPWA with BLE Beacons for sightseeing. With BLE Beacon, a smartphone could play the role of a trigger to receive the signal and deliver the information. On the other hand, in mountainous tourist areas, we thought that it would be possible to send out BLE radio waves from a smartphone, have the BLE device receive the radio waves, and transmit the data to the area where the radio waves can reach using LoRa. With this system, we conducted an experiment on long-distance data transmission using LoRa modules in order to realize a new system for managing the entry of tourists to mountains and parks and for distributing new information. As developing LoRaWAN Beacon by "The iBeacon Living Lab in Amsterdam" (Fig. 2.6), it is also possible to set up BLE Beacon via LoRa communication.

6.1 LPWA

Low Power Wide Area (LPWA) is now becoming popular for long-range license-free wireless communication technology. Bluetooth and WiFi are commonly used for the license-free near field communication technique. However, they can only cover 100 m or closer. LPWA can provide news services for long-distance communication (several 100 m - several km) in a rural area. LPWA is a name of communication technologies that use sub-Giga Hz band. The sub-Giga Hz band has excellent penetration. It is expected that LPWA can provide several features for IoT applications such as low cost, low power consumption, long distance communication, a connection of a massive number of IoT devices, and small data transmission (100 bps–1 Mbps).

6.2 Outline of LPWA

LPWA is strongly expected for communication technology for IoT systems. Ordinary communication technologies such as WiFi and Bluetooth since such technologies can connect only the adjacent area in 100 m, since these technologies are designed for personal use. LPWA can cover problems of existing technologies such as long distance and low power and become famous. LPWA has features as follows.

- Low cost
- low power (Except BLE, ordinary NFC technologies requires sufficient power supply)
- long distance (several 100 m - several km) (See Table 6.1)
- Connect many devices
- Small data (100 bps–1 Mbps)

The frequency band for LPWA is different from country to country, and we should follow the law in each country. In Japan, the use of 916.5–927.5 MHz is allowed for LPWA. Also, LPWA is required to follow the regulation of ARIB STD-T108 [43]. This regulation is defined for telemeter, telecontrol, and data transmission equipment using the 920 MHz band. Frequency allocation of LPWAN in different countries is described in Table 6.2.

Table 6.1: Band and distance of LPWAN

Name	**Band**	**Distance (m)**
Bluetooth	2.4 GHz	Class1 100 m, Class2 10 m, Class3 1 m
WiFi	2.4 GHz, 5 GHz	10 m–100 m
LTE	2.4 GHz, 5 GHz	3 km–30 km
LoRa	920 MHz	Open space: 10 km, Town: 2 km
Sigfox	920 MHz	Open space: 30 km–50 km, Town: 3–5 km

Table 6.2: Country Frequency (MHz)

Country	**Frequency**
Japan	916.5–927.5
U.S.A	902–928
Korea	917–923.5
EU	868–868.6
China	314–316, 430–434, 470–510, 779–787

6.3 Outline of LoRa

The most popular standard of LPWA is LoRa [44]. In particular, LoRa Alliance defines LoRaWAN [45]. The difference between LoRaWAN and LoRa is as follows. LoRa defines the modulation technology of the physical layer. On the other hand, the definition of LoRaWAN includes MAC layer. LoRaWAN specifies the interoperability of devices of LoRa. LoRa uses CSS (Chirp Spectrum Spread)[46]. By using spectrum spread with chirp signal, LoRa allows long distance communication. In the best case, LoRa allows communication of several tens of kilometers. When using LoRa, it is required to use two parameters: bandwidths (bw) and spreading factor (sf). Smaller bw allows communication in longer distance, and larger sf also allows communication in longer distance. However, if we would like to communicate longer distance, the transmission time becomes longer.

One of the largest benefits of LoRa is low power consumption. The comparison of power consumption of typical NFC technologies and LoRa is described in Table 6.3. The power consumption at the active case is 44% of BLE. Therefore, it is possible to send data from an IoT device for 10 years by using a small battery.

Table 6.3: Comparison of energy consumption of LPWAN

Country	Sleep (nA)	Active (mA)
Bluetooth LE	100	26
Zigbee	700	14.4
LoRa	100	10.5

6.4 Designed the hardware for evaluation

We designed the circuit (Fig. 6.1) for evaluation of LoRa. In our original PCB design, we used Easle's ES920LR [47] equipped with SEMTECH's SX1276 [48] as the LoRa module, and the board can be operated via USB communication and set parameter of LoRa configuration.

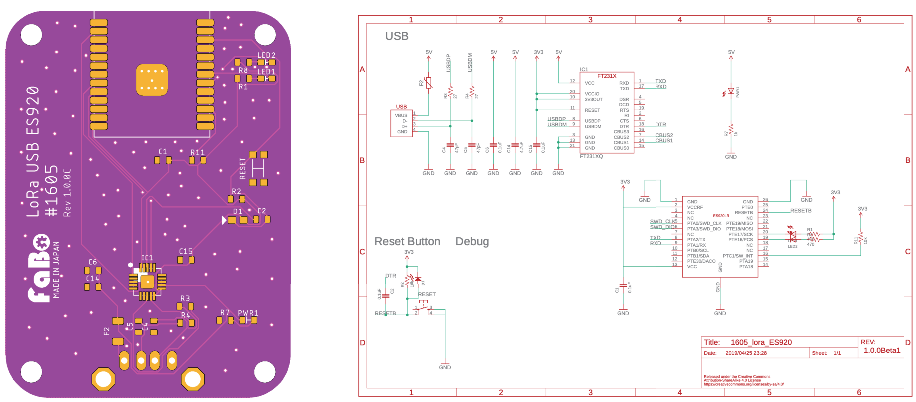


Fig. 6.1: PCB Design for Evaluation of LoRa

6.5 Developed test Application

We developed the android application for evaluation of LoRa (Fig. 6.2). The Android device and the developed module are connected via USB serial communication (Fig. 6.3), enabling LoRa parameter setting. Its application communicates with the LoRa Module via USB and can send and receive data via LoRa.

LoRa Reciever
(Map and Log)

LoRa Setting
(ES920LR parameter)

Fig. 6.2: Application for Evaluation of LoRa

6.6 Model

6.6.1 Outlook Distance

Outlook Distance is the maximum distance that can be calculated by considering the curvature of the earth, as described in Fig. 6.4. Table 6.4 shows some samples of the relation between the height of a sender and a receiver and the outlook distance. For example, if the sender and receiver are haled by users (about 1 m), the outlook distance is 8.24 km. And if the sender is 1 m and the receiver is 20 m, the outlook distance is 22.55 km.

6.6.2 Evaluation by Okumura-Hata-Model

The Okumura-Hata model [49] is a radio propagation model for predicting the path loss of cellular transmissions in exterior environments, valid for microwave frequencies

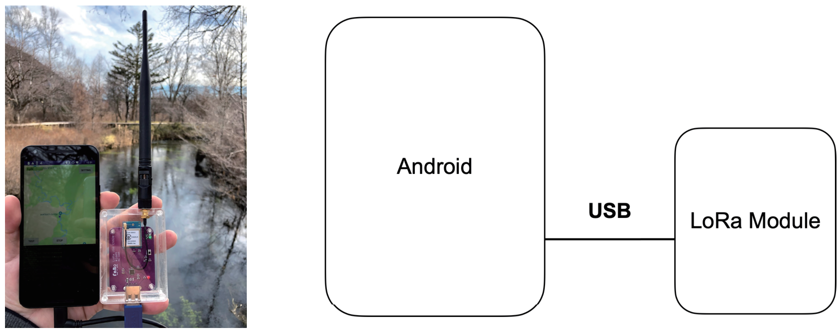


Fig. 6.3: Connection of Android and LoRa Module

$$d = 3.57\sqrt{K}(\sqrt{h_1[m]} + \sqrt{h_2[m]}) \fallingdotseq 4.12(\sqrt{h_1[m]} + \sqrt{h_2[m]})[km]$$

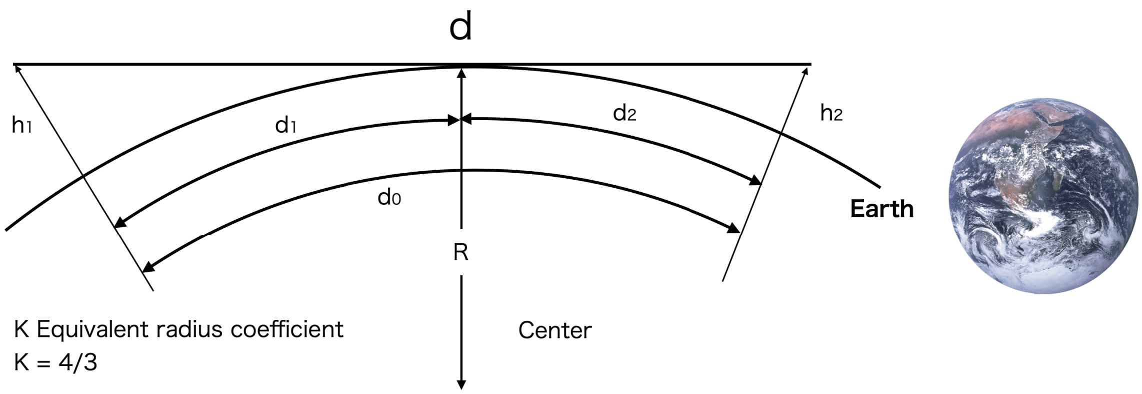


Fig. 6.4: Outlook distance model

from 150 to 1500 MHz. It is an empirical formulation based on the data from the Okumura Model and is thus also commonly referred to as the Okumura-Hata model. The model incorporates the graphical information from Okumura model and develops it further to realize the effects of diffraction, reflection, and scattering caused by city structures. Additionally, the Okumura-Hata Model applies corrections for applications in suburban and rural environments.

Table 6.4: Relation of outlook distance and height

h1 (m)	h2 (m)	d (km)
1	1	8.24
1	2	9.95
1.5	1.5	10.09
1.5	2	10.89
1	20	22.55

6.7 Experiments

In this section, we would like to introduce two experiments, one was in Oku-Nikko, and another was in Utsunomiya City.

6.7.1 Experiment in Oku-Nikko

In these trials, we set the parameters in Table 6.5 (Oku-Nikko).

Table 6.5: Parameter of LoRa in Oku-Nikko

bw	125MHz
sf	10
Tx power	13 dbm
LoRa Module	RAK811
gain of the antenna	0 dbi
Small data	100 bps–1 Mbps

In Oku-Nikko, there is a big mash and forest called Senjyo-gahara. We set a transmitter in the parking lot of Senjyo-gahara. At point 1, 400m west of the parking lot, we could receive the signal. At point 2, 2 km West from the parking lot, we received a signal every 5 min. Also, at tpoint 3, 2.3 km West from the parking lot, we received a signal every 20 min. The result is shown in Table 6.6.

6.7.2 Experiment in Utsunomiya

In these trials, we set the parameters in Table 6.7 (Oku-Nikko).

Table 6.6: Relation of outlook distance and height in Oku-Nikko

	Height of TX	**Height of RX**	**Dinstance**	**Success**
Point1	1m	1m	400m	100%
Point2	1m	1m	2000m	2%
Point3	1m	1m	2500m	0.001%

In this experiment, we put the receiver on the roof of our building. The hight of our building is about 20 m. Then the transmitter moved north. Table 6.8 shows the result of the experiment in Utsunomiya. The signal of LoRa was received by the receiver when the transmitter was 4.5 km from our building.

Table 6.7: Parameter of LoRa in Utsunomiya

bw	62.5MHz
sf	12
Tx power	13 dbm
LoRa Module	ES920LR
gain of the antenna	0 dbi
Small data	100 bps–1 Mbps

Table 6.8: Relation of outlook distance and height in Utsunomiya

	Height of TX	Height of RX	Dinstance	State of the receiving location
Point1	20m	1m	3400m	On a pavement
Point2	20m	4m	4000m	On a bridge
Point3	20m	1m	4000m	In a open space

6.8 Discussion

Figure 6.5 and Fig. 6.6 show the Okumura-Hata-curve by using in Oku-Nikko and Utsunomiya respectively. Experiment in Oku-Nikko (Fig. 6.5, our experiment shows the transmission distance was 2.0–2.5 km. This result fitted the rural area case of Okumura-Hata-curve when the band was 900 MHz, and both heights of Tx and Rx was 1 m. -140 dbm is the threshold of signal strength of LoRa. Experiment in Utsunomiya (Fig. 6.6, our experiment shows the transmission distance was 4.5 km. This result fitted the large city case of Okumura-Hata-curve when the band was 900M Hz, and both heights of Tx was 1m, and Rx was 20 m.

Therefore, we expect that the Okumura-Hata-model may give the proper estimation of the transmission distance of LoRa in Oku-Nikko and Utsunomiya.

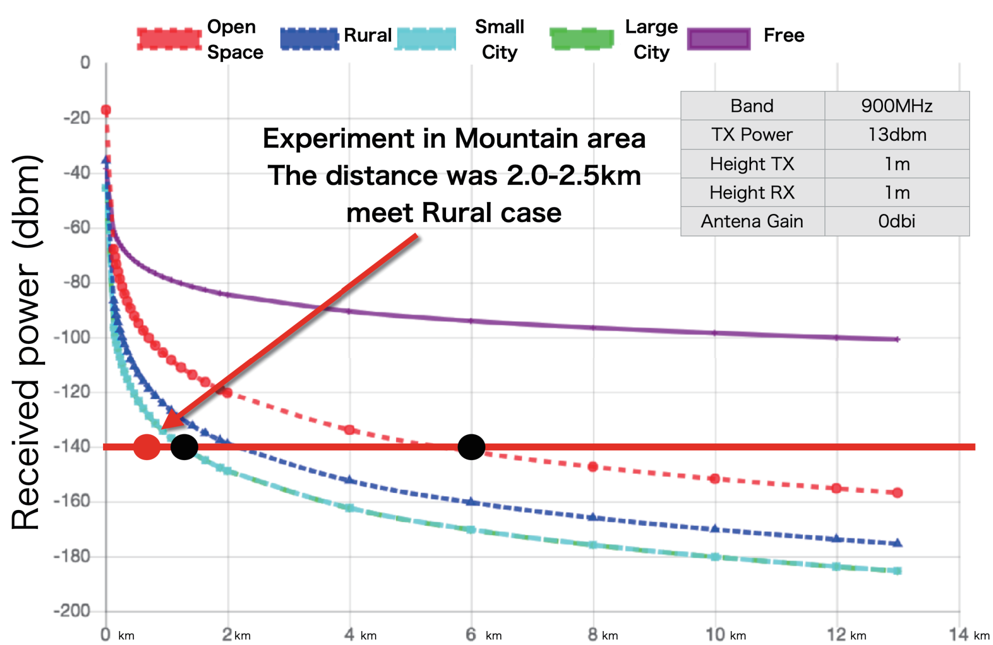


Fig. 6.5: Okuyama-Hata-curve in Oku-Nikko

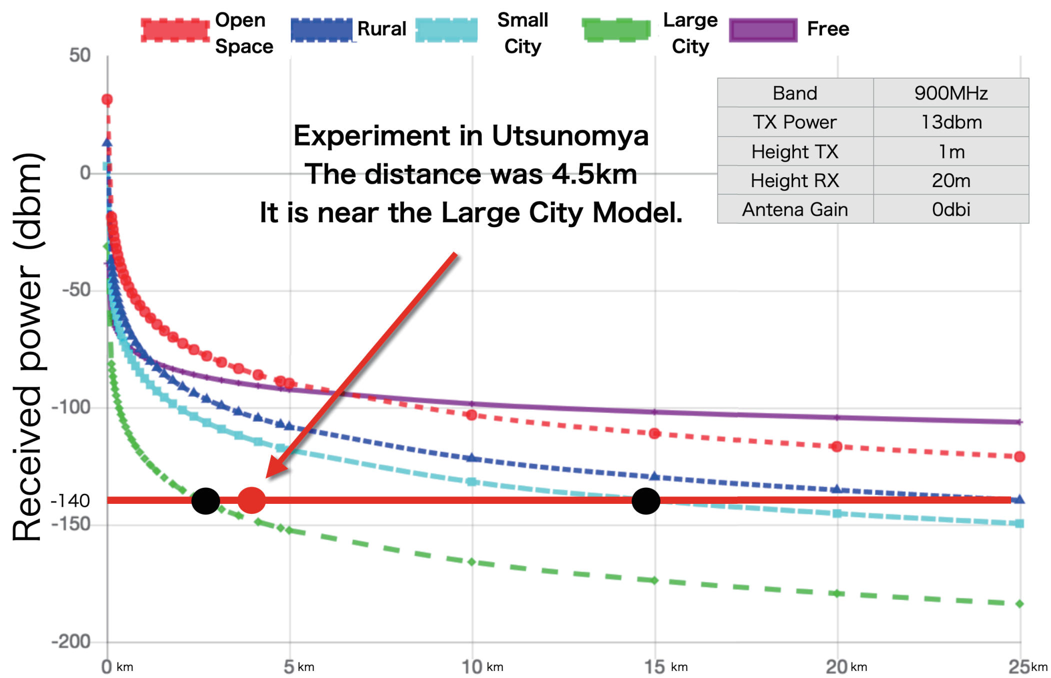


Fig. 6.6: Okuyama-Hata-curve in Utsunomiya

6.9 Conclusion and Further Study

In this experiment, the reach of LoRa was 2 km in the forest and 700 m in the city area. There are some reports that succeeded in transmitting data using LoRa 5 to 10 km. We are planning to tune the transmitter and receiver and measure the transmission distance in both city area.

we will develop applications using features of LoRa such as counting the number of hikers and sending weather data in the mountains in Oku-Nikko area to provide safety information.

We also thought that LPWA could be useful to observe children or older adults in the local community.

- Support more wide area.

- Continue to try measurement experiment at Utsunomiya University.

From the results of the experiment, it was found that it is possible to construct a wide-area network as shown in the Fig. 6.7.

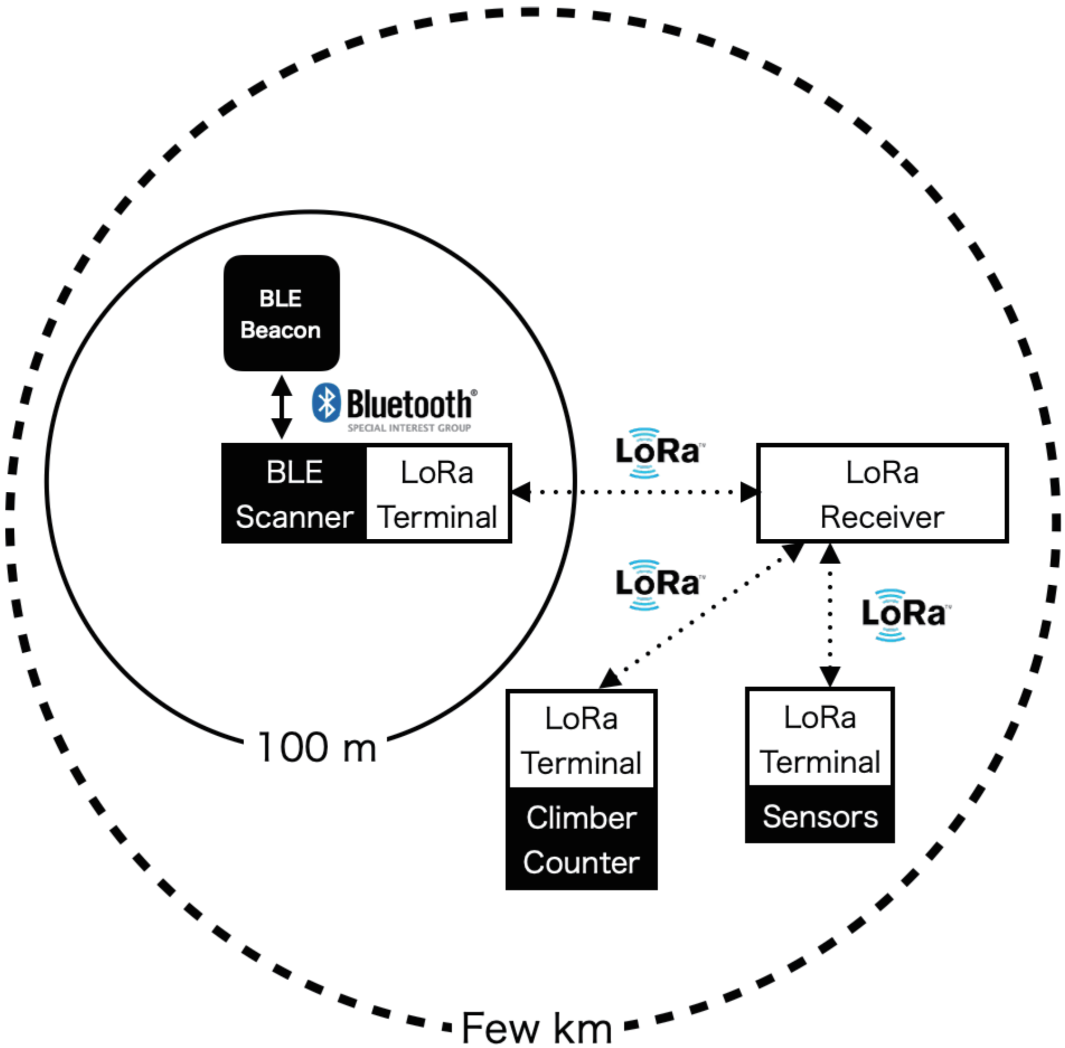


Fig. 6.7: BLE and LoRa network

Chapter 7

Conclusion

In this paper, we described the result of our research on a sightseeing support application that applies psychological effects to realize the optimal provision of sightseeing information.

First, we defined a cognitive model based on the Zegernik Effect and implemented it in the form of a quiz. As a result of the experiment, we were able to prove the effectiveness of the cognitive model for tourism. If the quiz can create a sense of satisfaction and expectation, it may be possible to increase the positive impression of Nikko.

Second, we explained the smartphone application design method based on Maslow's hierarchy of needs. We listed up required elements of sightseeing and categorized them into ten categories, then added priority to them based on Maslow's hierarchy of needs.

The previous studies could not provide the appropriate sightseeing information to a traveler during a trip. We started a study to solve that problem by using the Prospect Theory and Maslow's hierarchy of needs. We designed and evaluated an application that provides sightseeing information according to the changes in desires during the trip. Through the experiments, we proved that the information value could be changed according to a traveler's behavior and provide appropriate information to a traveler. Moreover, we confirmed that the user of this application could have a good image of the destination.

We showed that by combining the psychological effects and location information provided by BLE Beacons, we could deliver optimal information according to different needs, encourage people to look around, and as a result, increase satisfaction levels. By further improving the accuracy of the information provided, we would like to develop a technology that allows tourists to enjoy the scenery and cultural properties by providing an experience of walking with a support guide without looking at a smartphone.

We have conducted measurement tests to build a wide-area network using BLE and LoRa. We found that it is possible to realize a wide-area network. We will continue to develop a practical information distribution system for tourist attractions in a wide area by utilizing the knowledge gained from this research.

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