

Activity Support Based on Human Location Data Analysis with Environmental Factors

Hidekazu Kasahara

March 2016

Contents

1	Introduction	11
1.1	Background	11
1.2	Motivation	12
1.3	Research Scope	13
1.4	Research Overview	16
1.5	Data Sensing Process	18
1.6	Location Data	20
1.6.1	Consecutive Trajectory	21
1.6.2	Fragmented Trajectory	21
1.7	Data Analysis Process	23
1.8	Tourist Activity Support Service	24
1.9	Thesis Structure	24
2	Transportation Mode Inference	27
2.1	Introduction	27
2.2	Related Research	28
2.3	Environmental Constraints	29
2.4	Mode Inference by Environmental Constraints	32
2.4.1	Problem Setting	32
2.4.2	Overview of the Proposed Method	32
2.4.3	Preprocessing	33
2.4.4	Inference Using Observation Points	35
2.4.5	Revision by Segment with Context	36
2.5	Experiments	38
2.5.1	Overview of Experiments	38
2.5.2	Environmental Constraints	38
2.5.3	Thresholds for Preprocessing	40
2.5.4	Car Mode	40

2.6	Results	40
2.7	Discussion	41
2.8	Conclusion	43
3	Route Recommendation	45
3.1	Introduction	45
3.2	Related Research	47
3.2.1	Environmental Factor Based Tourist Transition Model . .	47
3.2.2	Tourist Transition Model Based on Human Factors	47
3.2.3	Spot Visiting Order in Case of Route Making	48
3.3	Route Recommendation Using Tourist Transition Model	48
3.3.1	Overview of Proposed Method	48
3.3.2	Gathering Past Tourist History and Spot Definition	50
3.4	Tourist Transition Model	50
3.4.1	Overview of Proposed Tourist Transition Model	50
3.4.2	Environmental Factor Model	51
3.4.3	Environmental Factor	51
3.4.4	Environmental Factors that Influence Spot Transitions . .	52
3.4.5	Search Effective Environmental Factors	54
3.4.6	Calculation of Necessary Time for Spot and Transition Time between Two Spots	55
3.4.7	Human Factor Model	56
3.5	Tourist Route Making	57
3.5.1	Formulation	57
3.5.2	Search Most Suitable Route	57
3.6	Experiments	58
3.6.1	Data	58
3.6.2	Evaluation of Environmental Factor Model	58
3.6.3	Necessary Time for Spot and Transition Time between 2 Spots	60
3.6.4	Evaluation of Tourist Route Making	60
3.7	Conclusion	61
4	Evacuation Support	65
4.1	Introduction	65
4.1.1	Importance of Information during Trips	65
4.1.2	Research Objectives	66
4.2	Related Research	67

4.2.1	Overview of the School Trip Scenario	67
4.2.2	Commercial Services for Ensuring Safety Using GPS	69
4.2.3	Safety Confirmation by Estimating Users' Location	69
4.2.4	Information Sharing	69
4.2.5	Evacuation Guidance	70
4.3	Tourist Information Systems Based on Positioning	70
4.3.1	System Specifications	70
4.3.2	Details of the Applications: Students	74
4.3.3	Details of the Applications: Teachers	76
4.4	Experiments and Results	80
4.4.1	Experimental Evaluation of the Effectiveness of Informa- tion Sharing	80
4.4.2	Evaluation of the Battery Life	87
4.5	Conclusion	87
5	ETSS User Expansion	89
5.1	Introduction	89
5.2	Mobile Safety Confirmation Service for Educational Tour	90
5.3	Existing Mobile Information Service for Tourist	91
5.3.1	Classification of Mobile Information Service	91
5.3.2	Business Model and Market Strategy of Existing Services	92
5.4	Business Model and Market Strategy for ETSS	92
5.5	Analysis of ETSS Case	94
5.5.1	Background Information of School Trip	94
5.5.2	Overview of ETSS	95
5.5.3	School Trip Market	96
5.5.4	Business Model	97
5.5.5	User Acceptance	100
5.6	Other Trip Market Applicable for ETSS	102
5.7	Conclusion	104
6	Conclusion and Future Work	105
6.1	Conclusion	105
6.2	Future work	107
	List of Publications	119

List of Tables

2.1	Velocity of Available Transportation Modes Given Environmental Constraints	30
2.2	Velocity Class Probability	35
2.3	Four-mode Recall of the Proposed Method (Recall 91.6%)	42
2.4	Three-mode Recall of the Proposed Method (Recall 93.6%)	42
2.5	Four-mode Recall of the Velocity-only Method (Recall 73.5%) . .	43
3.1	Environmental Factors	59
3.2	Accuracy of Next Visit Spot Estimation	59
3.3	List of Environmental Factors of Spots	63
3.4	Comparison of Editorial Distances of each Methods	64
4.1	System Specifications for ETSS	73
4.2	List of Interviews and Paper Questionnaires	81
4.3	List of Devices and Applications	82
4.4	Results of Quantitative Surveys Used to Obtain Overall Evaluations and Operability Assessments	82
4.5	Results of Quantitative Surveys of Positioning Function	85
4.6	Results of Evacuation Field Test	86
4.7	Results of Battery Consumption Test	87

List of Figures

1.1	Research Scope	14
1.2	Overview of Activity Support Based on Human Location Data Analysis with Environmental Factors	15
1.3	Consecutive Trajectory and Fragmented Trajectory	17
1.4	Sensing and Analyzing Human Activity with Environmental Factors	19
2.1	Static and Dynamic Environmental Constraints	31
2.2	Overview of the Proposed Method	33
2.3	Transportation Mode Revision from Linear Environmental Con- straints	37
2.4	Environmental Constraints Used in the Experiments	39
2.5	Example of Results	41
3.1	Framework of Travel Planning Support System	49
3.2	Relationship with α and Editorial Distance	61
4.1	ETSS Service Overview	72
4.2	Tourist Information Infrastructure	74
4.3	Map Application for Students	75
4.4	Overlapping Trajectory	76
4.5	VoIP Call Icon	77
4.6	Map/Positioning Application for Teachers	78
4.7	Broadcast Mails for Safety Confirmation	79
4.8	GPS Blind Zone near Kiyomizu-dera	80
4.9	Overall Evaluations and Operability Assessments for ETSS (Stu- dents)	83
4.10	Overall Evaluations and Operability Assessments for ETSS (Teach- ers)	84

5.1	Comparison with Existing Travel Information Services and ETSS	93
5.2	ETSS Service Overview [Reprint]	96
5.3	Distribution Construction of School Trip Market	98
5.4	Number of School Trip Students in 2012	100
5.5	Industrial Academic Alliance	101
5.6	Nessecity of Safety Confirmation Service	103
6.1	Contribution and Future Work	108

Chapter 1

Introduction

This thesis studies activity support based on human location data analysis with environmental factors. The location data used in this thesis was accumulated in an urban area, where the majority of people's activities occur and where they mostly require activity support. This chapter describes the research background, motivation, scope, and overview of this thesis.

1.1 Background

As a result of the popularization of mobile phones, sensors embedded in the environment and the Internet, human activity tracing is becoming easier than before. Downsized and cheap embedded sensors trace human activity during daily life, and the traced activity data is stored on a server via the Internet.

The traced activity data are analyzed for various purposes, for example, marketing, advertising, transportation usage surveys, personal health management, and law enforcement. It is known that some traced activity data are analyzed within global or national ranges, such as the purchase history for online shops. By analyzing purchase history, online shops can recommend goods and services to their customers to increase their revenue, and customers can find the goods and services they prefer. Thus, human consumer activity data analysis over a global or national range helps both consumers and online shops. In contrast, some traced activity data that are strongly related to physical activity can be used more practically if it is analyzed over the range of the main human sphere of action, such as an urban area. For example, traffic congestion in an area can be analyzed from floating car data, considering traffic accidents, traffic networks, and other environ-

mental factors in the area. People physically move for their own purposes in daily life, such as commuting, sightseeing, or shopping. Physical activity is sensed by sensors like Global Positioning System (GPS) sensors, which provide location data. Location data are the most important type of traced activity data related to physical activity.

Physical activity consumes social resources in an area. Social resources, in this thesis, means traffic and location resources. Traffic resources include road networks, trains, airplanes, and other all means of transportation. Location resources include offices, schools, shopping areas, tourism spots, and other destinations for other purposes. If the social resource allocation in an area fails, it causes social inconvenience such as traffic congestion. Heavy traffic congestion disadvantages the area's society and its drivers. Therefore, social resources should be adequately allocated.

The reason for such resource allocation failure is that people do not know the overall surrounding situation, which includes factors such as traffic status, traffic networks, and seasonal events. This information gap is called an information asymmetry, which is in contrast to the term "perfect information" in the economics field. It has been studied by Arrow [1], Akerlof [2], and Stiglitz [3]. In a situation in which information asymmetry exists, transactions cannot be optimized between persons who have information and other persons who do not. To resolve the inconvenience caused by information asymmetry, economics researchers have propose some countermeasures.

In economics, assuming that someone has enough information, signaling or screening [4] have been proposed as countermeasures to resolve information asymmetry by shrinking the information gap. In case of signaling, to dissolve the information gap, one person credibly conveys some information regarding the quality of goods and services to another person who does not have this information. However, from the viewpoint of informatics, the economics assumption cannot be used, because informatics researchers think that information should be generated from data and adequately distributed by any means possible. Therefore, when applying the idea of information asymmetry to social resource allocation, location data analysis and activity support for people are necessary.

1.2 Motivation

This section describes the motivation behind the research in this thesis, which studies the improvement of social resource allocation in an urban area by us-

ing activity support based on human location data analysis to shrink information asymmetry.

As mentioned above, information asymmetry causes personal and social inconvenience such as traffic congestion in non-disaster situations. In addition, the recent earthquake in Japan showed that information asymmetry in a disaster situation is even more serious. In the Great East Japan Earthquake in 2011, many disaster victims in the afflicted district could not access evacuation information, and their families experienced problems when attempting to find out safety information about the victims. As a result of calls from worried relatives, the telephone lines of local governments in the afflicted area became congested, which created problems for the local governments' rescue operations. In this case, information asymmetry existed among the victims of the disaster and their families, and social inconvenience arose as a delay in rescue operations caused by telephone disconnections. If the safety information regarding disaster victims could be conveyed to their families, such social inconvenience could be avoided.

For this reason, this thesis studies activity support based on location data analysis both in disaster and non-disaster situations.

1.3 Research Scope

For the purposes of this study, individual people can be divided into two types, tourists and residents, as Figure 1.1 illustrates. A tourist is defined as a person who is traveling far from his/her residence, and a resident is defined as a person who is traveling in the area near his/her residence. The research scope of this thesis is tourist activities, because a tourist needs activity support more than a resident, and his/her activity is more varied than that of a resident. Although the target of analysis is the tourist, the analysis methods used for tourist activity can be applied to residents because activity support for tourists includes that for residents.

A tourist is often not familiar with the tourism destination they are visiting; therefore, a tourist needs more activity support than a resident. For example, a tourist needs various kinds of activity support such as destination recommendations, travel route recommendations, traffic navigation, and evacuation support plans in case of a disaster. In contrast, most residents need only traffic navigation and evacuation support in case there is a disaster around his/her residence. In addition, while most residents repeat the same patterns such as commuting to school or work in their daily lives, most tourists act in various ways, such as visiting tourist spots, getting lost, shopping, or going on tours in the tourism destination

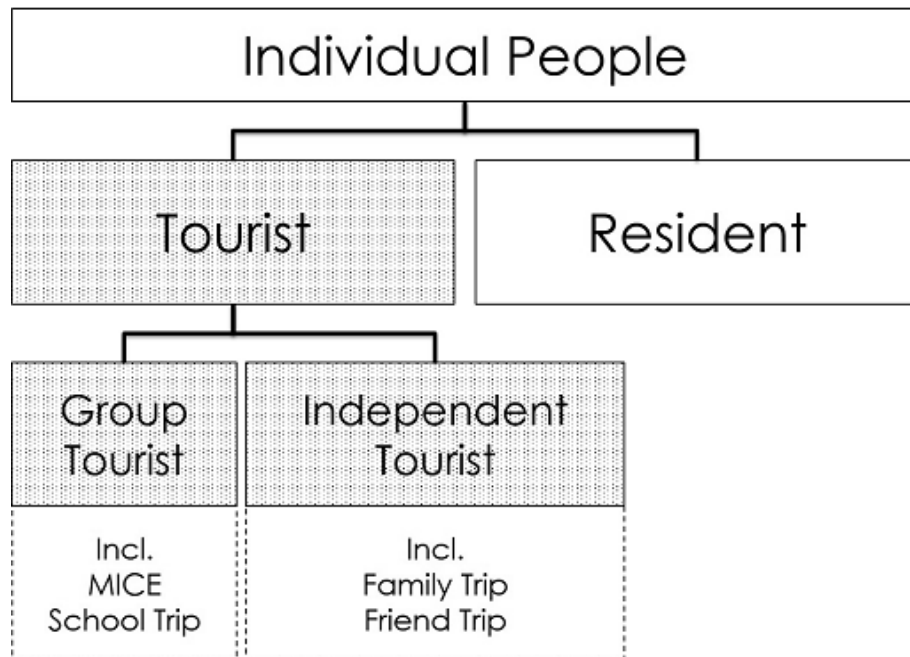


Figure 1.1: Research Scope

area. Therefore, from the viewpoint of academic research, it is more interesting to analyze the various activities of tourists from their traced activity data.

In addition, tourist activity analysis is useful for the community of a tourism destination area. As an actual example, the location data analysis of students on a school trip in Kyoto is introduced. School trips are a typical type of group tour in Japan. The location analysis of the school trip students during their stay in Kyoto makes clear their dynamic status. When this dynamic status was showed to Kyoto city local government disaster management division, which had responsibility for making evacuation plans in case of emergency, the results were quite different from their expectations. This fact shows that location data analysis in an urban area is useful for the community in that area.

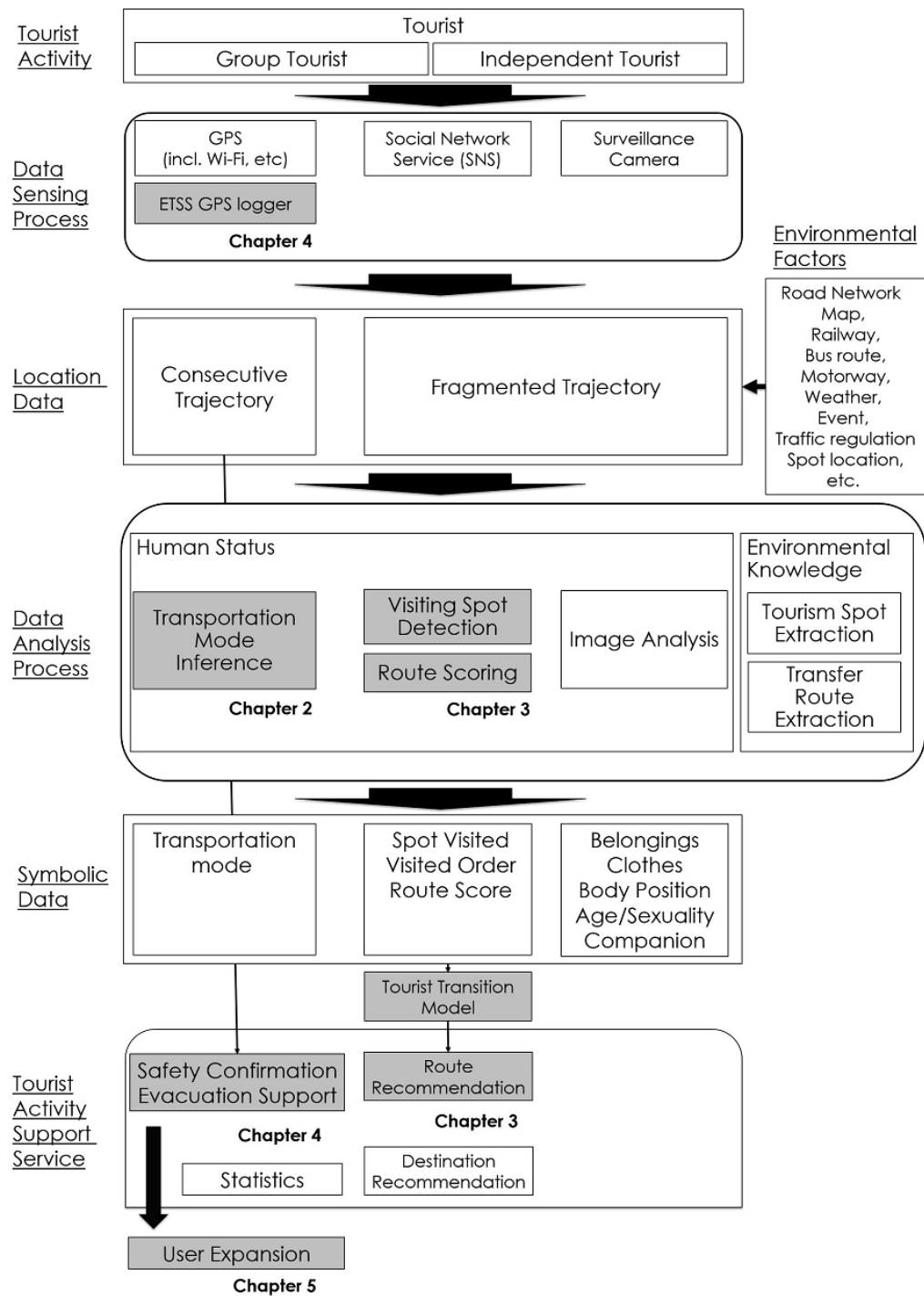


Figure 1.2: Overview of Activity Support Based on Human Location Data Analysis with Environmental Factors

1.4 Research Overview

This section describes the concepts for urban area activity support that is based on human location data analysis and environmental factors, as illustrated in Figure 1.2.

Data Sensing Process This thesis focuses on the analysis of tourist activities. Tourists are divided into two types, group tourists and independent tourists, as illustrated in Figure 1.1. The difference between the two tourist types affects the data collection methods. Tourist activity is collected using sensors like GPS, social network services (SNSs), and surveillance cameras.

While it is technically easy to collect location data, it is still difficult to collect location data for academic purposes. There are two issues when collecting location data: privacy and sampling issues. In this thesis, to deal with the data collection issues, a unique GPS logger application that collects location data from users called the Educational Tour Support System (ETSS) was developed. An ETSS user is limited to school trip students, which is one type of group tourist, because it was originally designed for evacuation support and safety confirmation for school trip students in case of disaster. However, ETSS can be adjusted for use with other group tourists, and can collect location data from them. Chapter 4 describes ETSS application development, and Chapter 5 discusses the user expansion of ETSS to other group tourists.

Location Data Location data can be categorized into two types, consecutive trajectories and fragmented trajectories, as illustrated in Figure 1.3. A trajectory is a time series of location data. A consecutive trajectory is a human movement trajectory sensed at regular intervals, and a fragmented trajectory is human movement trajectory that is intermittently sensed. A consecutive trajectory is obtained from GPS-measured location data, and a fragmented trajectory is obtained from SNS geotagged data and surveillance camera video. Although SNS geotagged data is a type of fragmented trajectory, the quantity of available data is huge. In the case of surveillance camera video, the location data of a person recorded in the video can be extracted using image analysis technology. However, image analysis of surveillance camera video is out of the scope of this thesis.

In addition to location data, environmental factors are used for data analysis in this study. There are many environmental factors that affect human movement in physical space. Environmental factors can be obtained from outside databases

like governmental map services, and it is relatively easier to obtain than location data.

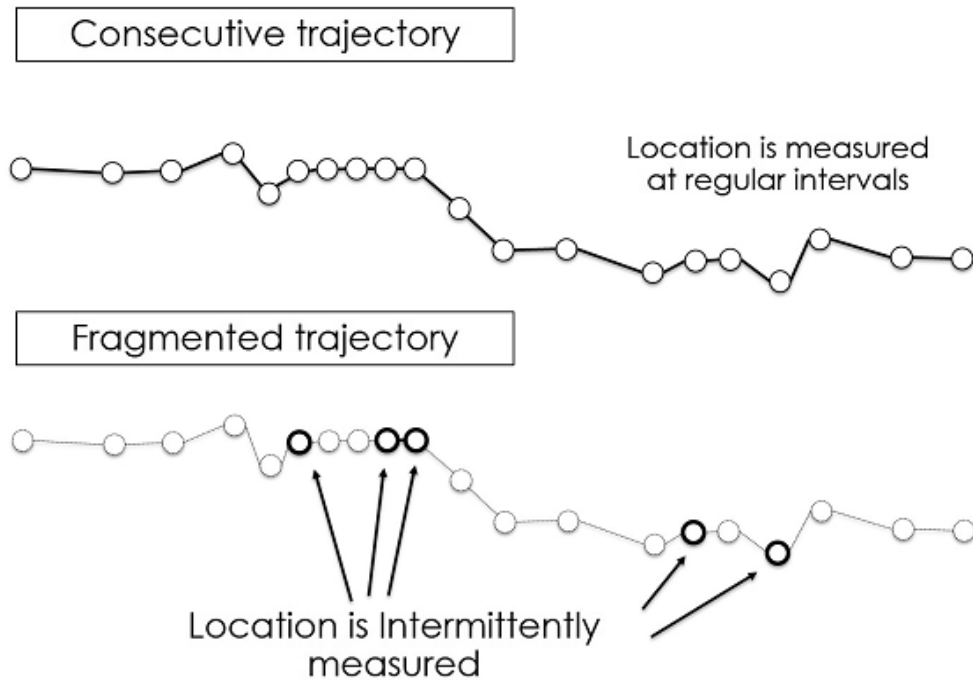


Figure 1.3: Consecutive Trajectory and Fragmented Trajectory

Data Analysis Process The location data are analyzed by a process that outputs symbolic data. In this study, the transportation mode, visiting spot, and travel route score of the tourist trajectory are analyzed. Ideally, a consecutive trajectory should be used for all analysis because of its completeness. However, a fragmented trajectory can be used to some extent because of the collection issues stated above. For transportation mode inference, a consecutive trajectory is necessary because the context of a trajectory plays a role in the inference. In contrast, a visited spot can be detected from both consecutive and fragmented trajectories. The route score is calculated from the number of tourists who visit that spot.

Symbolic Data and Services The symbolic data, analyzed from the location data, are used for the tourist activity support service. The role of the tourist activ-

ity support service is to provide adequate information to tourists in order to shrink information asymmetry. The following activity support services are provided to tourists: safety confirmation, evacuation support, route recommendation, destination recommendation, and traffic navigation. This thesis studies three services: safety confirmation, evacuation support, and route recommendation.

Transportation mode is inferred for safety confirmation, and it can also be used for other statistical aggregations. The spots visited and the order in which they are visited are used for spot transition modeling. In addition, the environmental factors that influence spot transitions are considered in spot transition modeling. The spot transition model is used for route recommendation, which recommends preferable routes to each tourist. In future, other route recommendation systems should be studied for reducing the concentration of tourists to some specific popular tourist spots like Kinkaku-Ji temple in Kyoto by taking into consideration the transitions of other tourists.

1.5 Data Sensing Process

As illustrated in Figure 1.4, human activity is affected by the surrounding environment, and sensors sense this activity as location data. The location data is analyzed to convert it into symbolic data that are used for the activity support service. There are two types of tourists, group tourists, who travel as members of a group, and independent tourists, who travel alone or with small number of companions like relatives or close friends. The shaded boxes of Figure 1.1 illustrate these two types of tourists.

Tourist activity is sensed by sensors such as GPS sensors, SNSs, and surveillance cameras. There is measurement error in the GPS data because of the propagation velocity of electromagnetic wave and other factors. Therefore, GPS location measurement is usually assisted by Wi-Fi, gyroscopic sensors (gyros), and other sensing devices.

While it has become easy to collect location data from the viewpoint of technology, it is still difficult to collect location data for academic purposes. To collect location data for academic purposes, there are two issues regarding privacy and sampling.

The location data that can be connected with an individual person are considered to be personal data, and the handling of personal data is regulated by law. Privacy law requires opt-in-permission to be obtained from the person who will be sensed before the data is collected. In case of third party usage of the

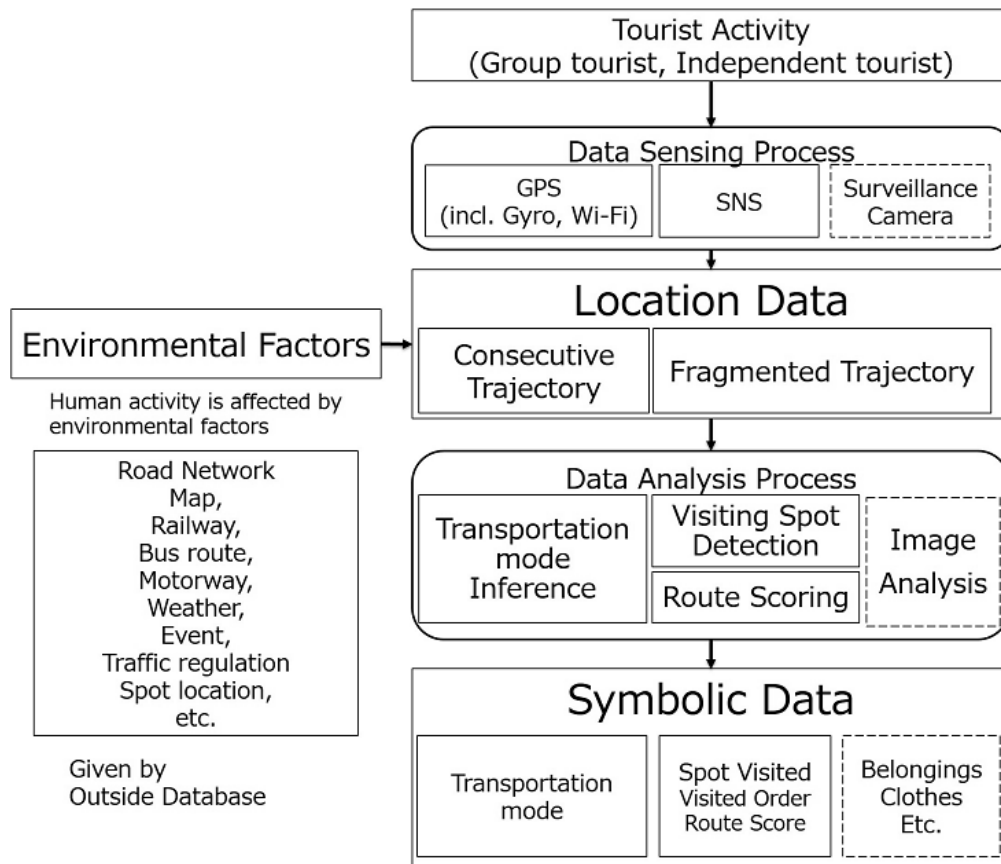


Figure 1.4: Sensing and Analyzing Human Activity with Environmental Factors

personal data, a usage agreement should be obtained from the recorded person before recording. Therefore, the re-use of location data that are collected for non-academic purposes by academic organizations is sometimes difficult and obtaining permission can be slow and costly. An example of typical location data for non-academic purposes is floating car data collected by a car navigation system for forecasting traffic congestion. An academic organization can collect location data by itself; however, the amount of such location data is far smaller than that for non-academic purposes.

In addition to the privacy issues mentioned above, there are also sampling issues. The location data should be collected from a representative population that reflects all activities in the target area. Some examples of collection issues

are as follows. The floating car data sensed by GPS sensors (assisted by a gyro) in the car navigation system are one of the best data sources from the viewpoint of data collection. However, the floating car data includes only car drivers, and does not reflect the movements of all the people in a target area. In addition, cellular phones sense a subscriber's location. The location data sensed by the cellular phones reflects the movements of a greater number of people than the floating car data because almost all people in Japan use cellular phones. However, the usage of the location data sensed by cellular phones is strictly limited by the Telecommunications Business Law.

In order to address the collection issues, location data researchers should consider how to collect sufficient location data for their research. In this thesis, a unique application called ETSS is proposed that collects location data from users while addressing the data collection issue. The location data collected by ETSS can be used for research purposes because opt-in-permission is acquired from the users before location sensing begins. ETSS users are limited to those on educational group tours because it is designed for school trips, and hence the scale of the potential user group is still small. However, the design of ETSS can be changed for users other than school trip students, and more location data could then be collected from them. Therefore, the expansion of ETSS users from the viewpoint of business is discussed in this thesis.

1.6 Location Data

This section discusses the location data sensed by the sensors. First, the categories of location data are discussed, because what is called "location data" includes various data types, and there are many approaches for collecting data. This thesis categorizes location data into two types, consecutive trajectories and fragmented trajectories, as illustrated in Figure 1.3. A trajectory is time series location data that consists of time and coordinates (longitude and latitude). A consecutive trajectory is a movement trajectory sensed at a regular intervals, except for ignorable short discontinuities caused by measurement error. In contrast, a fragmented trajectory is a movement trajectory that is intermittently sensed. The time resolution of the measurement interval is not essential for the definition of location data categorization.

1.6.1 Consecutive Trajectory

GPS sensor data creates a consecutive trajectory. GPS is the most popular location sensor because of its consecutiveness and accuracy. Location measurement using GPS is becoming easier than before because GPS is regularly equipped in mobile phones, car navigation systems, cycling navigation systems, and other wearable devices. To assist GPS measurements, gyros, Wi-Fi, and 3G assisted GPS data are frequently used. GPS can sense a movement trajectory with high temporal resolution. Using the consecutive trajectory sensed by GPS, the following information can be estimated:

- transportation mode
- spot visited
- order in which spots were visited
- amount of traffic

In addition to this information, from a consecutive trajectory, we can easily obtain personal information such as the location of a person's home, office, or frequently visited shops if the same person is consecutively tracked, and this leads to privacy issues. In Japan, careful handling, specified by the Personal Information Protection Law, is necessary for personal information. For these reasons, it is difficult for academic organizations to collect a large number of consecutive trajectories.

1.6.2 Fragmented Trajectory

Fragmented trajectories can be collected using surveillance camera videos and geotagged data (including photos and short descriptions) posted to SNSs.

Surveillance cameras The surveillance cameras installed in streets or inside buildings sense movement, and we can acquire the location data of recorded persons by using image analysis technology. A surveillance camera can only sense a part of the trajectory of a person because a surveillance camera can only sense this trajectory when it is within the camera's field of view. Therefore, only a fragmented trajectory can be acquired from surveillance camera videos. However, in addition to human location, surveillance camera videos provide the following rich information for analysis:

- number of tourists in the field of view

- belongings
- clothes
- body position
- age and sexuality

We should obtain usage permission from persons before recording if we would like to use the surveillance camera videos for academic purposes because surveillance camera video includes personal information. However, it is difficult to obtain permission because an unspecified large number of people may be recorded by the surveillance camera. Therefore, surveillance camera video is mainly used for criminal investigations and not for academic purposes at present.

Geotagged data Geotagged data posted to SNSs can be regarded as a kind of sensor data. A geotag includes time and coordinate data, generally sensed by a GPS sensor. Flickr, Twitter, Instagram, Panoramio, and Pinterest are typical SNSs to which subscribers can post geotagged data. By aggregating the same ID geotagged data, we can generate the fragmented trajectory of an SNS subscriber. When a SNS subscriber posts geotagged data with usage permission, we can acquire that data from the SNS servers and generate a fragmented trajectory from them. Because the number of SNS subscribers is huge, it is easier to collect a larger amount of the geotagged data than GPS and surveillance camera video data. This is the greatest advantage of using geotagged data.

On the other hand, geotagged data have two problems, incomplete trajectories and time resolution. SNS subscribers generally post geotagged data when they are at a location in which they are interested, and they do not post when they are at a location that is not of interest. Therefore, a fragmented trajectory generated from geotagged data may miss some visiting spots, and there is no way for researchers to know which spots are not included. This problem is called the *incompleteness of trajectory problem* in this thesis. The time resolution of geotagged data is generally lower than that of GPS data or surveillance camera video because we can use only the few location data that were sensed when the geotagged item was posted (or a geotagged photo was recorded). This is called the *time resolution of measurement problem* in this thesis. From the geotagged data, we can analyze following information:

- number of tourists who visit a spot
- the spot that was visited
- order in which spots were visited

Although the fragmented trajectory does not include the whole movement, it can be used for the spot recommendation or other applications.

1.7 Data Analysis Process

Location data analysis research can be broadly categorized into two types, one that focuses on human activity status, and another that focuses on extracting a characteristic geospatial place like a tourism spot. This thesis defines extracting characteristic geospatial places as environmental knowledge analysis.

Human status The human status analysis focuses on the movement of an individual human. This includes the transportation mode inference [5, 6, 7, 8, 9], frequent movement pattern extraction [10], and a spot transition modeling [11, 12, 13, 14].

Because the consecutive trajectory basically contains only coordinate and time data, a semantic description of the transportation modes is needed to understand the transportation usage of tourists. This is called transportation mode inference. In the study of transportation mode inference, an approach based on learning from the features of velocity or acceleration has been broadly studied [5, 6, 9, 15]. In these studies, the environmental factors that belong to the surrounding environments of the tourists are less used because of the difficulty of collecting them. However, in a physical space, there are many environmental factors around us that constrain movements, and velocity or acceleration are changed by these environmental constraints. The traffic regulations that prohibit tourists from entering specific areas or limit their velocity should be followed in all transportation modes, and some transportation forms like trains or buses should move along specific pathways. Taking into consideration these characteristics of physical movements, environmental factors should be used in the analysis, even if they are difficult to collect. In the existing work, some researchers have proposed methods that adopt environmental factors [16, 14]. However, these adopted factors are mainly natural environmental factors like weather and time, and the environmental factors that directly affect velocity or transition have not yet been considered. In this study, the environmental factors that directly affect velocity or transition are defined as the environmental constraints, and transportation mode inference that considers these environmental constraints is proposed in Chapter 2.

Extracting the spots visited by tourists and the number of tourists that visit it are the most popular goals of this analysis [13], as this information helps the for-

mation of a tourism policy for the tourism destination management organizations of any local government. In case of the tourism spot recommendation, the number of the visiting tourists and order in which they visit several spots are used for calculating the route score [17, 18, 19]. In the study of the tourism spot transition modeling for tourists, researchers model spot transitions based on the relationships of the spots, which are extracted from consecutive trajectories [13].

Environmental knowledge The extraction of characteristic geospatial places focuses on environmental knowledge discovery. It includes the extraction of tourism spots by clustering methods [12] as well as transfer route extraction. In the field of environmental feature analysis, the research focuses on statistical information like popular tourism spot extraction, and it tends not to pay attention to the activity of individuals. However, road networks and other environmental constraints are taken into consideration in some studies, and these approaches are helpful for human status analysis.

1.8 Tourist Activity Support Service

As a tourist activity support service, this thesis proposes a safety confirmation service, an evacuation support service, and a route recommendation service, which are designed to shrink the information asymmetry of tourists in various situations.

The safety confirmation and evacuation support services are designed to shrink the information asymmetry in case of a disaster by sharing safety information among afflicted people and their families and providing an evacuation map to school trip students. The route recommendation is designed to shrink information asymmetry by providing travel routes to tourists considering environmental and human factors.

1.9 Thesis Structure

This thesis consists of six chapters. Chapter 1 introduces the thesis. In Chapter 2, the method for off-line transportation mode analysis with environmental constraints is presented. Chapter 3 presents an analysis of tourist behavior based on environmental and human factors. Travel route recommendation using the proposed model is also implemented. Chapter 4 presents the evacuation support and safety confirmation sharing services for school trips in disaster situations as a

mobile information system. In Chapter 5, a business model and market strategy for the mobile information service for educational tours is presented. Chapter 6 concludes this thesis with some discussion and future work. The four studies described in Chapters 2, 3, 4, and 5 are summarized here as follows.

Transportation Mode Inference with Consecutive Trajectories Transportation mode inference, which is obtained using the location data analysis of consecutive trajectories, is discussed in Chapter 2.

A semantic description of the transportation modes of the consecutive trajectory is necessary for understanding tourists' activity. Evacuation support based on the understanding of transportation modes realizes efficient social resource allocation in case of disasters. In non-disaster situations, route recommendation considering the tourists' transportation usage helps to alleviate the concentration of tourists in certain spots. In addition, traffic statistics are calculated to help generate local government tourism policies.

Many studies infer transportation modes by machine learning methods using velocity features. However, because trains and buses temporarily stop at train stations or bus stops, respectively, when movement is at low speed, the transportation mode cannot be inferred correctly using velocity features. The locations where the train and bus temporarily stop are generally known. Therefore, the transportation mode can be correctly inferred by using the location data of the train stations and bus stops as environmental constraints. This chapter proposes a method to infer the transportation mode from consecutive trajectories using environmental constraints.

Tourist Transition Model and Tourist Route Recommendation with Fragmented Trajectories Route scoring using the tourist transition model, which is derived from location data using fragmented trajectories, is discussed in Chapter 3.

Score-based route recommendation, which is one of the proposed tourist activity support services, is discussed in the same chapter. Route recommendation helps alleviate areas of the tourist concentration as mentioned above.

Existing route recommendations calculate the scores of all spot transitions included in the travel routes, and recommend the travel route with the highest sum of scores, which is calculated based on the spot transition model. Existing tourist transition model include factors such as spot popularity, tour purpose, and the most recently visited spot, and use the same factors to all transitions. On the other

hand, the proposed tourist transition model integrates all considerable factors that affect the spot transitions such as seasonality, time, weather, and previously visited spots, and use different factor set to different transitions.

Evacuation Support and Safety Confirmation Service The ETSS tourist activity support service for school trip students both during non-disaster and disaster situations is discussed in Chapter 4.

The Great East Japan earthquake in 2011 clarified the communication issues during trips in case of disasters: the stakeholders of a school trip require safety confirmation for school trip students. ETSS is designed to shrink the information asymmetry among the victims of disasters and their families by sharing this safety information among stakeholders.

ETSS User Expansion The user expansion for ETSS is discussed in Chapter 5. An ETSS user is currently limited to school trip students; therefore, the number of available trajectories is not large. Thus, this chapter discusses the expansion of ETSS to additional users from the viewpoint of social employment. A market strategy and business model are both discussed.

Chapter 2

Transportation Mode Inference

2.1 Introduction

In this chapter, transportation mode is inferred by analyzing the consecutive trajectories of tourists within environmental constraints. A semantic description of the transportation mode used for a consecutive trajectory is necessary for understanding a tourist's activity.

By considering a tourist's transportation modes, he/she can be provided with adequate evacuation advice. For example, if a tourist rides on the train, the nearest station is the best evacuation place, not the nearest evacuation place. Evacuation support based on the understanding of the transportation mode efficiently allocates social resources allocation during a disaster situation. In non-disaster situations, route recommendation that considers a tourist's transportation usage helps alleviate the concentration of tourists by avoiding routes with crowded transportation. In addition, traffic statistics are calculated to assist the creation of local government tourism policies. Understanding a tourist activity is important for the tourism industry and the local government of the tourism destination when creating tourism policy or marketing strategy.

Traditional questionnaires, face-to-face interviews, and traffic analysis are frequently employed for tracking tourist activity including transportation mode tracking. With the technical advances of sensors, GPS smartphones can sense tourist activity and generate large volumes of consecutive trajectories. However, these consecutive trajectories lack semantic richness because they include only coordinates and time. To enhance tourist activity analysis, the semantic richness of the data should be improved.

Many researchers have studied the transportation mode inference using machine learning [5, 20]. However, because trains and buses temporarily stop at stations or bus stops, respectively, when movement is slow, the transportation mode can not be inferred correctly from velocity. However, the locations where the train and bus temporarily stop are generally known. Therefore, the transportation mode can be correctly inferred by using such location data as environmental constraints. This chapter proposes a novel method to infer the transportation mode from consecutive trajectories using environmental constraints.

This chapter is organized as follows. In Section 2.2, related research is reviewed. In Section 2.3, the environmental constraints are described. In Section 2.4, the proposed method is described. The experiments are described in Section 2.5, and the results are presented in Section 2.6. In Section 2.7, these results are discussed. This chapter is concluded and future directions for this work are discussed in Section 2.8.

2.2 Related Research

Many studies have investigated transportation mode inference. The approaches of the existing research can be categorized into two types: those based on the features of an observed object, and those that use features surrounding the observed object. The first approach is defined as an object feature approach, and the second one is defined as an environmental feature approach.

The object feature approach estimates the transportation modes by learning the features in the training data. Some studies have proposed the employment of decision trees [21, 7], hierarchical conditional random fields [8], and support vector machines (SVM) [5, 9]. However, as stated in Section 2.1, this approach is unable to distinguish some modes using velocity only in the case of occasional deceleration. In contrast to researchers that use velocity, Ohashi proposed a transportation mode inference method that uses the fluctuation of movement, measured by an accelerometer that is equipped in smartphones [22]. In addition, Hemminki inferred the transportation mode using an adaptive boost method and acceleration data measured by a three-axis accelerator [20]. These types of sensor data are difficult to collect. GPS trajectory data is used in this research because it is available in a broad range of wearable devices, and it is easy to collect.

Regarding the environmental feature approach, some researchers have proposed methods that use spatial data such as transportation networks or land use data [6, 15]. They divide the GPS trajectory data into moving episodes and stop-

ping episodes, and infers the activities of each episode [15]. A moving episode is inferred to be a transportation mode, and a stopping episode is inferred to be an event. In this method, the input is raw GPS trajectory data, and after the system corrects for the error, it divides the GPS trajectory using temporal-spatial features such as velocity, acceleration, and movement direction. The system infers the transportation mode of a moving episode and the activity of the stopping episode using outside knowledge, such as road type or land usage, and outputs the results.

They focus on inferring the activity of the stopping episode, and he does not describe the details of the transportation mode inference. It is possible that he simply infers the transportation mode from the corresponding road type.

Stenneth et al proposed an inference method using GIS information that belongs to the environment of the moving objects such as real-time public bus locations, railway networks, and bus stops [6]. For the real-time public bus locations, he used the real-time location data of all the public buses in Chicago, USA. He infers the transportation mode of each observation point using features for random forest machine learning that include average bus closeness (ABC), candidate bus closeness (CBC), rail line trajectory closeness, bus stop closeness rate, average velocity, average heading change, average acceleration, and GPS accuracy. He calculates the ABC feature as the average Euclidean distance between the object and the nearest bus, and the CBC feature as the smallest total of Euclidean distance between the object and each bus.

They improve the classification effectiveness using machine learning by identifying and deriving the relevant features related to transportation network information. However, the reason why ABC or GPS accuracy are adopted is not explained. In addition, if the real time public bus location in a certain area is known, the bus that the object rides on can be identified, and transportation mode inference is of no practical use. However, his research does not take into consideration such characteristics of real time data.

The proposed method in this thesis infers the transportation mode from a GPS trajectory using different inference standards corresponding to the position of the object.

2.3 Environmental Constraints

Movement in physical space is restricted by some factors that exist in the environment. The range of velocity is constrained depending on the time and location. The possible path for some transportation modes is limited, for example, for train

Table 2.1: Velocity of Available Transportation Modes Given Environmental Constraints

		Environmental Constraints e								
		Point		Line					Area	
				Car Road						
		Stop	Crossing	Bus Route		Others	Rail	Walk Road	Bicycle Road	Spot
Mode m	Walking	L	L	L	L	-	L	-	L	L
	Bicycle	L-M	L-M	L-M	L-M	-	-	L-M	-	L
	Motorbike	H	L-H	H	H	-	-	-	-	L
	Bus	L	L-H	H	H	-	-	-	-	-
	Automobile (incl. Taxi)	H	L-H	H	H	-	-	-	-	L
	Train	L	-	-	-	H	-	-	-	-

and bus routes. In this research, the restrictions on the movement that exist in the environment are defined as environmental constraints e .

An environmental constraint e can exist as a point, line, or area in physical space. Examples of point constraints are a railway station or bus stop. Examples of linear constraints are a road, railway, footpath, or cycling path, and examples of area constraints are a tourism spot or car park. These environmental constraints are not disjoint, and some environmental constraints can be allocated to the same point, like a railway and one of its stations. Therefore, we allocate the set $A_i = \{a_1, a_2, a_3, \dots, a_l\}$, which indicates the existence of all environmental constraints at each observation point of the GPS trajectory data, where l is the number of environmental constraints.

When inferring transportation mode m from the observation points of GPS trajectory data, the change of velocity that is caused by the environmental constraints e should be considered. Without this consideration, m cannot be correctly inferred. The velocity of available transportation modes given various environmental constraints are shown in Table 2.1. For some combinations of velocity and constraints, some of the transportation modes m cannot be available, and these case are indicated by “-” in this table.

When the ranges of velocity of multiple transportation modes are similar, we cannot infer the transportation mode m_i of a observation point i by the combination of velocity and environmental constraints e_i . Therefore, we infer transportation mode m_i by using the transportation mode of neighboring observation points and path constraints. In this research, these two are defined as context.

Here, environmental constraints e are regarded as constant with respect to

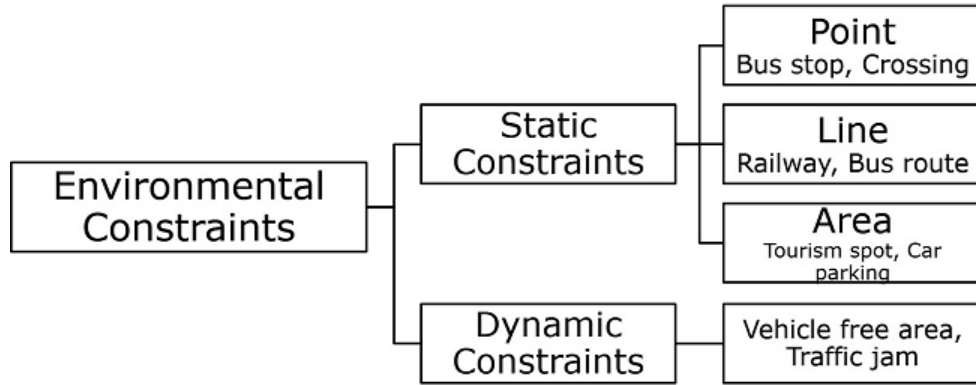


Figure 2.1: Static and Dynamic Environmental Constraints

time. However, e could be categorized as dynamic environmental constraints, which are variable with respect to time, and static environmental constraints, which are constant with respect to time (Figure 2.1). For instance, a road that changes to a vehicle-free street only on weekends is allocated a “road” attribute on weekdays and a “pedestrian road” attribute on the weekends.

In many cases, the location data of the static environmental constraints such as railways or bus routes are provided by governments or private business and can be easily used for research or business. In contrast, it is usually difficult to collect most dynamic environmental constraints like traffic congestion because these data are not measured or disclosed.

This research aims to be accurate enough to infer the transportation mode by using popularly available environmental constraints in as many cities as possible. Therefore, dynamic environmental constraints such as real-time bus locations or traffic congestion data are not used in this research.

2.4 Mode Inference by Environmental Constraints

2.4.1 Problem Setting

A GPS trajectory is defined as time series data consisting of observation points $i(x_i, y_i, t_i)$ (where x, y are the coordinates and t is time). In this research, the tourist's GPS trajectory data is input into the system and the system outputs a set of sequential data consisting of multiple transportation modes $m \in M$ (eq.2.1) of the tourist's movement:

$$M = \{m_1, m_2, m_3, \dots, m_n\} \quad (2.1)$$

Here, M generally includes walking, bicycle, motorbike, public bus, taxi, rental car, private car, and train modes. Some modes are not available in some areas. The transportation modes, which are the target of the inference, depend on the users of the inference results in the survey area. In this research, the transportation modes that are out of scope are lumped into one transportation mode because all observation points are labeled.

2.4.2 Overview of the Proposed Method

An overview of the propose method is shown in Figure 2.2.

Before inference, the GPS trajectory data is preprocessed. Because there is measurement error in the GPS trajectory data, this error is removed using the extended Kalman filter and fixed-interval smoothing. GPS trajectory data includes outliers that cannot be removed by the extended Kalman filter and fixed-interval smoothing when the tourist moves underground or indoors. Therefore, outliers are filtered and remove if the tourist velocity is over a threshold u .

Tourist velocity is calculated from the coordinates of the GPS trajectory data [23], and velocity class s_i is allocated to observation point i . Velocity class s_i is decided by dividing the velocity range into an adequate number of classes.

Next, the transportation mode of an observation point is temporally labeled using the environmental constraints e First, an A_i that indicates the existence of all environmental constraints at each observation point of GPS trajectory data is allocated. The transportation mode of the observation point is temporally labeled based on the combination of velocity class s_i and environmental constraints e_i . Second, the consecutive observation points with the same label are defined as a segment, and the transportation mode of the segment is revised using the context of the neighborhood segments. After revising all the segments, the GPS trajectory

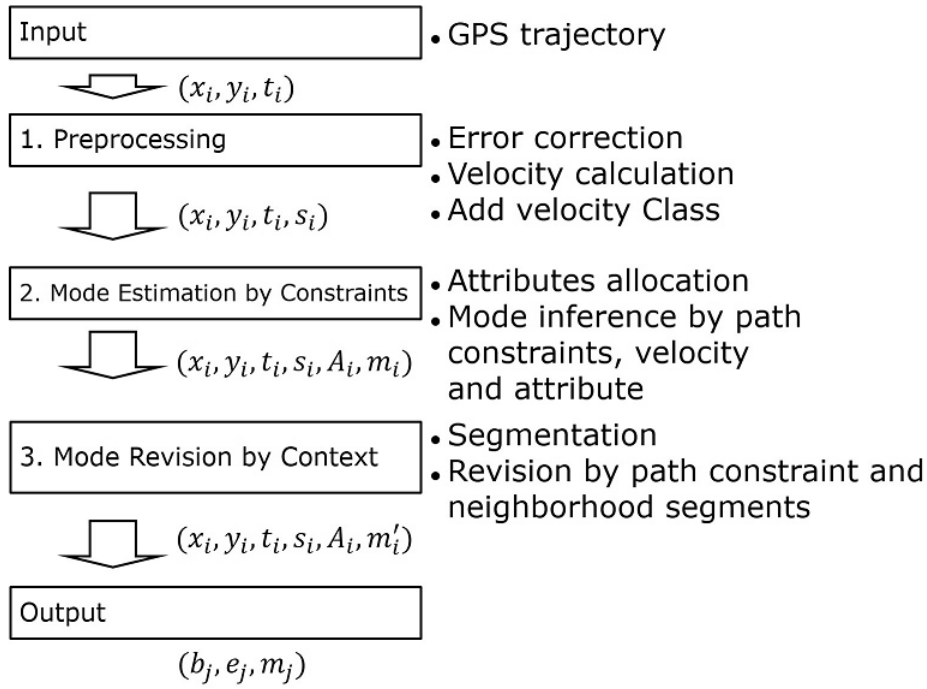


Figure 2.2: Overview of the Proposed Method

is processed based on the new labels, and the procedure is repeated until convergence. Finally, the system outputs the inference as a vector of segments g_j that consist of beginning time b_j , ending time e_j , and transportation mode m_j .

2.4.3 Preprocessing

This section details how the system removes the measurement error of a GPS trajectory, calculates the velocity based on this revised trajectory, and allocates a velocity class to each observation point. There is measurement error in the GPS trajectory data because of the propagation velocity of electromagnetic waves as well as influences of the ionization layer and atmosphere, and this error affects the determination of the environmental constraints. Therefore, in this study, the GPS trajectory is approximated using a linear discrete model, and the error is removed by an extended Kalman filter and fixed-interval smoothing [24].

Tourists do not move at a constant velocity, and they sometimes stop moving or change direction quickly. Therefore, the movement of tourists can be considered

a non-linear system. However, their movement over a very short interval such as 1 s can be assumed to be linear. This movement can be approximated as a linear discrete-time stochastic system [25]. The tourist status equation, expressed as a non-linear system, and its observation equation are, respectively,

$$\mathbf{x}_{k+1} = \mathbf{F}_k \mathbf{x}_k + \mathbf{G}_k \mathbf{w}_k \quad (2.2)$$

$$\mathbf{y}_k = \mathbf{H}_k \mathbf{x}_k + \mathbf{v}_k, k \geq 0 \quad (2.3)$$

where $\mathbf{x}_k$ is the true location of the tourist at discrete time k , $\mathbf{F}_k$ and $\mathbf{G}_k$ are the status transition and control input matrices, respectively, and $\mathbf{w}_k$ is the process noise. Furthermore, $\mathbf{v}_k$ in Eq. 2.3 is observation noise, $\mathbf{H}_k$ is the observation matrix, and $\mathbf{y}_k$ is the tourist's location as measured by the GPS at discrete time k . Initial status $\mathbf{x}_0$, system noise $\mathbf{w}_k$, and observation noise $\mathbf{v}_k$ are assumed to satisfy Eq. 2.4 and are Gaussian. Note that $\mathbf{F}_k$, $\mathbf{G}_k$, $\mathbf{H}_k$, $\mathbf{x}_0$, Σ_{x_0} , Σ_{w_0} , and Σ_{v_0} are given.

$$\begin{aligned} E\{\mathbf{w}_k\} &= \mathbf{0}, E\{\mathbf{v}_k\} = \mathbf{0}, E\{\mathbf{x}_0\} = \bar{\mathbf{x}}_0 \\ E\{[\mathbf{x}_0 - \bar{\mathbf{x}}_0][\mathbf{x}_0 - \bar{\mathbf{x}}_0]^T\} &= \Sigma_{x_0} \\ E\left\{\begin{bmatrix} \mathbf{w}_k \\ \mathbf{v}_k \end{bmatrix} \begin{bmatrix} \mathbf{w}_k^T, \mathbf{v}_k^T \end{bmatrix}\right\} &= \begin{bmatrix} \Sigma_{w_k} & \mathbf{0} \\ \mathbf{0} & \Sigma_{v_k} \end{bmatrix} \delta_k \\ \sum_{v_k} &> \mathbf{0}, E\{\mathbf{x}_0 \mathbf{v}_k^T\} = \mathbf{0}, E\{\mathbf{x}_0 \mathbf{w}_k^T\} = \mathbf{0} \end{aligned} \quad (2.4)$$

By applying the Kalman filter algorithm to the discrete linear model, we obtain an expanded Kalman filter algorithm. The Kalman filter is a linear stochastic system, where the input is observation value $\mathbf{y}_k$ and the output is the inference value $\hat{\mathbf{x}}_{k|k}$ of true location $\mathbf{x}_k$. The algorithm is given by the following equations.

$$\begin{aligned} \hat{\mathbf{x}}_{k|k} &= \hat{\mathbf{x}}_{k|k-1} + \mathbf{K}_k (\mathbf{y}_k - \mathbf{H}_k (\hat{\mathbf{x}}_{k|k-1})) \\ \hat{\mathbf{x}}_{k+1|k} &= \mathbf{F} (\hat{\mathbf{x}}_{k|k}) \\ \mathbf{K}_k &= \hat{\Sigma}_{k|k-1} \mathbf{H}^T (\mathbf{H}_k \hat{\Sigma}_{k|k-1} \mathbf{H}_k^T + \Sigma_{v_k})^{-1} \\ \hat{\Sigma}_{k|k} &= \hat{\Sigma}_{k|k-1} - \mathbf{K}_k \mathbf{H} \hat{\Sigma}_{k|k-1} \\ \hat{\Sigma}_{k+1|k} &= \mathbf{F}_k \hat{\Sigma}_{k|k} \mathbf{F}_k^T + \mathbf{G}_k \Sigma_{w_k} \mathbf{G}_k^T \end{aligned} \quad (2.5)$$

where K is the Kalman filter gain, and $\hat{\Sigma}$ is the covariance matrix of the estimate error. When a new observation value is gained, the system sequentially calculates a new estimate value. By applying fixed-interval smoothing to $\hat{x}_{k|k}$, coordinates are obtained for the velocity calculation. Velocity at observation point i is calculated from distance D between two consecutive observation points $p(x_p, y_p, t_p)$, $q(x_q, y_q, t_q)$ and transit time $t_q - t_p$. Distance D is calculated using Hubeny's distance formula, calculated as follows.

$$\begin{aligned} D(p, q) &= \sqrt{(d_y Q)^2 + (N d_x \cos(a_y))^2} \\ d_y &= y_p - y_q \\ d_x &= x_p - x_q \\ a_y &= \frac{y_p + y_q}{2} \end{aligned} \quad (2.6)$$

In Eq. 2.6, Q is the Earth's radius of curvature along the (north-south) meridian, and N is the radius of the curvature in the prime vertical. Velocity class s_i of observation point i is allocated based on the obtained velocity.

Table 2.2: Velocity Class Probability

	Velocity (m/s)	Car	Walk	Train
Low	0–2	0.18	0.81	0.01
	2–3	0.96	0	0.04
Middle	3–4	0.96	0	0.04
	4–6	0.95	0	0.05
	6–8	0.96	0	0.04
High	8–10	0.96	0	0.04
	10–20	0.94	0	0.06
	20–30	0.99	0	0.01
	30–50	0	0	1

2.4.4 Inference Using Observation Points

In this section, observation point i is temporally labeled with transportation mode m_i based on the combination of velocity class s_i and environmental constraints e_i .

We allocate A_i , which indicates the existence of all environmental constraints e , to an observation point i as $i(x_i, y_i, t_i, s_i, A_i)$, and calculate the probability $P_i(m)$ of each transportation mode corresponding to the environmental constraint e_i at observation point i . The transportation mode m that maximizes $P_i(m)$ temporally labels i .

Probability P_i is calculated using manually labeled training data. Because P_i varies depending on the environmental constraints e_i , even in the same velocity class, P_i is calculated as follows.

$$P_i(m; s, e) = \frac{r_{m,e}(s)}{\sum_{k \in M} r_{k,e}(s)}, m \in M, e \in E \quad (2.7)$$

In Eq. 2.7, s is the velocity class of the observation point, m is a transportation mode, M is the set of all transportation modes, e is an environmental constraint, E is the set of all environmental constraints, $r_{m,e}(s)$ is sum of observation points that are allocated velocity class s and are located in environmental constraints e in the training data. This probability for various transportation modes is listed in Table 2.2.

2.4.5 Revision by Segment with Context

Next, temporal labels are revised by applying the context. To apply the context, a segment is created by merging consecutive observation points that have the same label. The context is then applied to the segment. Different inference techniques are applied depending on the environmental constraints, because the temporal and topographical ranges of velocity change depending on the applied velocity constraints.

The point-based environmental constraints e_k^p constrain the velocity of observation points that are located in geographical neighborhood. The number of constrained observation points is relatively small. There are two cases of velocity and transportation mode change patterns around point-based environmental constraint e_k^p . In the first case, only the velocity changes. Transportation mode m_i of segment g_i that includes the constrained observation points is the same as transportation modes $m_{i \pm 1} = m_i$ of neighborhood segments $g_{i \pm 1}$. In the second case, both velocity and transportation mode change. Transportation mode m_i of segment g_i is not the same as transportation modes $m_{i \pm 1}$ of neighborhood segments

$g_{i\pm 1}$. The velocity change should be determined around point-based environmental constraint e_k^p according to the transportation mode changes or not for the revised label. The difference in these cases is that the transportation modes change or not depending on the number d_i of observation points of segment g_i . Therefore, d_i is scrutinized. The distribution of the number of observation points d can be determined from the training data. If d_i is subject to the distribution, the velocity change in segment g_i is a temporal velocity change caused by the point-based environmental constraints. The transportation mode can then be inferred as $m_{i\pm 1}$. If d_i is not subject to the distribution, the velocity change in segment g_i is caused by a transportation mode change.

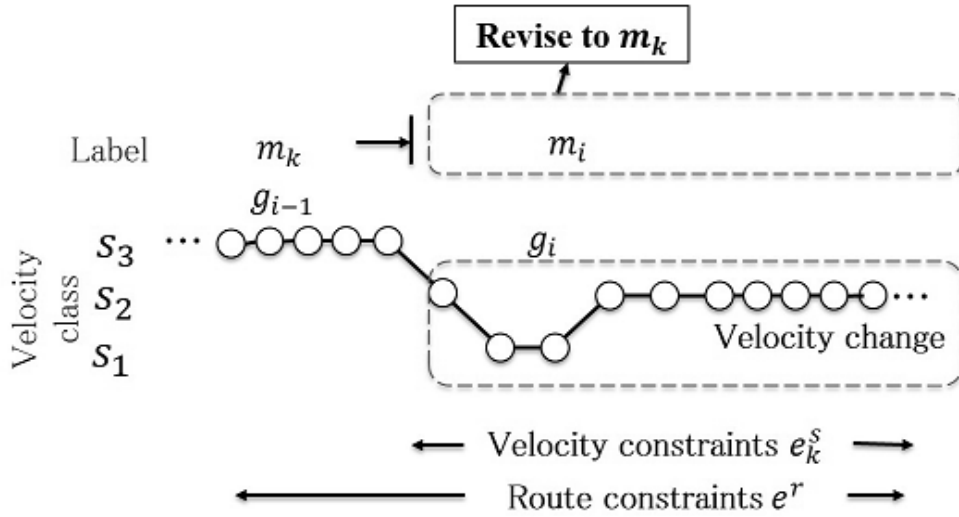


Figure 2.3: Transportation Mode Revision from Linear Environmental Constraints

The line-based environmental constraints constrain the velocity of additional observation points. The number of constrained observation points is more than those caused by point-based environmental constraints. In a segment g_i that has its velocity constrained by line-based environmental constraints e_k^s , if the transportation modes of the neighboring segments $g_{i\pm 1}$ are the same m_k and m_k does not conflict with e^r in the consecutive segments g_{i-1} , g_i , and g_{i+1} , the transportation mode of segment g_i is inferred to be m_k . This is illustrated in Figure 2.3. Stations and railways as well as bus stops and public buses are examples of combinations of velocity constraints e_k^s that constrain certain transportation modes m_k .

Most of the area-based environmental constraints limit the usage of transportation modes. Therefore, by applying the area-based environmental constraint, the available transportation modes can be limited.

2.5 Experiments

2.5.1 Overview of Experiments

To measure the performance of the proposed algorithm, the transportation mode with GPS trajectory data of actual tourists was inferred. For comparison, the transportation mode was inferred using only velocity without environmental constraints. The same dataset with the error removed was used for the comparison test.

Participants were students and their escorts during group activities of a school trip. The group leaders carried smartphones that had GPS loggers installed. The number of participants in the study was 16. Hence, the dataset was made up of the data of 16 GPS trajectories collected from the participants. The dataset included 288,400 observation points before preprocessing, and 287,377 observation points after outlier removal.

The participants moved in over the course of a day with GPS-enabled smartphones, and the trajectory data was collected by the GPS logger application. As the GPS logger application, the ETSS application was used[26]. Participants moved over a period of 6 to 10 hours in a day, from 8:00 AM until 7:00 PM.

As the survey area, Kyoto, Osaka, and Nara, where many students go on school trips, were selected. The transportation modes m that the participants could use were walking, taxis, public buses, and trains. No one used bicycles, motorbikes, rental cars, or private cars. The result was evaluated by a leave-one-out cross validation method. The correct classification for each observation point was determined by human verification.

2.5.2 Environmental Constraints

For the environmental constraints, the spatial information of bus routes, railways, and pedestrian areas, as shown in Figure 2.4, were used. For stations, railways, and motorways, transportation network data was acquired from a map company. For bus routes, public bus route data from digital national land information provided by the Geospatial Information Authority of Japan was used. For pedestrian

areas, the spatial data of tourist spots from Kyoto City local government were obtained. All data was provided in shapefile format, which is generally used for geoinformation system science.

A buffer was applied to point and line-based environmental constraints for convenience. A 40-m buffer was used for railways and motorways, and a 20-m buffer was used for bus routes. No buffer was used for pedestrian areas.



Figure 2.4: Environmental Constraints Used in the Experiments

According to the location in physical space, multiple environmental constraints can exist in the same location. In this experiment, priority is given to environmental constraints, and the probability $P_i(m_h)$ of the most prioritized environmental constraint m_h is allocated to observation point i . The order of the priority is as follows.

1. railways
2. bus routes
3. motorways
4. pedestrian areas

2.5.3 Thresholds for Preprocessing

The velocity threshold u for outlier removal of GPS trajectory data was set to 50 m/s. This was determined based on the velocity of the fastest transportation in the survey area.

2.5.4 Car Mode

Public buses and taxis operate at a similar velocity and hence, it is difficult to discriminate between them by using the velocity of observation points. Therefore, in this experiment, after inferring the mode to be car mode, which consists of both taxi and public bus modes, both modes were split by applying path and velocity constraints to the segments. Public bus routes were used as the route constraint, and bus stop were used as the velocity constraint.

Although the Geospatial Information Authority of Japan provides bus stop locations, the accuracy is not sufficient for use as a velocity constraint. Hence, bus stop locations are inferred from the training data. These locations were inferred to be where the public buses stopped in the training data. A stopping event is determined when the public bus moves at under 2 m/s.

2.6 Results

The results of the experiment are shown in Tables 2.3 and 2.4. Table 2.3 shows the result when public bus mode and taxi mode were inferred separately.

Table 2.4 shows the result when public bus mode and taxi mode were inferred as one mode. The results show that the total recall for the four-mode case was 91.6% and the total recall of the three-mode case was 93.6%. The recall of public bus, taxi, train, and walking modes were 66.9%, 75.6%, 90.2%, and 97.7%, respectively. The total recall of the comparison method, was 73.5%, as shown in Table 2.5.

Although the the comparison method inferred 3,599 segments, the number of segments inferred by the proposed method for four and three modes was 230 and 226, respectively. The true number of segments is 122. Figure 2.5 illustrates the mapped route of one tourist.

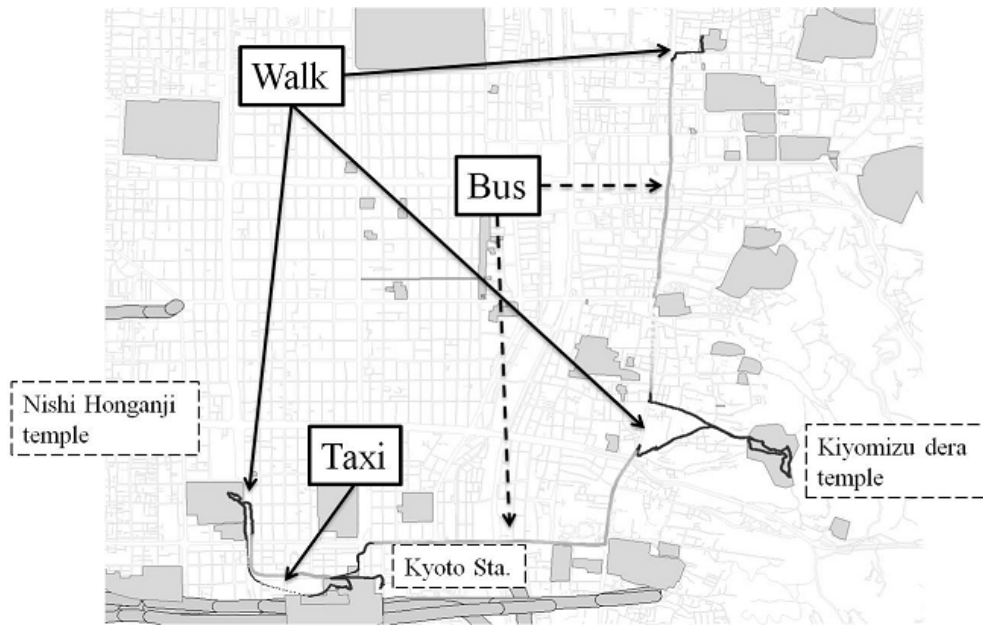


Figure 2.5: Example of Results

2.7 Discussion

As the results confirm, a 91.6% recall was achieved by applying the proposed method to GPS trajectory data (for four modes). The recall of three-mode temporal labeling is 86.8% and the number of segments is 1,875. By revising using context, 91.6% recall is acquired. The temporal labeling with environmental constraints resulted in an improvement of 13.3% over the velocity-only method, and decreased the number of segments by 1,724. The revision by context resulted in an improvement of 4.8% over the comparison method, and decreases the number of segment by 1,645. The proposed method lowers the number of segments because small segments are correctly merged into neighboring segments by considering the change of velocity caused by the point-based environmental constraints. As shown in Figure 2.5, the results of the proposed method match human judgment, and it has enough accuracy for practical usage.

Although the accuracies of the public bus mode and taxi mode are low, they will be improved if more precise bus location data is available. It is expected that it will soon become easy to use public geospatial data such as bus, bus stop, and

Table 2.3: Four-mode Recall of the Proposed Method (Recall 91.6%)

Inferred	True			
	Bus n=18,768	Taxi n=41,218	Train n=33,682	Walking n=193,721
Bus	66.9%	4.8%	0.0%	0.1%
Taxi	18.8%	75.6%	2.6%	2.0%
Train	0.3%	2.7%	90.2%	0.2%
Walking	14.0%	16.9%	7.3%	97.7%

Table 2.4: Three-mode Recall of the Proposed Method (Recall 93.6%)

Inferred	True		
	Car n=59,986	Train n=33,682	Walking n=193,721
Car	82.0%	2.6%	2.1%
Train	2.0%	90.2%	0.2%
Walking	16.0%	7.3%	97.7%

tourism spot location data that are now difficult to acquire.

In this research, the proposed method was evaluated by actual GPS trajectory data that included four transportation modes. Other GPS trajectory data including other transportation modes was not evaluated. Bicycle mode may be easily inferred because of its distinct velocity range. Other modes such as motorbike, rental car, and private car modes may be difficult to determine because of the similarity of the average velocity of these transportation modes. In order to infer these transportation modes, car parking location data, where only these modes are allowed to stop, could be useful. In addition, most tourists who use private cars may not use other transportation modes such as taxis and public buses. Similarly, there are relationships among some transportation modes that are simultaneously used. Such context of transportation mode usage in daily movement could improve the inference.

GPS accuracy would also improve the inference of the proposed method. In cases where a significant error may occur because of multilevel streets or other reasons, adequate environmental factors cannot be attached to the observation points. Map matching technology that can specify the tourist paths using traf-

Table 2.5: Four-mode Recall of the Velocity-only Method (Recall 73.5%)

Inferred	True			
	Bus n=18,768	Taxi n=41,218	Train n=33,682	Walking n=193,721
Bus	0.6%	9.7%	1.2%	0.6%
Taxi	52.5%	26.4%	47.0%	1.3%
Train	0.5%	38.2%	30.8%	0.1%
Walk	46.4%	25.8%	21.1%	98.0%

fic network data would be useful for car trajectories. However, people who move on foot sometimes walk along under 4 m wide roads, and it is difficult to apply map matching technology to such narrow roads.

In addition, dynamic environmental constraints like traffic congestion are considered to be one of the factors that decrease the inference accuracy. Traffic congestion affects the velocity of cars, and low velocity observation points may be inferred as walking mode without traffic congestion information. This study does not use the traffic congestion information because it is difficult to acquire.

2.8 Conclusion

This chapter proposes a transportation mode inference method that uses environmental constraints. The results of the experiments indicate satisfactory levels of accuracy for the practical application of tourist activity support. By determining the transportation mode, social resources will be allocated efficiently both in disaster and non-disaster situations.

In addition, the result can be used for touristic statistics, which is helpful for tourist destination management organizations. However, considering the application for tourist activity support or tourism spot recommendation, the development of an online transportation mode inference method should be studied in future. In case of the online transportation mode inference, the end of the segment is not determined from past data because the future data is not available. Therefore, the relationship between the transportation mode of the previous segment and the elapsed time of the current segment could also be used for analysis.

Chapter 3

Route Recommendation

3.1 Introduction

In this chapter, tourist transitions among spots are modeled by analyzing fragmented trajectories of tourists for calculating spot transition scores, which are used for travel route recommendation. Also, we develop a mobile application that recommends preferable travel routes to tourists by using spot transition scores that are calculated by the proposed tourist transition model. Travel route recommendation can shrink the information asymmetry of tourists in a region, and helps to alleviate the concentration of tourists in some famous tourism spots by leading to other tourism spots.

The tourist transition model combines an environmental factor model and a human factor model using fragmented trajectories. In the proposed environmental factor model, different environmental factors are separately combined for different spot transitions, while existing models use the same factor for all spot transitions. Namely, the proposed model assumes that the influential degree of each environmental factor is different for each transition, while the existing models assume that the influential degree of each environmental factor is the same for all transitions. As the environmental factor, the proposed model integrates seasonality, time, weather, and other features of visited spots. As the human factor model, the proposed human factor model adopts the collaborative filtering that describes tourists' taste for spots. Experiments were conducted for evaluating the proposed tourist transition model. The results of experiments showed that the proposed model could produce more similar travel route to the past tourists' actual routes than the route produced by other methods.

Tourists usually make a tour plan when they visit to some tourist destinations. Tourists look for preferable tourism spots and make travel plans which they can visit all spots in time. However, many tourists are concerned about if their travel plans are best for their taste, if they can visit all planned tourism spots in time, if the visiting order is adequate, if the planned tourism spots are suitable for season or time because the tourists are usually unfamiliar with the destination. A route recommendation system that recommends travel plan that are tailored to the season or time zone can resolve their anxiety. This research defines tourists' visits to some tourism spots as a tourist transition. The tourist transition consists of three environmental factors and a human factor. The environmental factors are a tourist as activity object, a next visiting tourism spot, a regional environmental factor like season, weather and visited tourism spots. The human factor is the tourist taste for the spot.

A spot where a tourist visits next can be estimated by modeling the tourist transition. Some studies model tourists' transitions to next spots by considering both of environmental and human factors. In this study, influential factors to spot transitions are called transition influence factors. Existing tourist transition models assume that all transition influence factors give the same influence to all transitions. For example, most of tourist transition models using simple Markov model that uses spots in where the tourist visited just before spots where the tourist is staying as the transition influence factor. However, the influential extent of transition influence factors to each transition is different. Therefore, it is thought that the tourist transition model that combines multiple transition influence factors to each transition can estimate the spot where the tourist will visit next more accurately.

This study proposes a tourist transition model that combines different transition influence factors for each spot transition, and develops a route recommendation method based on the results of the proposed tourist transition model. The tourist transition model and the recommendation system are independent for together, and each can be exchanged to another system or model. Transition influence factors are divided into two types; a human factor like tourists' taste, and an environmental factor like season, time, weather and spots visited before present spot. The proposed tourist transition model consists of the human factor model and the environmental factor model. The human factor model describes what kind of tourists tend to visit what kind of spot. The environmental factor model describes what kind of spots tend to be visited under what kind of environments. The travel route recommendation system makes a travel route by using the transition scores among spots that are calculated from the tourist transition model, and proposes travel routes that match a tourist's conditions.

3.2 Related Research

3.2.1 Environmental Factor Based Tourist Transition Model

Simple Markov model is broadly used as the tourist transition model that describes how extent general tourists visit to next spots [11, 12]. The simple Markov model assumes that spot transitions depend only on the present spot. However, actual spot transitions are affected by other environmental factors like spots where the tourists visited, season and time. Simple Markov model can not consider environmental factors besides of the present spots. In this regard, Kurashima et al. [13] propose a fusion model of simple Markov model and topic model. They use the information of spots where the tourist visited and spots where the tourist is staying to topic model. Also, Yamasaki et al [16] and Canneyt et al. [14] infer spots where the tourist will visit next by considering date and time. It can be interpreted that these existing studies focus on some specific environmental factors that affect tourist transitions, and researchers include these factors to their tourist transition models. In the proposed study, in order to consider more environmental factors, combination of environmental factors that have the highest conditional probability of transitions is included to the model. The highest conditional probability environmental factors are different for each destination spot, therefore, most efficient combination that makes the conditional probability at maximum is included to the model by analyzing past tourists' activity histories.

3.2.2 Tourist Transition Model Based on Human Factors

As the existing tourist transition models that focus on tourists' taste, a model describes destination spots based on the collaborative filtering [27]. The model infers destination spots of a tourist from similarities among other tourists and the tourist. Also, other models directly or indirectly score the tourists' taste to spots and recommend the travel routes based on the score. The system proposed by Maruyama et al. [28] requires the tourists to rank importance of all spots. Another system proposed by Vansteenwegan et al. [29] requires the tourists to input their own taste, and calculates all spot scores indirectly from tourists' input and spot data that were input before. Kurata et al. [30] assume that the tourist does not recognize all conditions on the travel plan, and their system recognizes the tourists' taste through an interactive communication, and scores the spot.

The methods that directly or indirectly calculate scores of spots require in varying degrees tourists' input, and it burdens to tourists. Therefore, in my study,

we adopt the collaborative filtering as human factor model.

3.2.3 Spot Visiting Order in Case of Route Making

The previous studies [28][30][29] generate the travel route by considering only spot scores. However, a spot visiting order is an important factor liked for good or bad of the route, too. As the travel route generation methods considering the spot visiting order, a method assumes past tourists' travel routes as a spot sequence, and obtain a travel route that are recommended to tourists through an analysis of the spot sequence. The method proposed by Okumura et al. [17] selects two past tourists' travel routes including the same spot, and obtains a new travel route by merging the first half and the second half of the routes. Arase et al. [18] assume a travel route as a spot sequence with time data (Temporary Annotated Sequence, TAS), and extract a frequent occurred travel route by applying the TAS mining method. These existing methods select the travel route that matched with tourists' input from obtained travel routes, and recommend them to the tourists. Therefore, the methods can not recommend if no routes match with the conditions.

In this regard, Lu et al. [19] define the score of spot transition among two spots as number of tourists who transit the spots in order and consider the spot visiting order by calculating the score of spot transition. The number of tourists who visit the spot are calculated from activity histories of past tourists. The proposed method recommends the route considering the spot visiting order by scoring the spot transition like Lu et al.[19].

3.3 Route Recommendation Using Tourist Transition Model

3.3.1 Overview of Proposed Method

In this study, the tourism transition model in a specific area is described as a combination of environmental factor model and human factor model. The environmental factor model describes transition tendency of the tourist under specific environments. The human factor model describes tourists' taste for visiting spots. Input data is the present spot, the required spot where the plan must include, and the excluded spot where the plan must not include. The proposed model outputs the score of the transition to the destination spot, the transition time among spots, and the necessary time in all spots. The score is calculated based on the

3.3. ROUTE RECOMMENDATION USING TOURIST TRANSITION MODEL 49

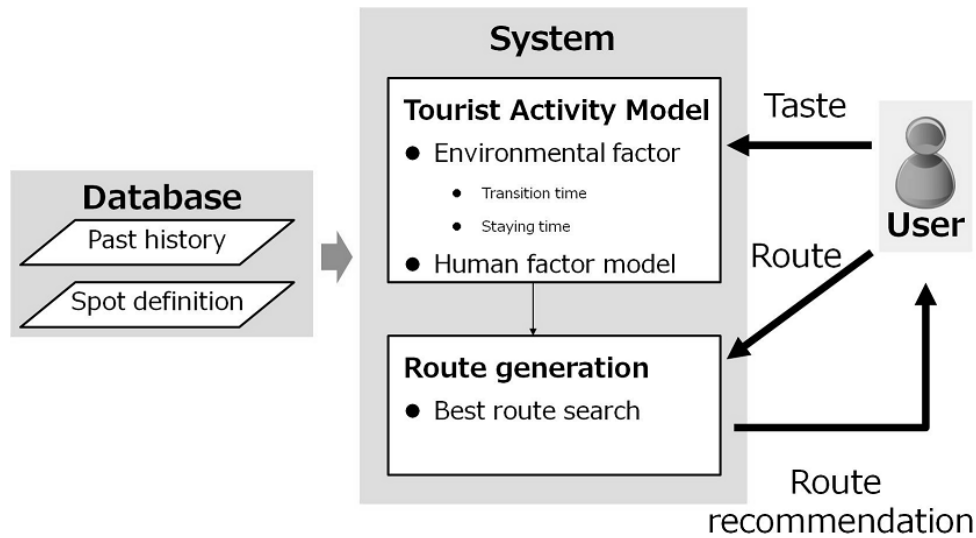


Figure 3.1: Framework of Travel Planning Support System

conditional probability under the combination of various environmental factors. The tourist transition model is extracted from the past tourists' activity history. How the tourists act under various environmental factors can be grasped from the activity history of the past tourists because the activity history includes day and time data of each activity. After here, the activity history of many tourists' who visited in the tourism area is called 'past tourist history'. Necessary time for the spot sightseeing and the transition time among two spots are calculated from past tourist history. The necessary time and transition time including the influence caused by the environmental factors can be obtained by using the past tourist history.

The proposed route recommendation system is input the spot transition score, the necessary time for spot, and the spot transition time that the tourist transition model outputs. The system recommends the most suitable route for the tourists by solving the maximization problem of sum of the spot transition score while satisfying the tourist condition as the constraint condition. The tourists' input is a travel time, a required spot, an excluded spot, a start spot and an end spot, and the upper limitation of the spot number.

The framework of the proposed system is illustrated in Figure 3.1. The past tourist history and the spot definition are given as an outside database. The spot

definition consists of a position and a name of a spot that is a target of the route recommendation.

3.3.2 Gathering Past Tourist History and Spot Definition

This subsection describes how to gather the past tourist history and how to define the spot.

The past tourist history is extracted from the geotagged photos that are uploaded to photo sharing websites. Set of the geotagged photos of each tourist ID ordered by time stamp is called as a photo history of a tourist [13]. The photo history of a tourist can be regarded as the activity history of the tourist. The accumulation of the photo history is used as the past tourist history.

For modeling the tourist activity, by corresponding between filming points and visiting locations, a tourist activity is described as a transition among a visiting location. For corresponding between a filming point and a visiting location, a new concept of 'spot' is introduced because it is necessary for dealing the visiting location as an area that covers a certain space. As the spot implementation method, there are two methods. One is manually given, and another way is automatically extracting by clustering [13, 31]. In this study, spots are given manually. An area corresponded to a spot is given as a polygon region.

3.4 Tourist Transition Model

3.4.1 Overview of Proposed Tourist Transition Model

We describe how to construct the tourist transition model in this section. This is believed that though the taste for the spot is different for each tourist, the visiting tendency of the spot for each environmental factor does not depend on tourists. In this study, it is assumed that the visiting tendency of the spot for each environmental factor and the taste for each spot are independent, and the tourist transition is modeled as a combination of the human factor model and the environmental factor model. The environmental factor model describes the tendency of the spot transition that is changed by the regional environmental factors like time, season, weather and geographical attribute of visiting spot. Also, the spot transition time and the necessary time for the spot are calculated. The human factor model describes the visiting tendency of the spot that is affected by the tourists' taste.

3.4.2 Environmental Factor Model

As the environmental factor model, some models focus on a specific transition influence factor that affects the tourism activity, and include the factors to the model [13, 14, 16]. In this study, it is assumed that different environmental factors affect on different spot transitions, and all environmental factors are listed, and the conditional probability of spot transition is calculated for each set of the environmental factors. For each spot where the tourist transits from, the highest conditional probability set of environmental factors is different. Therefore, the conditional probability is calculated from the past tourist history, and the highest conditional probability set of environmental factor is searched, and the acquired set of environmental factors is included to the model.

3.4.3 Environmental Factor

Set of environmental factors that is a candidate for including to the model represents $\mathcal{F}$, and an environmental factor represents $f \in \mathcal{F}$. A subset that is extracted from environmental factors $\mathcal{F}$ represents $F \subset \mathcal{F}$, and $F \subset \mathcal{F}$ is included to the model. Subset of environmental factors F is different for each spot where the tourist transits from. The environmental factors f have some sort of specific values like time and day. For handling easily, the specific values are mapped to one of a finite number of the environmental factor f 's status, and this represents a mapping status d_f . Possible number of the mapping status d_f corresponding to specific values is called subdivision number b_f of the environmental factor f . Serial number like time or angle is corresponded to mapping status by equally dividing. Set of the mapping status d_f of each factor f of environmental factor subset F is called mapping status set D_F .

When an environmental factor subset F is considered, and the corresponding mapping status set to F is D_F , the visiting probability of the tourist at spot s_i transits to another spot s_{i+1} represents $P(s_{i+1} | s_i, D_F)$. From Bayes' theorem,

$$\begin{aligned} P(s_{i+1} | s_i, D_F) &= \frac{P(s_i, s_{i+1}, D_F)}{P(s_i, D_F)} \\ &= \frac{P(s_i)P(s_{i+1} | s_i)P(D_F | s_i, s_{i+1})}{P(s_i, D_F)} \end{aligned} \quad (3.1)$$

$P(s_i)$ and $P(s_i, D_F)$ are independent from s_{i+1} , that is, by using constant number $K(s_i, D_F)$,

$$P(s_{i+1} | s_i, D_F) = K(s_i, D_F)P(s_{i+1} | s_i)P(D_F | s_i, s_{i+1}) \quad (3.2)$$

Assuming independence of mapping status of each environmental factor $d_f \in D_F$, $P(D_F | s_i, s_{i+1})$ is as follows;

$$P(D_F | s_i, s_{i+1}) = \prod_{d_f \in D_F} P(d_f | s_i, s_{i+1}) \quad (3.3)$$

Probabilities $P(s_{i+1} | s_i)$ and $P(d_f | s_i, s_{i+1})$ can be acquired from following most-likelihood estimation equation (3.4,3.5).

$$P(s_{i+1} | s_i) = \frac{N(s_i, s_{i+1})}{\sum_{s \in S} N(s_i, s)} \quad (3.4)$$

$$P(d_f | s_i, s_{i+1}) = \frac{N(s_i, s_{i+1}, d_f)}{N(s_i, s_{i+1})} \quad (3.5)$$

$N(s_i, s_{i+1})$ means the number of tourists' visits to spot s_{i+1} just after spot s_i in training data. $N(s_i, s_{i+1}, d_f)$ means the number of tourists' visits to spot s_{i+1} just after spot s_i under the mapping status d_f of environmental factor f in training data. S means set of all spots. For mitigating the impacts caused by small amount of data, an additive smoothing [32] is conducted. The additive smoothing prevents the probability being zero when some events do not included in the sample. By using the additive sampling, equation (3.4) and (3.5) are changed as follows.

$$P(s_{i+1} | s_i) = \frac{N(s_i, s_{i+1}) + 1}{\sum_{s \in S} N(s_i, s) + |S|} \quad (3.6)$$

$$P(d_f | s_i, s_{i+1}) = \frac{N(s_i, s_{i+1}, d_f) + 1}{N(s_i, s_{i+1}) + b_f} \quad (3.7)$$

$|S|$ means the number of factors of spot set S . From equations (3.2), (3.3), (3.6), (3.7), $P(s_{i+1}|s_i, D_F)$ can be acquired.

By doing this, the tourist at spot s_i under mapping status set D_F can be inferred to transit to spot s^* in equation (3.8).

$$s^* = \arg \max_{s \in S} P(s|s_i, D_F) \quad (3.8)$$

3.4.4 Environmental Factors that Influence Spot Transitions

This subsection discusses how each environmental factor affects on each tourist transition, and describes the possible factors of the environmental factor set $\mathcal{F}$ that was defined in section 3.4.3.

In this study, weather, season, time and visited spots are considered as possible environmental factors. These are decided considering the extent of influence to the spot transitions and easy to gather the data. Weather, time and season are generally recognized as factors affecting to tourists' activities, and some previous studies adopted [16],[14]. Also, a transition tendency to rely on the distance among spots is observed, that is, some tourists visit near spots, and the other tourists visit far spot. Therefore, the geographical attribute of the visited spots before is assumed one of environmental factors. Based on the assumption, region, angle and distance from just visited spot are considered as possible environmental factors to be involved in the model.

- **Season:**
For indicating the seasonal change of spot attractiveness, the travel season is included to model.
- **Time:**
For indicating activity change caused by time period, the visit time is included to model.
- **Weather:**
For indicating activity change caused by rain, the amount of precipitation is included to model.
- **Region:**
For indicating broad area where the spot locates in, the spot set is clustered and the cluster that visited spot just before the present spot is included to the model.
- **Angle:**
It is assumed that the tourist tends to select route to go easily, and not select a U-turn route. Base on this assumption, the angle from the present spot to the visited spot just before is included to the model.
- **Distance:**
It is assumed that the tourist transited to a near spot tends to transit to a near spot next, and the tourist transited to a far spot tends to transit far spot next. Based on this assumption, the distance among the present spot and the visited spot just before is included to the model.

3.4.5 Search Effective Environmental Factors

Efficient environmental factors f are different for each spot transitions. Also, if the subdivision number b_f is different even in case of the same environmental factor, how to include to model is different. Therefore, it is necessary to decide the subdivision number b_f adequately. Here, the environmental factor subset F with the highest inference accuracy is searched for each spot. The inference accuracy is evaluated by the conditional probability of next visit spot inferred by the model included the environmental subset F .

Here, a search problem of the efficient environmental factor is formulated. When a possible set of environmental factors $\mathcal{F}$ is selected, possible sets of environmental factors $\mathcal{F}$ with same environmental factor name and different subdivision number are treated as different sets. The environmental factor subset $F \subset \mathcal{F}$ that is subset of $\mathcal{F}$ is set to the search target, where F includes only one environmental factor f that has the same factor name. Under this condition, the objective of the search is to find the environmental factor subset F with the highest accuracy when F is included to the model.

When environmental factors to be included to model are searched among whole of possible environmental factor set $\mathcal{F}$, the number of combination is $\prod_{i=1}^m (e_i + 1)$, where number of environmental factor is m , and pattern of subdivision number of each environmental factor is $e_1 \dots e_m (i = 1, \dots, m)$. This is a search space of the search problem. For completing search within practical time period, the search space is limited. By roughly selecting environmental factors improving the inference accuracy if it is introduced to the model, the search space is limited. By repeating the search target to a part of the possible environmental factor set $\mathcal{F}$, the search space is getting small.

The search space reduction search is treated by recursive function *func* shown in Algorithm1. Recursive function *func* takes possible environmental factor subset F as its parameter. If the number of factor of F is lower than 1, it returns F . If not, it splits factors of F into F_L and F_R . Function *func* is recursively executed with F_L and F_R as its parameters. Factor set $func(F_L) \cup func(F_R)$ produced as the result is set to F' . Next, only targeting environmental factors included in F' , all selection pattern of environmental factors are searched Here, inference accuracy to all combinations of subsets of F' is calculated. Inference accuracy is calculated from next transit spots based on equation 3.8 and correct spots given as learning data.

N_{brute} most accurate environmental factor subsets are set to $F_1, \dots, F_{N_{brute}}$. At

last, $F_1 \cup \dots \cup F_{N_{brute}}$ is returned as the result of function $func$. The environmental factors included in $F_1 \cup \dots \cup F_{N_{brute}}$ can be considered as set of environmental factors that improve the model if they are embedded to the model. Also, the search space is limited by procedure 7 in Algorithm1.

Function $func$ is recursively called till the number of factors is under 1. Therefore, it is called as times as is proportional for the number of factors, $2n-1$ if the number of factors is n). The acquired environmental factors is used as the environmental factor subset defined in section 3.4.3.

Algorithm 1 Recursive Function $func$ for Search Range Limitation

```

1: function  $func$ (candidate factor set  $F$ )
2:   if number of  $F$  factor  $\leq 1$  then
3:     return  $F$ 
4:   end if
5:   Split candidate set  $F$  to  $F_L$  and  $F_R$ 
6:    $F' \leftarrow func(F_L) \cup func(F_R)$ 
7:   Search space limitation only for factors included in  $F'$ 
8:    $F_1, \dots, F_{N_{brute}} \leftarrow$  Upper  $N_{brute}$  factor set by accuracy
9:   return  $F_1 \cup \dots \cup F_{N_{brute}}$ 
10: end function

```

3.4.6 Calculation of Necessary Time for Spot and Transition Time between Two Spots

Here, necessary time for spot sightseeing and spot transition time are calculated. From past tourist history acquired from photo sharing websites, arrival time to spot is extracted as the time when the tourist took the first photo, and departure time from spot is extracted as the time when the tourist took the last photo, and necessary time is inferred as the difference among them. Spot transition time is extracted from past tourist history. If past history is not available, route guide of map service is used. In case of route guide, fluctuation of transition time caused by environmental factors can not be grasped. Therefore, correcting by transition time acquired from past tourist history, the transition time is calculated with considering fluctuation caused by environmental factors. As necessary time and transition time, mean values are used. No correction is treated in case individual differences is big.

3.4.7 Human Factor Model

Required spot is assumed to reflect tourists' taste. Therefore, for inferring tourists' taste for each spot from required spot data, collaborative filtering is adopted [27]. Collaborative filtering infers the target tourist's evaluation for each spot under assumption that similar tourists similarly evaluate the same spot.

For inferring tourists' taste for spots by collaborative filtering, past tourist history is used. Set of many tourists traveling to a specific sightseeing area in the past is set to U . Set of all spot where the tourists visited is set to S_u . Binary value $a_{u,s}$ indicating whether a tourist u visit to spot s or not is defined as follows.

$$a_{u,s} = \begin{cases} 1 & \text{if } s \in S_u \\ 0 & \text{otherwise} \end{cases} \quad (3.9)$$

For applying collaborative filtering, it is necessary to decide the similarity indicating how target tourist u^* and another tourist u are similar. In this study, both of tourist u visited spot S_u and required spot $S_{preferred}$ of the target tourist u^* are considered as groups. And similarity $w_{u^*,u}$ among S_u and $S_{preferred}$ is defined as how similar are these groups. Jaccard coefficient is used for similarity scale. $w_{u^*,u}$ can be calculated as follows.

$$w_{u^*,u} = \frac{|S_{preferred} \cap S_u|}{|S_{preferred} \cup S_u|} \quad (3.10)$$

$|S_{preferred} \cap S_u|$ is the number of common spots of $S_{preferred}$ and S_u . $|S_{preferred} \cup S_u|$ is the number of spots that are included in at least $S_{preferred}$ or S_u .

Using collaborative filtering, score v_s against spot s is calculated as follows.

$$v'_s = \begin{cases} 0 & \text{if } s \in S_{preferred} \\ \sum_{u \in U} w_{u^*,u} a_{u,s} & \text{otherwise} \end{cases} \quad (3.11)$$

$$v_s = \frac{v'_s}{\sum_{s \in S} v'_s} \quad (3.12)$$

In case of $s \in S_{preferred}$ like equation (3.11), spot s must be included in travel route, therefore, score is set to zero. In case of $s \notin S_{preferred}$, similarity $w_{u^*,u}$ among each tourist $u \in U$ and target tourist u^* is calculated, and sum of $a_{u,s}$ weighted by similarity $w_{u^*,u}$ is set to score v'_s . Score v_s is normalized value as sum of scores to all spots is 1 described in equation (3.12). Score v_s is human factor model that indicates the taste of target tourist u^* to spot s .

3.5 Tourist Route Making

3.5.1 Formulation

In this section, using the output of tourist transition model described in section 3.4 and the input of tourists, travel route is scored, and the route that maximizes score is indicated. The output from tourist transition model is spot transition score, spot transition time and spot necessary time. Tourists' input is travel time, required spot, excluded spot, start and end spot and the upper limitation of the spot number.

Travel route generation is formulated as a constraint optimization problem. Object function g toward travel route $R = (s_1, \dots, s_{|R|})$ is defined as follows.

$$g(R) = (1 - \alpha) \sum_{i=1}^{|R|-1} P(s_{i+1} \mid s_i, D_{F_i}) + \alpha \sum_{i=1}^{|R|} v_{s_i} \quad (3.13)$$

D_{F_i} is a status set of mapping status set to environmental factor subset F_i at spot s_i . α is a parameter that is set between 0 to 1. The first term of equation (3.13) corresponds to the score calculated from the environmental factor model, and the second term corresponds to the score calculated from human factor model. The smaller α , the impact from the environmental factor model bigger. The bigger α , the impact from the human factor model bigger.

In this study, the route to fulfill the following constraints and to maximize object function shown in equation (3.13) is searched. Constraints to route R are as follows.

- Sum of spot necessary times and spot transition times is within travel time.
- Travel route includes all required spots.
- Travel route excludes all excluded spots
- The first spot and the last spot of travel route equal to the start spot and the end spot.
- Number of travel route equals to the upper limitation of the spot number.
- Travel route does not include the same spot.

3.5.2 Search Most Suitable Route

Here, the travel route that maximizes target function (3.13) and fulfills the constraints described in section 3.5.1. This problem is NP-hard. Therefore, We decrease calculation time of route search within acceptable limits by using annealing method as is meta heuristic search method.

3.6 Experiments

To measure the performance of the proposed methods, destination spots were inferred by using actual past tourists histories, and travel routes were generated.

Performances of the environmental factor model and the route planning by the combined model were evaluated. For evaluating the performance of the environmental factor model, we compare the results of simple Markov model with that of the proposed method. For evaluating performance of the route planning, we compare similarity among the routes made by the proposed method and actual routes of past tourists. We do not evaluate a single performance of the human factor model because we adopt a collaborative filtering as the human factor model.

3.6.1 Data

We collected 436,031 geotagged photos that were taken from January 2004 to March 2014 from Flickr. Photos that have no accurate location data were filtered by existing method [17]. 30 major sightseeing areas were set to spots in Kyoto area. Each spot is defined as a polygon area in a map space. Geotagged photos were corresponded to spots by 'Select Layer By Location' function of ArcGIS. In case that no spot is corresponded to geotagged photos, the geotagged photos were removed. The number of geotagged photos for experiments is 14,710.

After correspondence with geotagged photos and spots, the tourist histories that visited under 2 spots was removed. As the result, the number of tourists was 412.

3.6.2 Evaluation of Environmental Factor Model

For evaluating the proposed environmental factor model, We investigate whether the proposed method infer spot transition with high accuracy or not. Here, inference accuracy is defined as the ratio of true inference of next visiting spots. We search the environmental factor subset with the highest accuracy per each spot by using Leave-one-out cross validation. The target environmental factor is indicated in Table 3.1.

The proposed method searches environmental factors to each spot. Therefore, for evaluating the performance, assuming the same common environmental factors affect on all spots, the environmental factors are searched by using the same factor for all spots. Here, the parameter N_{brute} is set to 5 in the search space reduction search. For comparison with the proposed method, we searched the environ-

Table 3.1: Environmental Factors

Transition Influence Factor	Correspondence Method	Subdivision Number
Region	k-means clustering	2,3,4,5,6
Direction	Equally divided (0 - 360, east is 0)	2,3,4,5,6
Distance	Equally divided (0 - max)	2,3,4,5,6
Season	Equally divided (Jan to Dec)	2,3,4,6
Time	Equally divided (0 - 23)	2,3,4,6
Weather	Equally divided (amount of precipitation)	2,3,4,5

mental factors by using simple Markov model without environmental factors and polynomial distribution model that spot transitions are independent from present spot, and tourists are assumed to transit to popular spots in where many tourists visit. The comparison of the inference accuracy is illustrated in Table 3.2.

We describe a list of the environmental factors searched by the search space reduction search in Table 3.3. The results in Table 3.3 show that different factors are efficient for different spots. For 10 spots including Ninna ji temple, no environmental factors are efficient. This means that no environmental factors improve the inference accuracy for these spots.

The experimental result shows that the proposed method improves the inference accuracy by including various factors to the model more than simple Markov model and polynomial distribution model. Also, the inference accuracy by the search using different factors for each spot is higher than that by the search using the same factors for all spot. The result shows that different factors are efficient for each spot.

Table 3.2: Accuracy of Next Visit Spot Estimation

Method	Accuracy
Search using different factors for each spot	38.3%
Search using the same factors for all spot	32.5%
Simple Markov Model	27.9%
Polynomial distribution model	18.2%

3.6.3 Necessary Time for Spot and Transition Time between 2 Spots

Spot necessary time and spot transition time are calculated by the method stated in section 3.4.6. As the environmental factors affecting on the transition time, 'season' with subdivision number 4 is adopted. The spot transition time that is acquired from Yahoo!Route Guide ¹. Business hours of spots do not considered.

3.6.4 Evaluation of Tourist Route Making

We generated route plans by using 412 tourist histories that were acquired in section 3.6.1 by using the leave-one-out cross validation. Flickr data do not supposed to use for input to the proposed method. Therefore, assuming that past tourists used the proposed system, the input data is extracted from the past tourist history. Travel routes are generated from the supposed input data, and similarities among the generated route and actual travel route are calculated. When a travel route is generated for a tourist, other tourists' past histories are used for generating. It is difficult for the result of the proposed method to compare with the existing method directly because the proposed method is a mixed model of the environmental factor model and the human factor model. Therefore, in experiments, we compared with three travel routes, one route is generated by the proposed method, and other routes are generated by a random method and a shortest transition time method. The overview of each methods is as follows.

- **Random**
Randomly generate travel routes satisfying tourists' conditions.
- **Shortest transition time**
Generate travel routes that minimize a sum of transition time among spots. Travel route is searched in the same way as the proposed method.

Supposed input data to system is extracted as follows. Starting time and date of a tourist is defined as the date and time when the tourist firstly takes a photo. Possible travel time is defined as enough long time. Number of spot n_{spot} is defined as the number of spot where the tourist visited. Tourists do not necessarily take photos in all spots during travel. Also, tourists may visit to locations where are not

¹<http://transit.loco.yahoo.co.jp/>

defined as spot in the way. Therefore, if possible travel time is defined from the past tourist history, travel route with more spots are generated than actually visited spots. Required spot is defined as the first visited spot of the tourist. Removal spot, starting spot, and destination spot are not input. As the measure for evaluation of similarity with generated route and actual route, editorial distance [33] is adopted. The route generating methods are evaluated by mean value of acquired editorial distance. The results of route generation by proposed method is affected by the parameter α in objective function. The mean value of editorial value when α is changed from 0.0 to 1.0 by 0.5 is illustrated in Figure 3.2. Loop number N_{loop} in annealing is set to 10,000. As the result of experiments, a mean value of editorial

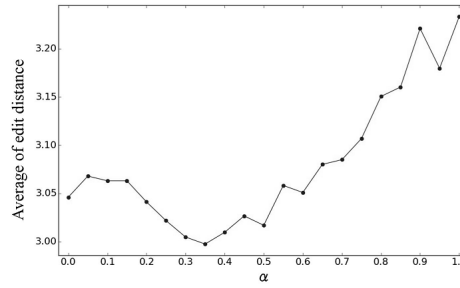


Figure 3.2: Relationship with α and Editorial Distance

distances is at a minimum when $\alpha = 0.35$. Therefore, α is set to 0.35 for this experiment. This result shows that a combination of the environmental factor model and the human factor model improves the performance of route generation.

The comparisons between the proposed method and comparison methods are illustrated in Table 3.4. The results show that the proposed method can generate more similar routes to actual past tourists' routes by using the past tourist history than the random method and the shortest transition time method.

Average calculating time is 0.34 seconds for searching travel routes. The search program is implemented by C++, and is executed on Google Compute Engine virtual machine (CPU Xeon 2.50GHz, memory 7.5GB).

3.7 Conclusion

In this chapter, we proposed a tourist transition model that combines an environmental factor model and a human factor model by analyzing fragmented trajec-

ries of tourists for calculating spot transition score. Also, we developed a mobile application that recommended preferable travel routes to tourists by using the spot transition scores that were calculated by the proposed tourist transition model.

As the results of experiments for evaluating the environmental factor model, 38.3% accuracy was achieved by applying the proposed environmental factor model to fragmented trajectory data. To contrast, the performance of the simple Markov model was 27.9%. The result shows that the proposed method improves the inference accuracy by including different environmental factors to different spot transitions. As for evaluations of travel route generating, we compared travel routes generated by the proposed method and actual travel routes of past tourists. As the results, we confirmed that we can improve the route generation performance by combining the environmental factor model and the human factor model. However, differences to performances of other methods are small, and there is room for improving the model. For example, we can improve the model by increasing the number of environmental factors.

The proposed model can be applied for other destination areas than Kyoto by using geotagged photos acquired from SNSs. For evaluating the effectiveness of the proposed model, next step is to apply the proposed model to other areas.

Table 3.3: List of Environmental Factors of Spots

Spot Name	Environmental Factor Group
Kiyomizu dera	Season(4), Weather(4)
Kyoto Station	Time(6)
Kinkaku ji	Time(3), Weather(3), Distance(5)
Fushimi Inari	Time(3), Season(6) Weather(3), Direction(6), Distance(2)
Yasaka jinja	Season(2)
Togetsu kyo	Time(6), Weather(4)
Ginkaku ji	Time(6), Season(2), Weather(4)
Nanzen ji	Direction(3), Distance(5)
Nijo jo	Weather(3), Distance(6)
kyoto gosho	Time(3), Season(4), Direction(3)
Ryoan ji	Direction(5)
Heian jingu	Time(3), Weather(3), Region(6)
Chion in	Season(6), Direction(6)
Kitano tenmangu	Weather(2), Region(5)
Kodai ji	Weather(3), Direction(3), Distance(5)
Tofuku ji	Season(4), Weather(4)
Kyoto tower	Time(4), Season(4)
Daitoku ji	Time(4), Weather(3)
Honen in	Season(4), Weather(2)
Shoren in	Direction(6)
Ninna ji	no
Eikan do	no
Sanju sangen do	no
Higasi hongan ji	no
Kennin ji	no
Shimogamo jinja	no
Toh ji	no
Tenryu ji	no
Jo jako ji	no
Daigo ji	no

Table 3.4: Comparison of Editorial Distances of each Methods

Method	Average of editorial distance
Proposed method($\alpha = 0.35$)	2.998
Random	3.466
Shortest transition time	3.344

Chapter 4

Evacuation Support

4.1 Introduction

This chapter discusses a tourist activity support for school trip students both in case of the non-disaster and the disaster situations, and the method is implemented to a mobile application called ETSS (Educational Trip Support System). ETSS is designed for shrinking the information asymmetry among the victims of disaster and their families by sharing the safety information of the victims among stakeholders. By sharing the safety information, we can avoid failing the telecommunication network resources like a telephone and an e-mail in the afflicted area.

4.1.1 Importance of Information during Trips

If a person is not familiar with the location where they perform an action, the person requires an activity support like guidebook and map. The tourist is a typical example of the unfamiliar person because the tourist is generally unfamiliar with the destination. Many researchers have investigated recommendation system [34, 35, 13] and navigation system [36, 37] for the tourists in non-disaster situations. However, the recent earthquake in Japan showed that the tourist could not access the evacuation information and family of the tourist experienced problems when accessing the tourists' safety.

The research subject of this study is a school trip, which is a representative type of group tour that occurs in Japan. Furthermore, the student activities that occur during school trips are similar to other school activities and the system can be developed to include most risky situations, specifically group activities. In the

case of a group tour, the number of people involved is often high. Individual tourists are not included in the scope of the present study.

4.1.2 Research Objectives

The objectives of ETSS are to help students to escape to an evacuation area rapidly by providing evacuation information and to share safety confirmations with relevant people during disaster situations. To support rapid evacuation, a student should know its current location and the locations of nearby evacuation areas. The evacuation process during the disaster situation is assumed as follows: (1) disaster alert, (2) confirmation of the current location, (3) confirmation of the evacuation areas, (4) selection of the route to an evacuation area, and (5) movement to the evacuation area. Our objectives are to minimize the time required for (2) and (3) by using ETSS system. Route navigation (4) is outside the scope of the present study because our system cannot estimate the availability of roads during the disaster situation. Effectiveness of our system is assessed based on a field test in a disaster-simulated situation, and a quantitative survey of the evacuation map function.

To share student safety confirmation, ETSS provides accurate location data for students at any time to all relevant people. In this research, I mainly use the location data to confirm student safety. Voice and e-mail functions are also included in ETSS as subsidiary methods. The effectiveness of information sharing depends on the user's subjective evaluation. Thus, the effectiveness is assessed based on user evaluations in a quantitative survey.

The major contributions of this study include the following:

- A description of a mobile application system for confirming safety during school trips and sharing information with relevant people;
- A method to facilitate the rapid evacuation of students that saves time and reduces their concerns about the situation;
- Detailed evaluations of the performance obtained using the proposed mobile system.

This chapter is organized as follows. Section 4.2 describes related research into evacuation guidance systems, safety confirmation applications, and information sharing systems. Section 4.3 presents the proposed information system, which was developed by an academic-industrial alliance. Section 4.4 provided the results of the experiments. Section 4.5 concludes the chapter.

4.2 Related Research

This section introduces related researches. First, we provide an overview of the school trip scenario that applied in Japan. Second, we compare existing commercial services and ETSS. Third, we introduce related research including studies of evacuation assistance systems, safety confirmation applications based on GPS, and information sharing systems for use in disasters.

4.2.1 Overview of the School Trip Scenario

In Japan, approximately three million students per year participate in school trips. In general, students participate in school trips during the third year of junior high school and again during the second year of senior high school. This is one of the largest group trip segments in the Japanese travel market. The school trips are organized mainly by components of the tourism industry (e.g., travel agencies and accommodation sectors) and by local government (e.g., Kyoto City) [38].

Teachers escort the students and they are responsible for their safety during these trips. This is different from a personal trip, where tourists are responsible for their own safety. Of course, it is also expected that the students will exercise autonomy during the planning of these sightseeing tours and while visiting tourist attractions [39]. Teachers, chaperones, and parents need to use information technology to keep track of the students' locations to achieve two contrasting goals: security and autonomy. Teachers cannot keep track of students involved in group activities at present. However, if the teachers could determine the students' locations, they might help them more rapidly in the event of a disaster or accident. Existing security methods for school trips are based on the premise that these methods will only be needed during the accidents and minor incidents that may occur in non-disaster situations. Thus, they are not designed for disasters. For example, the manual for school trips to foreign countries [40] only covers safety measures related to injury, disease, and theft. As the result, it was difficult for school staff to confirm the safety of their students during the Great East Japan Earthquake in 2011. In the case of the School of Engineering at Tohoku University, almost half of the students from this university who were affected during the earthquake did not confirm their safety [41]. The US government allowed GPS users to receive a non-degraded signal in 2000 and other positioning technologies that use mobile station are available [42, 43], but only GPS-equipped cellular phones that are designed mainly for voice communication are used during school trips.

After the earthquake, teachers and travel agencies were required to confirm the safety of students who were participating in school trips. Thus, safety information, such as the student's location data, should be shared with the teachers who accompany them on the trip, as well as with their parents and the teachers who remain at the school, because all relevant parties in the students' hometown need to know about their safety.

During disaster situations, the communication infrastructure tends to become saturated because of the vast amount of voice and data packet traffic for emergency call. Immediately after the Great East Japan Earthquake, the cellular phone lines were congested in the affected area and the Tokyo metropolitan area. Tokyo is far from the affected area, but many people in Tokyo made phone calls to confirm the safety of their relatives and friends. Thus, many teachers recognize that the availability of a mobile network is a key factor when confirming safety of students, and there is a requirement for an alternative safety confirmation method in case of network failures.

For clarity, we discuss the typical features of school trips. Three types of teachers are usually involved in school trips. A schoolmaster is responsible for the safety of the students during the school trip, and he/she usually travels with the students. Escort teachers, including homeroom teachers, the head teacher for the given grade, and other attending teachers, also travel with the students. A second master is an associate schoolmaster who usually remains at the school. Field headquarters are generally established to organize crisis management if trips experience problems, which are managed by the schoolmaster and the escort teachers. If the field headquarters lose their management capabilities due to a disaster, the second master must confirm the safety of the students and the teachers, and inform the parents.

The need to confirm the safety of the students is most urgent during group activities [39]. In general, a school trip is divided into two components: a main component and a group activity. The main component includes travelling from the hometown to the destination city, breakfast, dinner, sleeping, and a few excursions to major attractions. It is easy for the escort teachers to confirm the safety of the students during the main component because all of the students travel together. During the group activities, however, the students split into small groups of 4-6 members where the groups travel individually to preplanned attractions. The entire school trip normally lasts about 3-5 days and the group activities occupy 1-2 days.

4.2.2 Commercial Services for Ensuring Safety Using GPS

At the beginning of the history of the smartphone, GPS-enabled smartphones were assumed to be a good platform for public safety applications [44]. Many services that ensure safety based on GPS have been released commercially for iOS/Android smartphones (b-safe 2013; circleof6 2012; SafeApp 2012; Smart-Safe 2014). These services display the user's current location on the smartphone, as well as sharing location data with permitted people and sending alerts in case of emergency. These features are similar to ETSS, but there are some major differences due to the different service scopes. The main differences are as follows: (1) the existing services are designed basically for personal use and they do not consider usage by general tour groups, (2) the existing services are designed based on the assumption that anyone can help the user if the user issues an alert (voluntary evacuation is required in the case of a disaster), and (3) the existing services do not provide evacuation area information.

4.2.3 Safety Confirmation by Estimating Users' Location

As described in Section 4.2.2, GPS positioning is used widely for safety confirmation. However, GPS cannot measure locations in indoor areas or other inaccessible areas, thus non-GPS-based positioning methods are required for safety confirmation. Some studies have used indoor sensor networks for position estimation (e.g., gyro, ZigBee, and monocular cameras) [45, 46, 47, 48, 49]. Systems that can be used during network failures or disconnections have also been proposed based on actual experiences of network failures during previous earthquakes [50]. In the present study, we implemented Wi-Fi positioning using the MAC address for simple indoor positioning because indoor situations were rare in our survey area, but other methods may improve the accuracy of positioning.

4.2.4 Information Sharing

Information sharing is becoming increasingly important during disaster situations. The effect of information sharing via social media services has been analyzed previously [51, 52]. From the viewpoint of media research, some researchers have highlighted the risk of disinformation [53]. Thus, a closed group that limits membership may be effective for guaranteeing the trustworthiness of social information. Previous researchers have proposed the concept of a community response grid for information sharing via telecommunication networks during a disaster

where the members comprise community residents (Jeager et al. 2007). Similar to the community response grid concept, ETSS facilitates the sharing of safety information related to students with a community of school trip-related people via a mobile network.

4.2.5 Evacuation Guidance

Disaster information is classified in terms of the timeline as a disaster alert or as evacuation information. A mobile information service called “Area Mail” was developed previously to provide disaster alerts [54]. Our proposed system is based on the premise that the service is available. Route navigation to the evacuation area is important as evacuation guidance. Some researchers have used sensor networks to detect possible routes [55], whereas others have proposed the sharing of route information among evacuees via wireless ad-hoc communications technology [56]. Simulation experiments using evacuation guidance via a GPS-equipped mobile phone are challenging because large-scale field tests are difficult in the real world [57, 58]

We do not employ route guidance in the proposed system because large-scale sensor networks are not available in outdoor environments and route information can only be shared among a limited number of users. Furthermore, this is a response to the lessons we learned from the previous earthquake. Before the earthquake, the students were required to wait for instructions from teachers before trying to escape. However, many of the students from one elementary school died when they followed incorrect instructions [59]. This was treated as an important lesson and the escape policy for students was made voluntary based on correct information. The request for evacuation guidance is based on this change.

4.3 Tourist Information Systems Based on Positioning

4.3.1 System Specifications

We propose the use of a GPS-enabled information system for school trips, which can be deployed as a smartphone application. The specifications of ETSS system are described in Table 4.1. A diagram of ETSS system is shown in Figure 4.1. The main aims of ETSS are to help the students to escape rapidly to an evacuation

area, to confirm the safety of students, and to share the safety information with relevant people.

In particular, the application collects real-time GPS location data for each of the student groups and provides their current locations and movement histories. Wi-Fi positioning is used in underground areas where GPS cannot be accessed. The location data are transmitted every 30 seconds and are stored on a server. Using these data, the teachers can confirm the locations of the students at all times. In situations where wireless lines of communication are disconnected around the affected areas due to a disaster, the second master, who is located at the school and is not affected by the disaster, can obtain the student's location immediately before the disaster occurred.

Teachers cannot confirm the status of students using the location data. However, the teachers can use broadcast mail and VoIP as direct communication methods with the students. Direct communication functions are equipped because teachers stressed the importance of interactive communication methods. ETSS uses VoIP calling as the voice communication service and broadcast mail transmission function as the mail service. The call and mail history is available to the teachers, which allows them to confirm the safety of students in disaster situations.

ETSS is designed to consider the possibility that the network availability will be low. Thus, the students can access an evacuation area map even if no wireless service is available. The map data are downloaded incrementally to the smartphone during normal operation. ETSS uses VoIP as a direct communication method because the availability of wireless data services was better than that of wireless voice services during the earthquake in 2011, thus we assume that VoIP would be more disaster-resistant.

The battery lifetime of the proposed system is an important issue. ETSS application drains the battery quickly because it operates constantly when the smartphone is switched on. A regular battery is not sufficient for ETSS application to be used for over 8 hours each day. Given its likely usage in disaster situations, the battery life should exceed 10 hours. Therefore, an extended-life battery was developed for the system.

ETSS application uses the students' location data, which must be protected from illegal usage by a malicious third party. Thus, ETSS application adopts an access restriction function. All teachers have access to information related to the locations and movement histories for some or all of the student group members, but access may be based on permissions. The students only have limited access to the information related to their own group. The difference between the school-master, the escort teacher, and the second master is defined by the access authority

level.

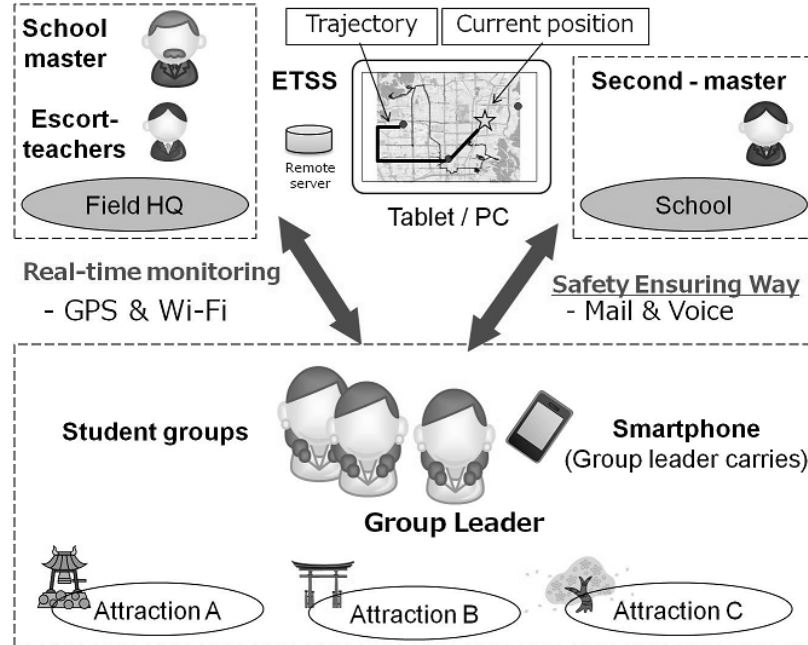


Figure 4.1: ETSS Service Overview

An ETSS smartphone/tablet application was constructed in Android SDK for Android 4.0. For the mapping function, we used Google Maps Android API. The server-side application was constructed as Java servlets, which are executed in an Apache Tomcat container.

Concept of the Tourist Information Infrastructure (TII)

Before this study, our research team developed the concept of a TII that collects real-world information via sensor networks, offers this information to tourists in typical situations, and provides safety information in the event of a disaster, as shown in Figure 4.2 (Author 2012a). The present ETSS system was developed as part of the interface for this TII system. The system can be used by tourists to acquire real-world information about events such as traffic jams and it can be used indirectly to improve the attractiveness of destinations. We consider that these efforts can produce a positive spiral of improvement in human communication, both

Before the trip	Planning in advance
Non-disaster situation	Display the locations of observing attractions on the map. Monitoring the students' trajectories Track students in real-time (each 1 second) Transmitted the students' trajectories to the server (each 30 seconds) Store students' trajectories in the remote server (Tokyo) Graphical presentation of the students' trajectories Indicate students' current locations and movement histories Acquire the current location data of the students when the teachers require
Disaster situation	Graphical presentation of evacuation areas Display the evacuation areas on the map near the students and the teachers Store the evacuation map in case of wireless network disconnection Display the latest locations of the students if the teachers require this information Voice and mail communication Broadcast confirmation mails to the students from the teachers VoIP calls among the permitted users

Table 4.1: System Specifications for ETSS

in non-disaster situations and in disaster situations by promoting the circulation of information and removing various forms of miscommunication.

4.3.2 Details of the Applications: Students

ETSS is provided to students as a smartphone application. The details of the application for students are as follows.

Map

This application presents two maps to the students. These maps display the area around the group. Figure 4.3 shows screenshots of both maps. The screenshot on the left in Figure 4.3 shows the typical map that displays the planned attractions, the current location of the group, and the movement history. The screenshot on the right shows the evacuation map, which displays the official evacuation areas located near the group.

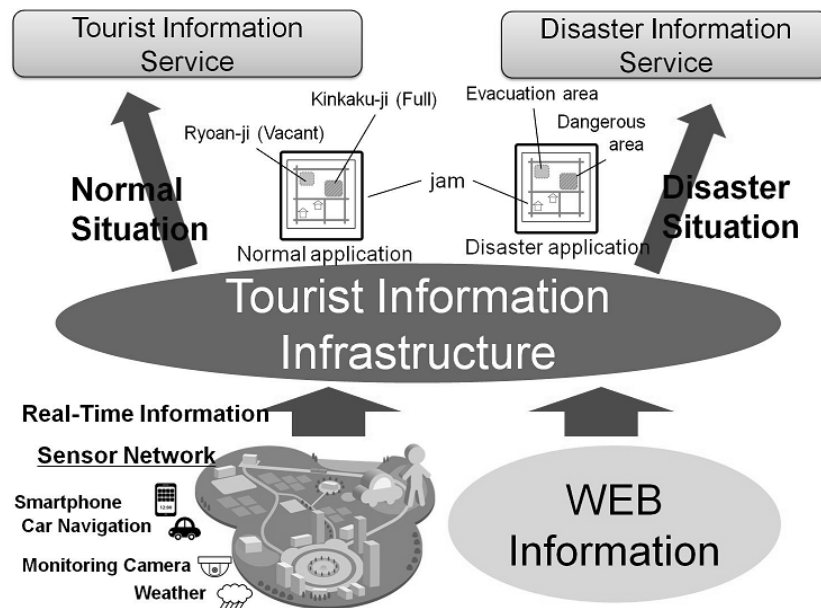


Figure 4.2: Tourist Information Infrastructure

On the regular map, the current location is indicated by a green circle and the movement history is indicated by a red line. One of three movement history

modes can be selected as follows: (1) current location, (2) 1 hour before, (3) the complete history. Three different view modes were developed because the line that indicates the trajectory overlaps with itself and it is difficult to see, as shown in Figure 4.4. The students can select the view mode by tapping on the icon above the map. Attractions are shown on the map as blue flag icons. The locations of these icons are determined and registered by the student groups via a PC before the school trip begins.

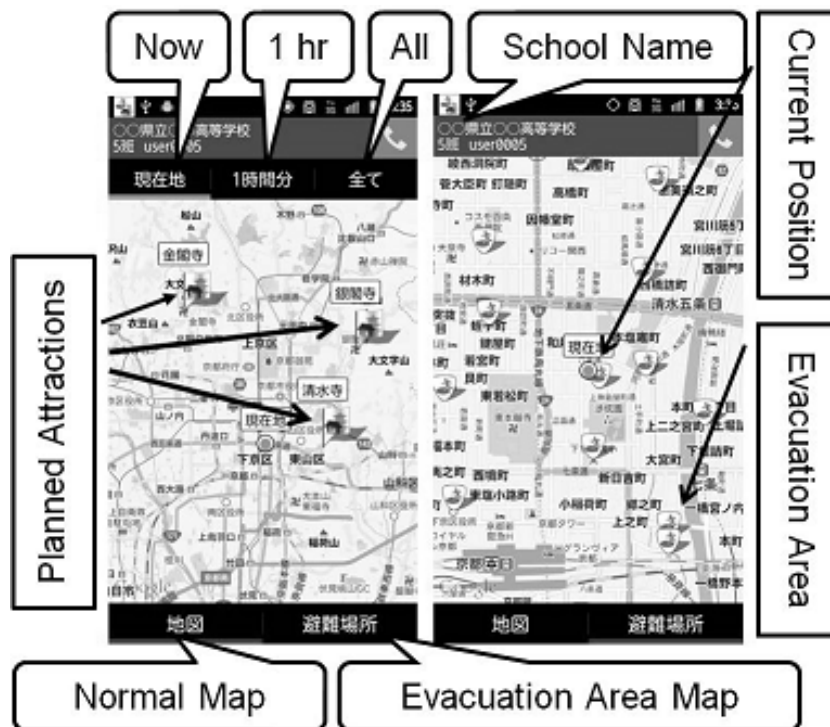


Figure 4.3: Map Application for Students

Using the evacuation map, the students can view the evacuation areas within 3 km of their current location by tapping an icon below the map. The evacuation areas are indicated by green running man icons, as shown in Figure 4.3 (right). The map can even be used if the wireless network becomes disconnected because the application slowly downloads map data in the background based on the student's current location.



Figure 4.4: Overlapping Trajectory

Voice and mail communication

The students can call their teachers by tapping the phone icon at the top of the screen, as shown in Figure 4.5. The students can only call permitted terminals, which are usually those of the escort teachers. The teachers can also use broadcast mail to confirm the safety of the students. This function is described in Section 4.3.3.

4.3.3 Details of the Applications: Teachers

The application is provided as a smart tablet application for all the types of teachers. Tablets have good visibility for managing many student groups. In addition, the students' locations and movement histories can be viewed on a PC. This functionality is typically used by the second master. The tablets have 10-inch screens. The tablets are not particularly heavy, but some teachers who participated in the experiments requested a change to lighter 7-inch tablets or 5-inch smartphones because of weight considerations. Figure 4.6 shows a screenshot of the application.



Figure 4.5: VoIP Call Icon

Map

All of the teachers can view the current locations and movement histories for all or some of the student groups. The access authority can be controlled for each individual teacher. In general, the schoolmaster and the second master would be able to access all of the groups. The escort teacher's access authority is sometimes limited because of administrative restrictions. These restrictions may be due to variations in the number of student groups. For example, the smallest number of student groups from a single school that participated in the experiment was four, whereas the largest number of groups was over 40. Observing too many groups will drain the tablet batteries rapidly. The escort teachers usually patrol outside during the students' group activities. Therefore, the battery life is an important issue. Before the use of ETSS, student information was gathered during the teacher's patrols or check-points were concentrated in the field headquarters (see Figure 4.1). However, the information was not shared effectively among the teachers in the field. By using ETSS application, all teachers can determine the locations of the student groups. Even in non-disaster situations, the teachers can check the locations of the student groups.

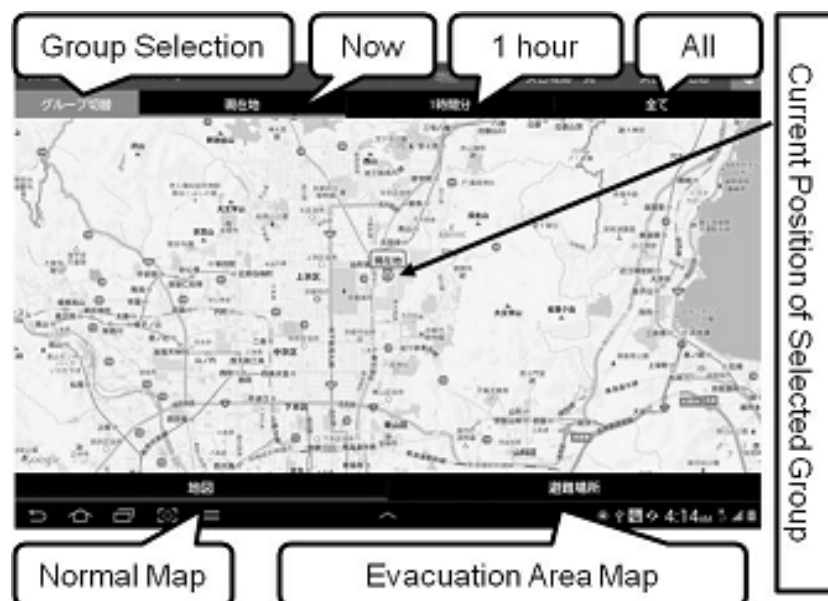


Figure 4.6: Map/Positioning Application for Teachers

Voice and mail communication

All of the teachers can send broadcast mails to the students' terminals to confirm their safety. Teachers can send short messages, as shown in Figure 4.7 (left), and the students select their reply from the list, as also shown in Figure 4.7 (right). The students can also add short messages to their replies. The reason for adopting a reply selection form is that it is likely that the students will be under stress and they will need to respond rapidly in disaster situations. All of the confirmation mails and reply mails can be viewed in a list format, which allows the teachers to identify the groups that have replied and those that have not in a single glance.

There was a problem with the broadcast mail notification system because the reply rate did not reach 100% during the experiment. This was because most of the groups received the mails while they were moving and they did not feel the vibration alert or hear the alert sound used for notification.

Positioning

ETSS system uses GPS and cell station (CS) positioning techniques. The techniques work well but locations cannot be measured in underground and indoor

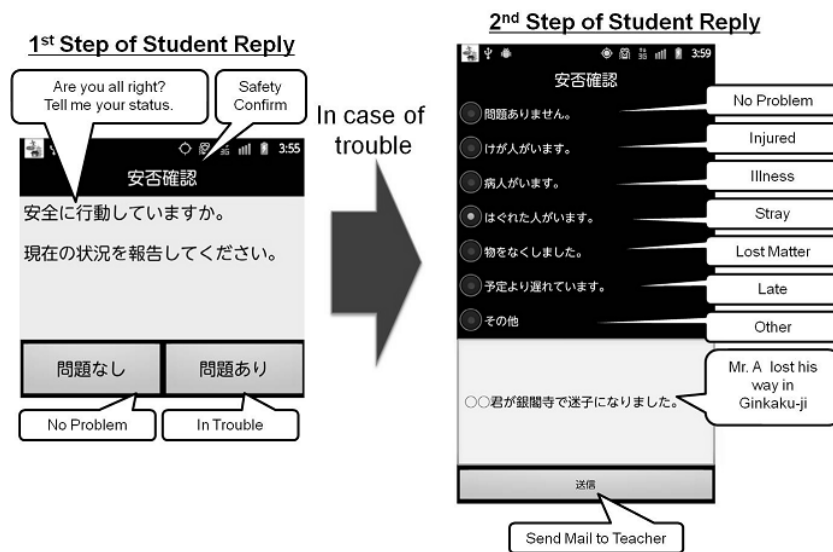


Figure 4.7: Broadcast Mails for Safety Confirmation

places. In particular, GPS/CS can not measure location in subways and underground malls, as well as in arcade malls and buses on occasions. Figure 4.8 shows a typical example of GPS/CS blind zone. Some of the most popular places for school trip students are GPS/CS blind areas (e.g., the Shin-Kyogoku arcade mall and Kyoto station underground mall). In the GPS/CS blind areas, ETSS can not determine whether the student group has entered a building or an underground area, or disorder of ETSS application. This means that escort teachers will lose the students' locations for around 30-60 minutes if students ride on subway. To solve the GPS/CS blind problem, we use a Wi-Fi positioning function to gather the MAC addresses of Wi-Fi routers installed in the main subway stations in Kyoto. ETSS application displays blue train icons when it detects a Wi-Fi router that is installed in an underground area. This method does not provide detailed locations of students, but escort teachers can know whether a student group has entered an underground area or ETSS disorder.

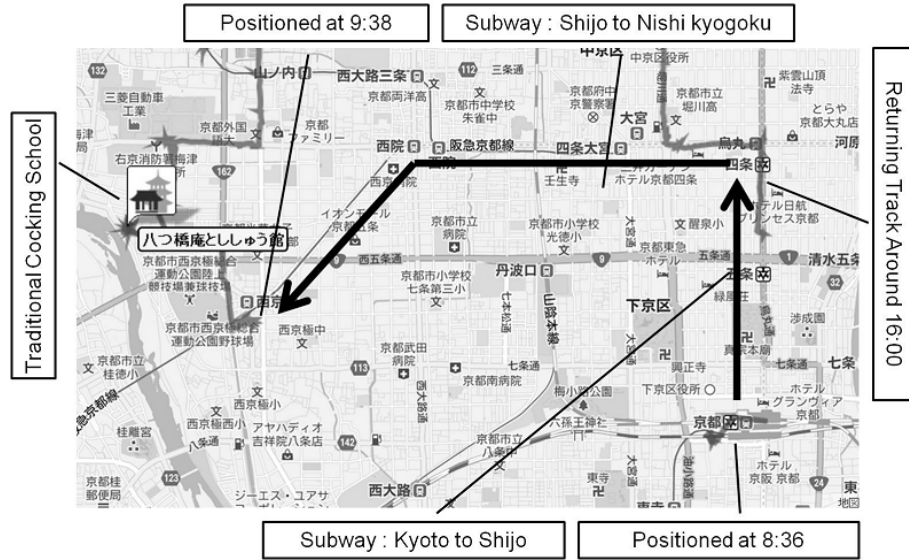


Figure 4.8: GPS Blind Zone near Kiyomizu-dera

4.4 Experiments and Results

This section presents the results of our experimental evaluations of the effectiveness of ETSS. First, we assessed the effectiveness of the information sharing function based on quantitative surveys to obtain subjective user evaluations and the results are presented in Section 4.4.1. Second, we evaluated the effectiveness of the evacuation map function in simulated disaster conditions during a field test. In addition, we obtained the subjective user evaluations of the evacuation map function based on quantitative surveys and the results are presented in Section 4.4.2. Finally, we tested the battery consumption because the battery capacity is a critical factor during practical usage and the results are described in Section 4.4.2.

4.4.1 Experimental Evaluation of the Effectiveness of Information Sharing

To measure the effectiveness of ETSS system's information sharing function, we performed an overall evaluation of its operability where we assessed the positioning and communication functions in quantitative surveys. This is because the information sharing function comprises positioning and communication functions.

In addition, the concept of “information sharing” was difficult for the students to describe directly. The teachers also answered the same questions. The results of the overall evaluation and assessment of the operability of ETSS application are given in Section 4.4.1, while the evaluations of the positioning and communication functions are presented in Section 4.4.1. Quantitative surveys were conducted using a questionnaire in experiments Nr.1-7. The questionnaire is provided in the appendix. The questionnaire included some open-ended questions. The quantitative survey obtained 216 valid responses from the student group leaders and 41 from the teachers at seven junior high schools. Table 4.2 shows some details of the respondents. During the group activity, each respondent used ETSS application, which was installed on a smartphone, as described in Table 4.3. The group leaders used smartphones and the escort teachers used tablets. To clarify the structure of a typical school trip, we present the itinerary used in experiment Nr.1. All five groups started from a hotel located near Kyoto station at 08:00. All of the groups visited Kinkaku-ji temple, Kitano-tenmangu shrine, and Kiyomizu-dera temple. Two of the groups only visited these three attractions. Two of the groups also visited Ryoan-ji temple and one group visited Nishiki-ichiba market. Finally, the students went to a hotel located in Osaka at 17:30. The students travelled by train, subway, bus, and foot. None of the groups used a sightseeing taxi service or rental cycle service. The total free activity time was 9 hours and 30 minutes.

Table 4.2: List of Interviews and Paper Questionnaires

No.	Date	Number of groups	Number of teachers	Respondents
1	2013/4/11	5	0	Teachers
2	2013/5/29	33	7	Leaders
3	2013/5/31	40	8	Leaders
4	2013/6/1	23	5	Leaders
5	2013/6/2	47	4	Leaders
6	2013/6/7	29	8	Leaders
7	2013/6/8	39	9	Leaders
Total		216	41	

¹We did not use the spare battery in the battery consumption test and the evacuation test.

Table 4.3: List of Devices and Applications

No.	Student smartphone	Battery ¹	Teacher tablet	Trajectory tracking	Direct communication
1-7	Samsung Galaxy S3	Regular + 1200 mAh spare battery	Samsung Galaxy	GPS & Wi-Fi	Voice & Mail

Table 4.4: Results of Quantitative Surveys Used to Obtain Overall Evaluations and Operability Assessments

Question	Teachers (n = 41)	Student leaders (n = 216)
Q1: Overall evaluation : Considering your experience with ETSS, how do you rate the quality of the application you used?	Ave. 3.7 / 5.0	Ave. 3.8 / 5.0
Q2: Operability : Considering your experience with ETSS, how do you rate the operation of ETSS application?	Ave. 3.4 / 5.0	Ave. 3.8 / 5.0

Overall Evaluation and Operability

The average overall evaluation rating by teachers was 3.7 out of 5. The proportion of respondents who rated ETSS as 4 or 5 out of 5 was 63.4%. The average score given by the student leaders was 3.8 out of 5. The proportion of group leaders who rated the application as 4 or 5 out of 5 (70.8%) was higher than that among the teachers.

Table 4.4 shows a summary of the results. Figure 4.9 and Figure 4.10 show the distribution of the overall evaluation scores. The average overall operability rating by teachers was 3.4 out of 5. This was relatively low, but it was possibly due to the failure of the VoIP function in experiment Nr.2. The proportion of respondents who rated ETSS as 4 or 5 out of 5 was 46.3%. The average score given by student leaders was 3.8 out of 5. The proportion of the group leaders who rated the application as 4 or 5 out of 5 (69.9%) was much higher than that among the teachers. Figure 4.10 and Figure 4.10 show the distribution of the operability scores. Based on the open-ended questions, we found that some teachers highlighted the effective sharing of student information using ETSS and the benefit of the early detection of student group problems.

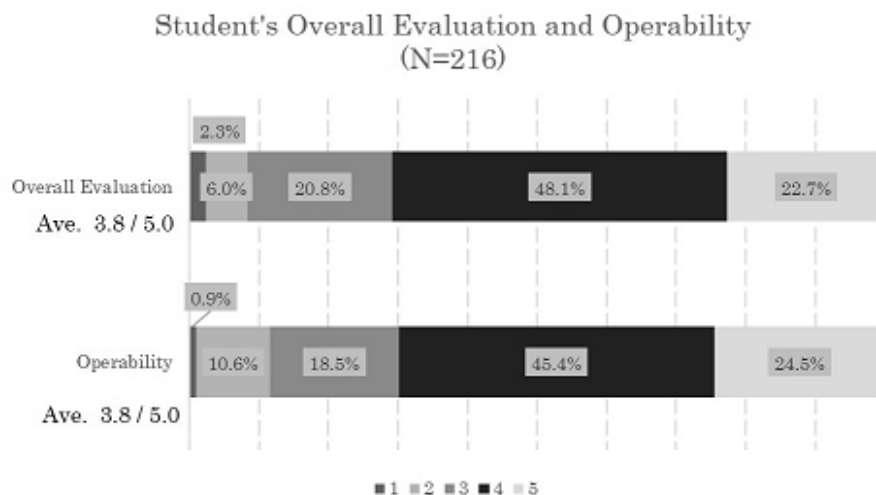


Figure 4.9: Overall Evaluations and Operability Assessments for ETSS (Students)

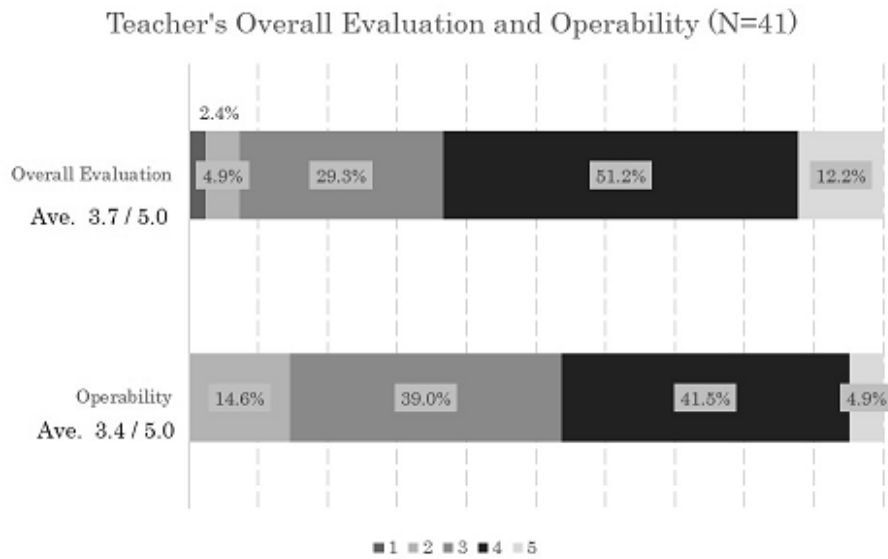


Figure 4.10: Overall Evaluations and Operability Assessments for ETSS (Teachers)

Evaluation of the positioning and communication functions

Positioning We obtained the evaluations of the positioning functions based on the following three questions: (Q3) ease of identifying the location, (Q4) accuracy of positioning, and (Q5) location tracking capacity. For the “ease of identifying the location,” the average rating by the teachers was 2.7 out of 3 and that by the leaders was 2.7. For the “accuracy of positioning,” the average rating by teachers was 2.0 out of 3 and that by the leaders was 2.1. For the “location tracking capacity,” the average rating by teachers was 2.5 out of 4 and that by the leaders was 2.8. Thus, the ratings for accuracy were not good, which may have been caused by GPS errors. Table 4.5 shows a summary of the results.

Voice and mail function The teachers’ evaluations of the VoIP function were not good. The average rating by teachers was 2.1 out of 3. The teachers treated the VoIP application as an alternative to a normal telephone service and they expected the same level of service. In addition to system failures, the main reasons for the poor ratings were as follows.

Table 4.5: Results of Quantitative Surveys of Positioning Function

Question	Teachers	Student leaders
	(n = 41)	(n = 216)
Q3: Eases of identifying the location :	Ave.	Ave.
When you looked for your location in ETSS, how did you rate the identification of your location?	2.7 / 3.0	2.7 / 3.0
Q4: Accuracy of the location :	Ave.	Ave.
When you looked for your location in ETSS, how did you rate the accuracy?	2.0 / 3.0	2.1 / 3.0
Q5: Location tracking capacity:	Ave.	Ave.
When you looked for your location in ETSS, how frequently was it displayed?	2.5 / 4.0	2.8 / 4.0

- The teachers had to use the handset via the tablet.
- The use of the VoIP application was not easy to understand.
- The teachers could not check the students' locations while making a call.

There was no major dissatisfaction with the mail system, apart from the system failures.

Experimental assessments of the evacuation guidance function

To assess the effectiveness of the evacuation map function, we conducted a field test using simulated disaster conditions. In addition, we obtained subjective user evaluations of the evacuation map function based on quantitative surveys.

Evacuation test

We assumed that the evacuation process in the disaster situation occurred as follows: (1) disaster alert, (2) confirmation of the current location, (3) confirmation of the evacuation areas, (4) selection the route to the evacuation area, and (5) movement to the evacuation area. ETSS could help students to evacuate rapidly by minimizing the time required for (2) and (3). We assessed this model based on a field test in simulated disaster conditions. We tested the model by comparing the activities of ETSS users and non-ETSS users, where the key factor was velocity.

We conducted the test with university students who were aged around 20 years. The participation of senior or junior high school students was desirable, but it was difficult for them to participate because they had no time to undergo the test during their busy school trips. During the test, each student used ETSS application, which was installed on their smartphone, as described in Table 4.3. Eight students participated in the test and we divided them into two groups. Group A used ETSS whereas group B only used a paper map. We refer to the group members as A1-A4 and B1-B4. The students started walking after being instructed to obey the messages that they would receive later. The members of group A were ordered to move to the evacuation area in 10 minutes and they were given permission to use ETSS by e-mail, whereas the members of group B received the same order but they only used a paper map.

The results of the test are shown in Table 4.6. The results showed that the average velocity of group A was higher than that of group B. The result for B1 was an outlier because he lost track of his location and could not reach any of the evacuation areas. We consider that the assumptions of the evacuation model were confirmed and that ETSS was beneficial for evacuation.

Table 4.6: Results of Evacuation Field Test

Member	(A)	(B)	(B)/(A)
	Total time (hh:mm:ss)	Distance (meters)	Velocity (meters/minute)
A1(ETSS) ²	0:05:35	518	93
A2(ETSS) ²	0:04:29	336	75
A3(ETSS) ²	0:05:25	485	90
A4(ETSS) ²	0:06:19	1,156	183
B1(Map) ³	LOST	LOST	LOST
B2(Map) ³	0:09:33	354	37
B3(Map) ³	0:12:51	817	64
B4(Map) ³	0:06:34	510	78

²Average velocity of group A members = 114 meters/minute

³Average velocity of group B members = 58 meters/minute

Evaluation of the evacuation guidance function

We evaluated the evacuation guidance function by asking the following question: (Q6) ease of identifying the evacuation areas. The average rating by teachers was 2.6 out of 3 and that by the leaders was 2.8. These ratings were very high but this is the evaluation for guidance map. The respondents did not move to the evacuation area by following the guide.

4.4.2 Evaluation of the Battery Life

ETSS application drains batteries very rapidly. In our battery consumption test, we found that it drained a regular Galaxy S3 battery in about 7 hours in the worst case, without using VoIP calls, mail, or other operations such as web browsing. The results of the test are shown in Table 4.7.

We consider that ETSS application could be used for up to 10 hours during a disaster. Thus, a spare battery or an extended-life battery is essential. Spare batteries can be connected to phones via a USB cable after the regular battery has been drained. An extended-life battery is exchanged for the regular battery. A 1200 mAh spare battery was used in experiments Nr.1-7.

Table 4.7: Results of Battery Consumption Test

(unit: hh:mm:ss)		Situation	
4	GPS	Indoor	Outdoor
	logging interval		
	every 1 sec	7:46:25	8:19:31
	every 30 sec	8:17:27	11:09:52

4.5 Conclusion

In this chapter, we proposed a tourism information system for school trips called ETSS. The objectives of ETSS system are to help students to escape rapidly to an evacuation area by providing evacuation information and to share safety confirmation information with relevant people during disasters. The evacuation guidance function is based on a hypothetical evacuation activity model. In this study, we

⁴The participants did not use mail, VoIP, or any other functions during the test.

provided an overview of ETSS and confirmed the evacuation activity model based on a field test and detailed evaluations of the performance obtained using ETSS system.

ETSS commenced semi-formal operation in December 2013 and started the formal operation in April 2014. The system will be improved during practical operation. We forecast that the total number of ETSS users during FY2014 will reach to around 15,000 users.

We have various plans for future work. We consider that the evacuees would want to plan their route to navigate their way to safety during evacuation. From the viewpoint of evacuation during a disaster, navigation should be based on the real-time status of the affected areas where the disaster occurs because the evacuees cannot move via disaster-affected routes. To acquire real-time status information, it will be necessary to combine external sensors, thus we will need to collaborate with ubiquitous sensing network researchers [58, 57]. We consider that surveillance cameras and the GPS systems installed in automobiles could be potential sensing devices. There are some examples of the use of the large-scale GPS trajectory data collected by car navigation systems for detecting the available routes in areas affected by disasters (e.g., tsunamis and heavy snow).

There is also a problem with indoor location estimation. At present, we use the Wi-Fi MAC addresses for indoor estimation, but this is not sufficient to estimate the location accurately. We consider that a more accurate indoor location estimation technique is required. We will collaborate with other researchers who have investigated location estimation with smartphones using stochastic process models [46, 60]. We also need to consider situations where Wi-Fi routers are not available. For example, the existing distribution of Wi-Fi routers is not adequate in regional cities at present. In these cases, dead reckoning-based localization techniques may be considered [61].

For information sharing, we are considering the possibility of collaboration with local governments. If the local governments can share the safety information related to students during disasters, this would dramatically improve the efficiency of rescue activities. Collaboration with the local governments will help us to utilize the outdoor sensing networks owned by governments (e.g., surveillance cameras, water gauges, and fire monitoring systems).

Chapter 5

ETSS User Expansion

5.1 Introduction

This chapter discusses the expansion of the Educational Travel Support System (ETSS) to additional users from the viewpoint of social employment such as a market strategy and business model. By expanding ETSS to other group tourist, more stakeholders of group tourists in the afflicted can share the safety information of group tourists than school trip students. Also, the number of available trajectories increases for research purposes.

Since the Great East Japan Earthquake and New Zealand Canterbury Earthquake, teachers and parents now require to ensure the security of students during school trips by using information technology. Our research team developed and commercially released ETSS for student safety in 2014. In this chapter, we show an ETSS' business model based on a combination of an application bundle model and an oligopolistic partner of distribution channel, and we verify the practical effectiveness and the validity of the ETSS business model and market strategy for the school trip market through on actual productization. We took particular note of business to business (B2B) characteristics of school trip. In addition, we discuss the applicability of ETSS to each category of MICE (Meeting, Incentive tour, Convention, Exhibition).

5.2 Mobile Safety Confirmation Service for Educational Tour

In Japan, 2.0-2.5 million senior / junior high school students go school trip annually and, this is the biggest educational tour in Japan. Also, 30 thousands senior high school students go on an overseas study program [62]. The safe control of the students during the educational tours is mainly managed by teachers and tour escorts, however, in NewZealand earthquake that many students died in 2011 and the Great East Japan Earthquake that many school trip students were suffered, the difficulties of the safety confirmation was made clear in case of such big disasters because teachers and school escorts are suffered, too. So, the school relatives and the parents expect for informatization of the safety confirmation of the students during the educational tours by using the location data.

Some educational organizations manage educational tours as a tour coordinator or a host, and these organizations have responsibility of the safety management or safety confirmation of students who take part in during educational tours. This differs to independent tours. Independent tourists are responsible for his / her safety. This fact shows that service for educational tours is a kind of B2B services but business to consumer (B2C) services. Because of communication technology and downsizing, safety confirmation services that teachers and the escort staff have been managed can be provided as mobile information services. However, contrast to the needs of teachers and parents, safety confirmation services for educational tour managers have not been provided. So, a market strategy and business model for safety confirmation services for educational tour managers are not well-known, and the research about the market strategy and business model is socially required.

Therefore, we have developed ETSS based on location data analysis for school trip that is a representative educational tour in Japan [63]. ETSS has been provided for schools since 2014. In this study, we show the business model and the market strategy of ETSS, and verify the effectiveness and adequateness based on ETSS productization case. It is difficult to verify the effectiveness and adequateness of ETSS's market strategy because the service period of ETSS service is only 1 year. Therefore, we only analyze the status of ETSS business. The technical detail of ETSS was stated in Chapter 4.

This chapter is organized as follows. In Section 5.3, we discuss the business model and the market strategy of existing tourist mobile information services. In Section 5.4, we describe the business model and the market strategy of ETSS. In

Section 5.5, we discuss effectiveness and adequateness of ETSS. In Section 5.6, we discuss applicability of ETSS to other group tours. We conclude this chapter and discuss future work in Section 5.7.

5.3 Existing Mobile Information Service for Tourist

5.3.1 Classification of Mobile Information Service

Tourist mobile information services, including services for educational tours, are categorized to (1) safety confirmation and ensuring, (2) travel guide and booking, (3) other specialized services such as educational supports for educational tour, event information for event tour. In this section, we discuss the safety confirmation and ensuring services for tour managers stated in (1). As for services stated in (2) and (3), we discuss necessity of implementing in ETSS.

Independent tourists, educational tour participants and managers of educational tours have different needs for the safety confirmation services stated in (1). The participants require functions to inform tour managers of their safety and to inform them where to evacuate. The tour managers require functions to know all participants' safety, to view all safety information at ease, to share the safety information among all managers, to help the evacuation activity and the rescue activity by two-way communication with participants. Whereabouts confirmation using an e-mail, a telephone and a location data has been used for the safety confirmation. The combination use of multiple methods is preferable from a viewpoint of availability in disaster situations. As services for business use, some integrated services provide both of broadcast mail distribution and electric bulletin board functions for safety confirmation and status viewing [64]. Area mail [54] and some other services provide locations of evacuation shelters and disaster alert for customers but they lack management functions.

Travel planning support, booking, travel guide and destination/spot recommendation stated in (2) should not be newly developed because they are generic services and many third party products are there. Conference assistance functions in academic communities [65], and augmented reality functions for education [66, 67] are proposed for wide array of travel applications as specialized services stated in (3). However, these services lack versatility because they are specialized for applications. Though these educational supports is expected to equipped in ETSS in future, we decided not to equip educational functions when ETSS was launched.

5.3.2 Business Model and Market Strategy of Existing Services

Here is the business model that is generally adopted for mobile information business. Most of mobile information business adopt combination with revenue from mobile ads, revenue from sales of goods, revenue from subscription fee. According to Gartner [68], free applications would account for 89 percent of total downloads. In terms of the applications that consumers are buying, 90 percent of the paid-for downloads cost less than 3 US dollar each. In Japan, most of the paid-for applications cost less than several hundreds yen. More applications use in-app accounting, but the trend is limited to game application. Distribution channel for consumers is limited to two digital distribution platform like AppStore and GooglePlay, and service providers can not differentiate by distribution.

It is difficult to adopt generic business model to ETSS for educational tour. Mobile ads on educational applications for students are questioned, and teachers are split on whether mobile ads can be displayed or not, and it is left open. According to our listening survey, among junior high school teachers in compulsory education period, negative opinions were relatively strong. Outside revenue from mobile ads, sales of goods should be corporation with other companies, and bargaining cost among them is high. High subscription fee covers all cost associated with, but customers who are used to free applications may avoid downloading. Therefore, business model depending on subscription fee should provide some service elements for convincing customers to accept the subscription fee.

Generic mobile information business generally adopt market strategy to boost market share in the early stage of product life cycle by improving the awareness. This is because why distribution channels are limited and subscription fee is mostly free. Most of tourist mobile information business follow the strategy. However, it is not impossible that the business uses another distribution channel.

5.4 Business Model and Market Strategy for ETSS

As stated in chapter 5.3, there are different needs for safety confirmation function for managers in educational tour than individual tourists. Also, depending on characteristics of the educational tour, mobile ads model is not appropriate to be applied. Based on the analysis of existing services, we discuss the business model for ETSS. Comparison with the existing model is described on Figure 5.1. Upper left shows the business model for the existing individual tour information mobile service, and upper left shows the business model for ETSS.

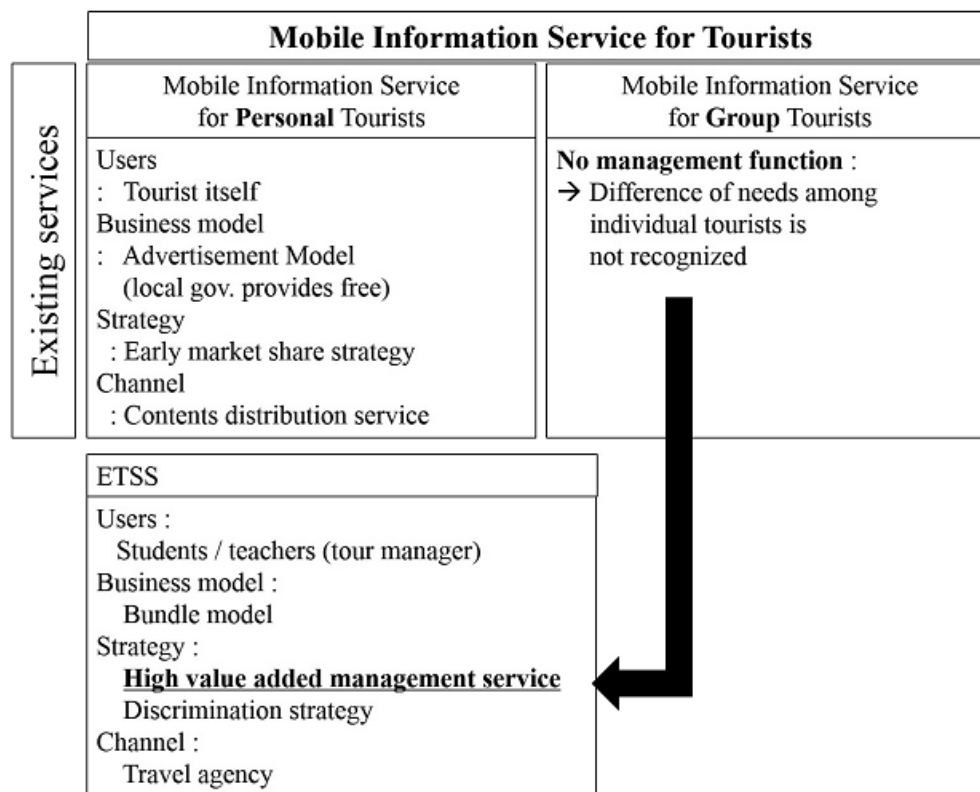


Figure 5.1: Comparison with Existing Travel Information Services and ETSS

ETSS provides safety confirmation for managers, and its users are students as participants and teachers as managers. For managers, ETSS provides (1)confirming safety of participants, (2)viewing safety, (3)sharing safety information among managers, (4)two-way communication among managers and participants. For participants, ETSS provides (1)reporting safety to managers, (2)helping participants evacuation. considering system load in case of disaster, ETSS is not equipped the direct communication function with parents.

ETSS business model is a bundle model that lends ETSS installed smartphone. Because bundle model includes a rental fee of smartphone in the subscription fee, ETSS service provider can increase average sales per user. The more monthly number of usage, the more ETSS profitability because communication fee sets monthly fixed.

Also, in case of bundle model that uses only one type smartphone, we can

develop application without a need for a consideration of hardware compatibility. ETSS business collaborates with private company that has prominent distribution channel to educational organizations that are users of ETSS instead of digital distribution platform.

Market strategy of ETSS business is differentiation strategy. ETSS business introduces high-value-added services in educational market, and builds the brand image by early market penetration. The educational travel market is business to business (B2B) niche market, and ETSS has few competitive products in this market. High-value-added safety confirmation service for managers and strong channel control brought by collaboration with a company that oligopolizes the distribution channel to educational organizations are differentiators for ETSS.

The aim of ETSS market strategy is seeking the first-mover profit by early entry to low competitive market, the strategy can be regarded as one of blue ocean strategy. In the blue ocean strategy, "red oceans" represent known competitive market space, and in contrast, "blue oceans" represent unknown market space, and untainted by competitions. The blue ocean strategy argued that companies can succeed not by battling competitors, but rather by creating "blue oceans" of uncontested market space [69]. In our case, individual tourists information application market can be considered as "red ocean" because many guide applications are competing.

5.5 Analysis of ETSS Case

In this section, we verify effectiveness and adequateness of ETSS' business model that is developed for educational tour market through actual business case. Effectiveness means the degree how much the business model contributes enhancing the competitiveness of ETSS, and adequateness means how much the business model conform to the market.

5.5.1 Background Information of School Trip

History of School Trip

School trip is an educational tour which requires overnight lodging in remote location. Normally all year classes of a junior / senior school take part in. School trip is a traditional school event whose origin reaches back into the 19th century, Meiji period.

School trip is prescribed in Government curriculum guidelines as travel/ group lodging event, and it is institutionalized in Japanese secondary education. Prefectural Board of Education Practice Standards formulates practice standard that stipulate detailed destination, period and cost. In western Europe cultural environment like Australia, there is an educational tour called "School Excursion" [70] and some travel agency specialized in the tour. However, in my investigation, no country institutionalize the school trip more than Japan, and has formulaic practice standard.

Informatization of School Trip

School trip is not so informatized. One of the factors that keep informatization of school trip from progressing are its long tradition and detailed practice standard. For training of independence that is expected to learn for students during the school trip, group activity including planning is effective. However, difficulty of monitoring the behavior during the group activity is burden to teachers, and the advance planning and telephone call can not resolve concern of teachers. Amano et al. cited these issues in [39] 40 years ago. Information technology using location data is useful for understanding the student behavior. However, no significant information technology has not been introduced other than a mobile phone or a personal handy-phone system (PHS) or a voice mail system that are used for emergency call. Safety confirmation during the group activity has been kept unresolved.

A lack of progress in school trip informatization is due to the detailed practice standard that discourages against introducing new trial, concern about using location data of students, and teachers' hesitation of using information technology something like technophobia [63]. Also, travel agency who purchase travel service as an agent of teachers are unfamiliar with information services.

5.5.2 Overview of ETSS

The main aims of ETSS are to help the students to escape rapidly to an evacuation area, to confirm the safety of students, and to share the safety information with relevant people. A diagram of ETSS system is shown in Figure 5.2.

ETSS application collects real-time location data by GPS and Wi-Fi. Using these location data, teachers can confirm locations of all student groups at all times, and students can confirm current locations of their own group. ETSS application is installed in smart tablets for teachers and smartphones for students.

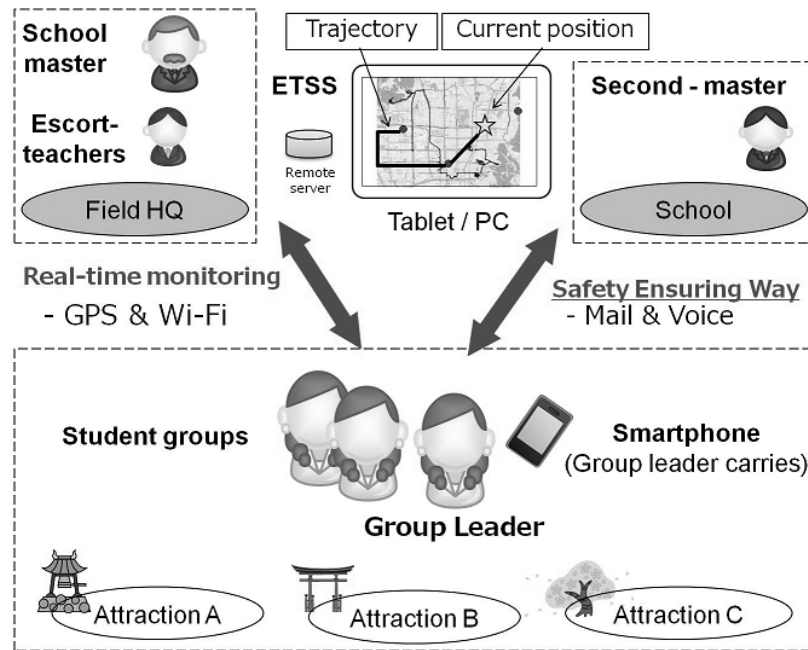


Figure 5.2: ETSS Service Overview [Reprint]

Teachers and students can use broadcast mails and VoIP as direct communication methods among them. In situations where wireless lines of communication are disconnected around the affected areas due to a disaster, the location data are transmitted every 30 seconds and are stored on a server. Using these data, teachers can obtain students' location data immediately before disasters occur. The broadcast mail and VoIP are subsidiaries of safety confirmation using location data. Teachers can rapidly respond to students' troubles like losing ways in non-disaster situation because all teachers share the status of students among all teachers.

5.5.3 School Trip Market

In Japan, approximately 2 to 2.5 million students per year participate in school trips. Though the market size is relatively small, in comparison with mobile phone market that has over 100 million subscribers, this is one of blue ocean market with few competitors. In this section, we analyze the school trip market from the viewpoints of 1) service suppliers, 2) customers, 3) local governments.

Here's description about 1) suppliers. Accommodation transportation fees are

account for a large share of all expenses of school trip. The limited accommodations have capacity to stay hundreds of students, and these large accommodations historically keep strong relationships between large travel agencies that can send customers. Because of these background, the travel agencies offer centralized purchase of the school trip as a proxy of school. This structure is illustrated in Figure 5.3 The travel agencies involve overall travel management of school trip including assisting the group activity planning, tour conductors dispatch other than procurement. Only a few travel agencies can deal with the overall travel management of school trip. JTB (Japan Travel Bureau) and KNT (Kinki Nippon Tourist) have very high shares in nationwide school trip market, and almost no player enter the market because of market shrink caused by decrease in the number of children. The market can be called as a typical oligopoly market. The sales channel to schools is very limited because of Oligopoly. Therefore, collaboration with one of oligopoly players are essential for promoting ETSS.

Here's description about 2) customers. Though the end user of ETSS is students, teachers who manage the school trip select the services. In some school, students' will is reflected to selection of school trip destination, and the number of the school is getting increase. However, students do not involve the purchase process in any school. The fact shows that school trip services have an aspect of B2B services. The teachers are cautious about using mobile information services because most of teachers are less familiar with information technology and concerned with handling the personal information.

Here's description about 3) local governments. Economic impact of school trips is large to local economies of school trip destinations. Safety is one of the important brand factors that affect attracting tourists as it is clear that the number of school trip students who visited to the Western Japan and Nagano prefecture increased. Some local governments provide mobile application for providing disaster alert and sightseeing guide to tourists cite. However, most of local governments fail to penetrating their applications to market, and the applications are not tend to use without the collaboration with travel agencies and media. Therefore, we did not collaborate with local governments as ETSS distributors.

5.5.4 Business Model

Bundle Model

The ETSS business model is the bundle model that lends ETSS installed smart-phones, and the distribution model is the alliance model that collaborates with an

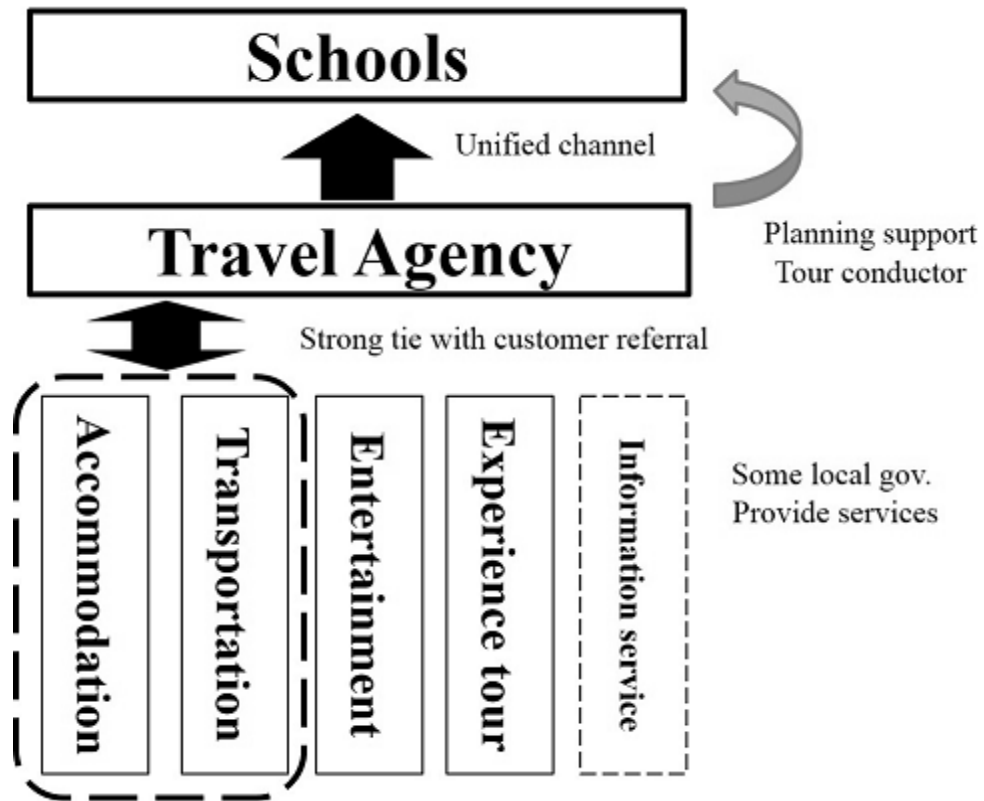


Figure 5.3: Distribution Construction of School Trip Market

oligopoly company. This section describes the profitability and the distribution channel of ETSS.

Yieldability The subscription fee of ETSS is around 8,000 - 10,000 JPY including a rental fee of smartphone. The cost consists of mobile communication expense, system management expense, labor cost, selling and other overhead. The cost details and the number of user schools are prohibited to exposure because of corporate confidential. Monthly profit is calculated as follows;

Monthly profit = Revenue - system management expense * number of system usage - monthly communication expense * number of subscription - (labor cost + overhead)

Monthly communication expense includes the data communication fee and

the amortization payment of smartphone purchase that is prorated to the usage period, and the expense is paid to mobile carrier based on the number of subscription. System is managed by Application Service Provider (APS), and the system management fee is paid per use. Labor cost and overhead are fixed fees. Though ETSS business is profitable as alliance total, there are some issues of profit distribution among alliance members that is caused by power relative.

ETSS is commercially launched with 150 phones from Spring season in 2014 after test running over 200 groups of 12 school trips. The number of smartphones increase to 300 by Summer season in 2014. In future, the number of smartphone is getting increase to 1,000. Service area of ETSS is Kyoto, Tokyo, Okinawa, Yokohama and Osaka. A disadvantage of the bundle model is the ownership cost of smartphone. The ownership cost raises up the break-point because the cost is fixed cost. In addition, as illustrated in Figure 5.4, the number of school trips increases in Spring and Fall. Though the number of monthly usage of smartphone in busy periods are 4 - 5, almost of all smartphones are not used in off-season. The seasonal affection could be avoided if smartphone we need for operation can be rent. However, ETSS provider should own smartphones for its operation in busy period because no rental service have enough number of smartphone. ETSS provider is trying to cultivate other customers who use ETSS for study tour or out-of-school learning to solve the off-season issues, and improve the annual usage of smartphone.

Distribution Channel As a distribution channel of ETSS, ETSS provider collaborates with one of oligopoly travel agencies in school trip market. In this alliance, ETSS provider, a relatively small venture, provides ETSS service and manages the system, and the travel agency provides the sales channel to schools, and a research organization plans the basic design and makes technical advice. The structure of the alliance is illustrated in Figure 5.5. The travel agency makes a exclusive sale agency contract because it recognizes ETSS as a tool for acquiring comparative advantage to a rival company by differentiating. Especially in Tohoku and North Kanto areas where were affected by the Great East Japan Earthquake, ETSS features as a strong competitive factor. Most of schools that used ETSS in the first year are located in these areas.

Market Strategy

Market strategy of ETSS business is differentiation strategy that introduces high-value-added management services for teachers in a blue ocean educational tour

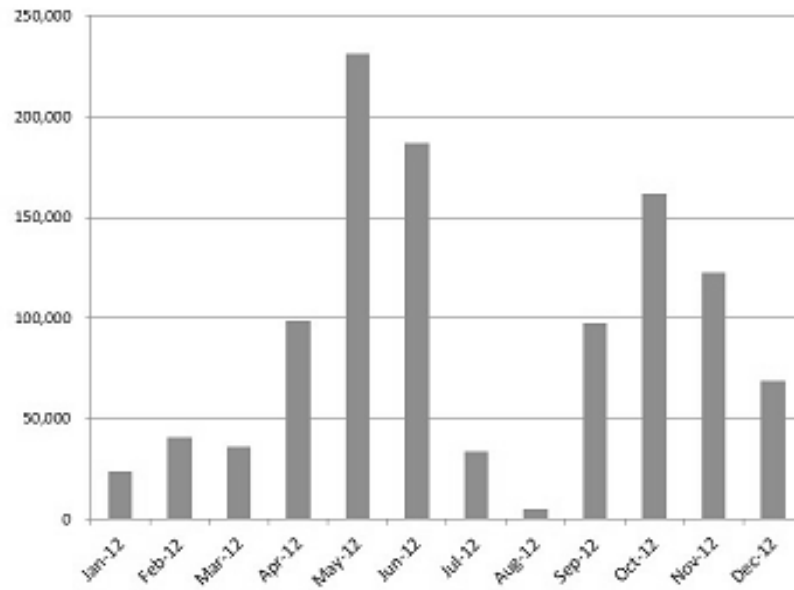


Figure 5.4: Number of School Trip Students in 2012

market as B2B niche market. ETSS is the first disaster management service for teachers in the school trip market, and the partner travel agency confirms that competitors started developing the similar products after publishing ETSS. However, in this stage, we can not confirm that ETSS can succeed in establishing the brand image of disaster management service.

5.5.5 User Acceptance

This section describes results of user surveys that was conducted for confirming the effectiveness of the business model and improving the system. In the user survey, a quantitative survey with a questionnaire and a qualitative research on school teachers, students and agency staff were conducted.

In the quantitative survey, respondents were asked to evaluate ETSS system. The number of respondent students is 216, and respondent teachers is 41. Average score of total ETSS system was 3.7 in 5 scores, and top 2 box was 63.4%. Top 2 box means sum of the proportion of the highest and the second highest evaluations.

In the qualitative research, respondents were asked the acceptance of bundle

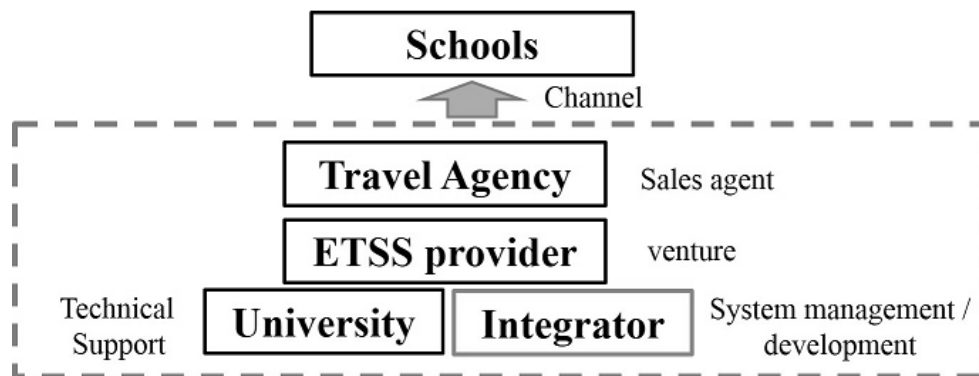


Figure 5.5: Industrial Academic Alliance

model, usability and opinions for improvement by face to face interview. The number of respondents was 24 including students, teachers and agency staff. The agency staff was added to the respondents because they sometimes act the role as tour manager in trips of high school.

Here's the acceptance of bundle model by managers. For teachers and agency staff who are in charge of school trip management, ETSS that are installed in smartphone looks similar to PHS that has been used for emergency call in school trip for long time. PHS are highly recognized by teachers, and because of similarity ETSS is accepted by teachers without a feeling of strangeness. Also, teachers who belongs to schools that prohibit using mobile phones welcome bundle model services. Though a few wants to install ETSS to student's smartphone for price down, we guess that bundle model is accepted by most of teachers and students.

Here's usability and opinions for improvement. Most of teachers answered that ETSS meets functional needs. In fact, ETSS was used for finding and helping lost students during experiments. Heads of year and class teachers who have responsibility of field management highly evaluated ETSS. Students did not feel comfort and discomfort, and they had a sense of security from monitoring. Complaints were frequently heard that the size of tablet or smartphone and battery lifetime. These issues can be improved by using other types. So, it is considered that ETSS mostly meets the needs.

Personal Information

In face-to-face interview, many teachers concerned with handling of personal information. Though this is not a complaint for ETSS, the location data that ETSS application collects is one of personal information and needs careful treatment. For wiping out teacher's anxiety about personal data handling, a research organization who are a member of alliance supervises the personal data handling guideline. Concretely speaking, the guideline regulates that ETSS provider should opt in the purpose of usage to school when location data is used for service and academic research. The usage rate of SNS like LINE among the age group that the students belong to is higher than other age groups. Therefore, the possibility of identifying of students or school by cross matching location data and SNS log is high. We should take these things into consideration when we use location data.

In this section, we analyzed effectiveness and adequateness of ETSS business model in the school trip market through actual business case. ETSS business is profitable, and users accept bundle model. From the viewpoint of competitiveness, ETSS effectively works as a differentiating factor for travel agency, the distribution channel. From these facts, the proposed ETSS business model has a certain amount of adequateness and effectiveness in school trip market.

5.6 Other Trip Market Applicable for ETSS

In section 5.5, we described that the proposed ETSS business model has a certain amount of adequateness and effectiveness in school trip market. In this section, we discuss the areas where ETSS has a competitive edge other than an educational tour market along three factors like service, bundle model and alliance with oligopoly company. We use MICE category that has been attracting attention in recent years as group tour category. MICE is a generic term of Meeting, Incentive tour, Convention, Exhibition.

Here's discussion about the area where safety confirmation service for management has a competitive edge. We illustrate the necessity of the safety confirmation service for management in Figure 5.6. The vertical axes indicates the degree of freedom to take part in the tour, and the horizontal axes indicates the degree of necessity for tourist protection. The degree of freedom to take part in the tour means the extent of the obligation of taking part in the tour. For instance, the degree of freedom is low in case of school trip or training tour, and high in case of academic society. We guess that the safety confirmation service for manage-

ment is competitive in the areas where managers have a responsibility of tourist protection and the degree of freedom is low, for example, training tour or seminar tour. In fact, the travel agency required to use ETSS for the short term linguistic training in oversea, and we examined an operation test in Australia. The degree of necessity for tourist protection is getting low when the participants are adult. On the other hand, we guess that the safety confirmation service for management is not so required in the areas where international convention or exhibition because the degree of necessity for tourist protection is relatively low and the degree of participation freedom is high.

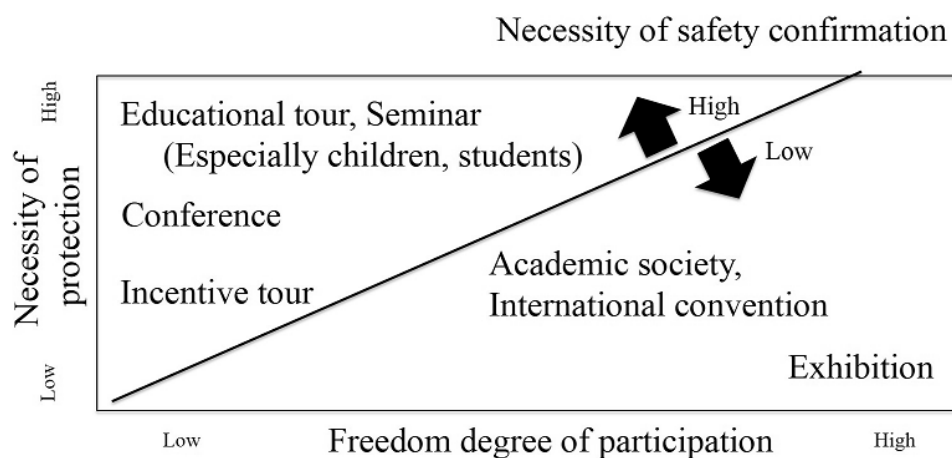


Figure 5.6: Necessity of Safety Confirmation Service

Here's discussion about the bundle model. Foreign tourists have a motivation for rental smartphone because they can not use their own smartphone, and the bundle model can be effective for foreign tourists. However, domestic tourists have no motivation for using bundle model service, and they do not like carrying two phones during their trip. Therefore, install model service is effective for domestic tourists, and ETSS business should increase the unit price by providing high value-added service for them. As the high value-added service, the society assistance service that was developed by Sumi et al. [65] will be a good reference.

Here's discussion about the distribution model that is collaborated with an oligopoly company. Major traditional travel agencies is raising the awareness to MICE because online travel agencies steal the market share in a independent tour market in recent year. For instance, some major travel agencies is entering to the

conference management service market like academic society, and some agencies establish specialized department. Though it is not so monopolized in the conference management market now, because conference management requires technical know-how, the market may be monopolized in future by major agency or specialty agency. Though there is an option to collaborate with these agencies, as it became obvious in ETSS, the profit distribution issue among partners will be occurred when the differences of channel control power or company size among partners are big.

With these discussions, as the MICE areas where ETSS model has a competitive edge, the same education tour areas where outbounds to foreign countries from Japan or inbounds to Japan are positive. Partners may be major or specialty travel agency. In addition, without bundle model, usage of safety confirmation service by domestic tourists will be getting increase. However, in this case, we should redesign the revenue model.

5.7 Conclusion

For expanding ETSS users, we discussed the applicability of ETSS to each category of MICE (Meeting, Incentive tour, Convention, Exhibition). From the discussion, we reach a conclusion that ETSS has a strong possibility of success in the short term linguistic training in overseas. This is because that the safety confirmation service that is provided by ETSS for tour managers is competitive in the areas where managers have a responsibility of tourist protection and the degree of freedom is low. ETSS has a competitive edge for the education tours or seminar tours where participants outbound to foreign countries from Japan or inbound to Japan.

We observed that many teachers kept monitoring students via ETSS to detect abnormal behaviors of students even in non-disaster situations. Student monitoring is burdens to teachers, and it will ease the burdens to detect the abnormal behaviors automatically. The abnormal behavior detection function strengthens the competitive edge of ETSS in school trip market, and helps to increase ETSS users. Technically, it is difficult to detect abnormal behaviors of students from location data. Therefore, new detection methods that use other activity data and location data are necessary.

Chapter 6

Conclusion and Future Work

6.1 Conclusion

In this thesis, we discussed the analysis of the location data obtained from human movement accumulated in an urban area considering with the environmental factor, and the activity support based on the analysis results of the location data. We categorized location data into two types, consecutive trajectories and the fragmented trajectories, and we proposed analysis methods, environmental factor models, and human activity support methods corresponding to each location data. We grasped human movement in an urban area from the view of effective allocation of the social resources, and we designed activity support methods for improving social resource allocation by shrinking the information asymmetry both in disaster and non-disaster situations. Considering all components from location data sensing to application development for end users, we proposed a technical and social architecture combining the trajectory analysis method considering environmental factors, and the activity support method based on the analysis results. The architecture was described in chapter 1, and was illustrated in figure 1.2.

In this thesis, as the location data analysis using the consecutive trajectories, we discussed transportation mode inference from a consecutive trajectories using environmental constraints. Semantic description of transportation mode for consecutive trajectories is necessary for understanding tourists' activity. Based on the understanding of transportation mode of tourists, we can support following human activities, and improve social resource allocation. The evacuation support based on the understanding of the transportation mode realizes efficient social resource allocation in case of disaster situation. In case of non-disaster situations, the route

recommendation considering the tourists' transportation usage helps to alleviate concentration of tourists in certain spots. Also, traffic statistics is calculated for making tourism policy by local governments. The method can correctly infer transportation mode in case buses or trains temporally decrease velocity near stations or bus stops by applying different inference standards to different geospatial regions with environmental constraints. Contrast to the proposed method, existing inference methods infer transportation modes by machine learning methods using features of velocity. However, because trains and buses temporally stop at stations and bus stops, we can not infer transportation mode in case of such low velocity by using velocity features. On the other hand, transportation mode could be correctly inferred by using the location data of stations and bus stops as environmental constraints. We showed accuracy of the transportation mode inference acquired by applying the proposed method is improved than that by applying existing methods. As the results of experiments, a 91.6% recall was acquired by applying the proposed method to the consecutive trajectory of the school trip students. We described the proposed inference method in chapter 2.

In this thesis, we proposed a tourist transition model combining an environmental factor model and a human factor model using fragmented trajectories. The environmental factor affects tourists' determination of spot transitions, and the human factor is based on tourists' taste for tourism spots. Existing tourist transition models include factors such as tourists' taste for spots, tour purposes, visited spots just before, and use the same factor for all spot transition. On the other hand, the proposed tourist transition model integrates all factors that affect the spot transitions like seasonality, time, weather and the visited spots, and most influential environmental factors are separately combined for each spot transition. In addition, we implemented a mobile application that recommends preferable travel route to tourists based on the proposed tourist transition model, and we confirms validity of the mobile application. Route recommendation helps to alleviate concentration of tourists as told before. We described the tourist transition model and the mobile application in chapter 3.

In this thesis, we proposed a tourist activity support service for the school trip students both in case of the non-disaster and disaster situations, called ETSS. The Great East Japan earthquake in 2011 clarified communication issues during school trips in case of disaster, and stake holders of school trips required an safety confirmation for school trip students. ETSS was designed for shrinking the information asymmetry among victims of disaster and their families by sharing the safety information among stake holders. We proposed a tourist evacuation support and safety confirmation method by recording tourists' location data in a remote server.

Stakeholders can share the recorded location data of tourists in case of mobile network fault, and tourists can evacuate by viewing an offline map near current locations. The proposed evacuation method was implemented to a mobile application for school trip students. As the result of the effectiveness assessment based on a field test in disaster-simulated situation, it was confirmed that the mobile application can assist evacuation activity. We described the mobile application called ETSS described in chapter 4. In addition, we discussed the user expansion of ETSS. An ETSS user is currently limited to school trip students; therefore, the number of available trajectories is not large. Thus, we discussed user expansion of ETSS from the viewpoint of social employment, such as a market strategy and business model in chapter 5.

6.2 Future work

For improving social resource allocation in a region, following two issues should be solved for human activity support in future. The first issue is applying results of the proposed transportation mode inference method to tourist activity support like the evacuation support and the spot recommendation. In case of applying the transportation mode inference for the tourist activity support, transportation mode should be inferred online. As an approach for achieving enough accuracy of online transportation mode inference for practical usage, the transportation mode of tourists is inferred by considering with other tourists' trajectories. The second issue is using results of image analysis of surveillance camera movies to tourist activity support. The future work is illustrated in figure 6.1.

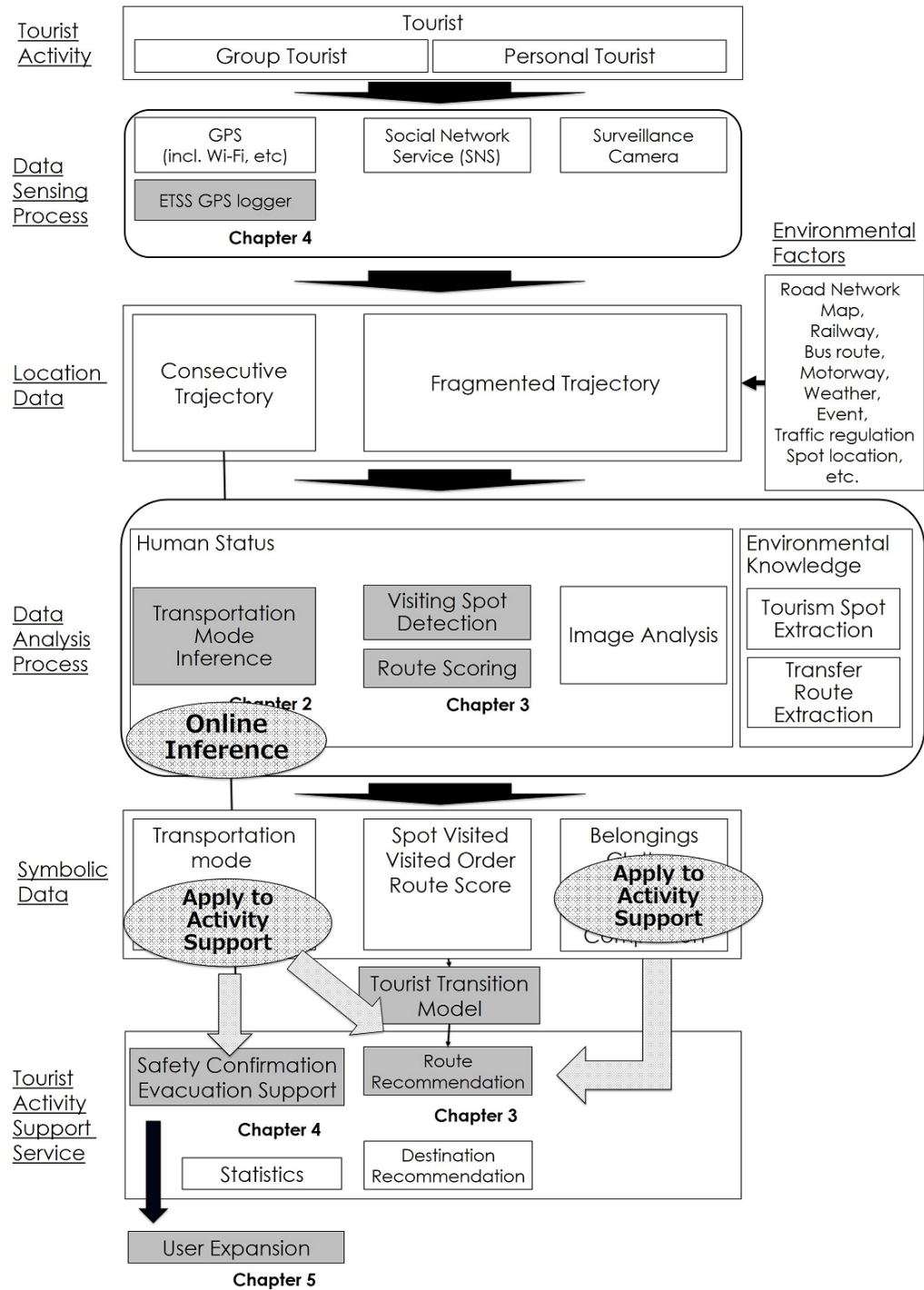


Figure 6.1: Contribution and Future Work

Acknowledgments

The ETSS research described in in chapter 5 was supported by JSPS KAKENHI Grant Number 24650055. The ETSS development was supported by Kinki Nippon Tourist and the Career Education Coordinator Network Association in coordination with the schools that discussed the service improvements. I would like to express my thanks to the following six schools that took part in our field experiments during their memorable school trips to Kyoto: Okatsu Junior High School, Osu Junior High School, Chiba Senior High School, Sendai West Senior High School, Naka 1st Junior High School, and Konan Junior High School.

Bibliography

- [1] Arrow, K. J.: Uncertainty and the welfare economics of medical care, *The American economic review*, pp. 941–973 (1963).
- [2] Akerlof, G. A.: The market for” lemons”: Quality uncertainty and the market mechanism, *The quarterly journal of economics*, pp. 488–500 (1970).
- [3] Stiglitz, J. and Greenwald, B.: *Towards a new paradigm in monetary economics*, Cambridge University Press (2003).
- [4] Spence, M.: Job market signaling, *The quarterly journal of Economics*, pp. 355–374 (1973).
- [5] Bolbol, A., Cheng, T., Tsapakis, I. and Haworth, J.: Inferring hybrid transportation modes from sparse GPS data using a moving window SVM classification, *Computers, Environment and Urban Systems*, Vol. 36, No. 6, pp. 526–537 (2012).
- [6] Stenneth, L., Wolfson, O., Yu, P. S. and Xu, B.: Transportation mode detection using mobile phones and GIS information, *Proceedings of the 19th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems*, ACM, pp. 54–63 (2011).
- [7] Zheng, V. W., Zheng, Y., Xie, X. and Yang, Q.: Collaborative location and activity recommendations with GPS history data, *Proceedings of the 19th international conference on World Wide Web*, pp. 1029–1038 (2010).
- [8] Liao, L., Fox, D. and Kautz, H.: Extracting places and activities from gps traces using hierarchical conditional random fields, *The International Journal of Robotics Research*, Vol. 26, No. 1, pp. 119–134 (2007).

- [9] Zheng, Y., Chen, Y., Li, Q., Xie, X. and Ma, W.-Y.: Understanding transportation modes based on GPS data for web applications, *ACM Transactions on the Web (TWEB)*, Vol. 4, No. 1, p. 1 (2010).
- [10] Giannotti, F., Nanni, M., Pinelli, F. and Pedreschi, D.: Trajectory Pattern Mining, *Proceedings of the 13th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, KDD 2007, New York, NY, USA, ACM, pp. 330–339 (2007).
- [11] Ashbrook, D. and Starner, T.: Using GPS to learn significant locations and predict movement across multiple users, *Personal and Ubiquitous Computing*, Vol. 7, No. 5, pp. 275–286 (2003).
- [12] Zheng, Y.-T., Li, Y., Zha, Z.-J. and Chua, T.-S.: Mining Travel Patterns from GPS-Tagged Photos, *Proceedings of the 17th international conference on Advances in multimedia modeling*, Vol. 1, pp. 262–272 (2011).
- [13] Kurashima, T., Iwata, T., Irie, G. and Fujimura, K.: Travel route recommendation using geotagged photos, *Knowledge and information systems*, Vol. 37, No. 1, pp. 37–60 (2013).
- [14] Canneyt, S. V., Schockaert, S., Laere, O. V. and Dhoedt, B.: Time-dependent recommendation of tourist attractions using Flickr, *23rd Benelux Conference on Artificial Intelligence (BNAIC)*, pp. 255–262 (2011).
- [15] Yan, Z., Chakraborty, D., Parent, C., Spaccapietra, S. and Aberer, K.: Semantic trajectories: Mobility data computation and annotation, *ACM Transactions on Intelligent Systems and Technology (TIST)*, Vol. 4, No. 3, p. 49 (2013).
- [16] Yamasaki, T., Gallagher, A. and Chen, T.: Geotag-based travel route recommendation featuring seasonal and temporal popularity, *Information, Communications and Signal Processing (ICICS) 2013 9th International Conference on*, IEEE, pp. 1–4 (2013).
- [17] Okuyama, K. and Yanai, K.: A travel planning system based on travel trajectories extracted from a large number of geotagged photos on the Web, *The Era of Interactive Media*, Springer, pp. 657–670 (2013).

- [18] Arase, Y., Xie, X., Hara, T. and Nishio, S.: Mining people's trips from large scale geo-tagged photos, *Proceedings of the international conference on Multimedia*, ACM, pp. 133–142 (2010).
- [19] Lu, X., Wang, C., Yang, J.-M., Pang, Y. and Zhang, L.: Photo2trip: generating travel routes from geo-tagged photos for trip planning, *Proceedings of the international conference on Multimedia*, ACM, pp. 143–152 (2010).
- [20] Hemminki, S., Nurmi, P. and Tarkoma, S.: Accelerometer-based transportation mode detection on smartphones, *Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems*, ACM, p. 13 (2013).
- [21] AOKI, M., SEKO, S., NISHINO, M., YAMADA, T., MUTO, S. and ABE, M.: An estimating method for activity modes using location data, *IPSJ SIG Notes*, Vol. 67, pp. 7–12 (2008).
- [22] Ohashi, H., Akiyama, T., Yamamoto, M. and Sato, A.: Modality classification method based on the model of vibration generation while vehicles are running, *Proceedings of the Sixth ACM SIGSPATIAL International Workshop on Computational Transportation Science*, ACM, p. 37 (2013).
- [23] Nagao, M., Kawamura, H., Yamamoto, M. and Ohuchi, A.: Analysis of circular tour activity based on GPS Log, *Information and Communication Technologies in Tourism 2006*, pp. 87–98 (2006).
- [24] Durbin, J. and Koopman, S. J.: *Time series analysis by state space methods*, No. 38, Oxford University Press (2012).
- [25] Tokunari, N., Minoru, S., Satoshi, I. and Naoki, O.: Smoothing GPS Data Using Extended Kalman Filter, *The Japan Society Applied Electromagnetics and Mechanics*, Vol. 19, No. 3, pp. 591–598 (2011).
- [26] Kasahara, H., Kurumatani, K., Mori, M., Mukunoki, M. and Minoh, M.: Evacuation support and safety confirmation sharing in disaster situations for school trips by mobile information system, *Information Technology & Tourism*, Vol. 14, No. 3, pp. 197–217 (2014).
- [27] Jannach, D., Zanker, M., Felfernig, A. and Friedrich, G.: *Recommender systems: an introduction*, Cambridge University Press (2010).

- [28] Maruyama, A., Shibata, N., Murata, Y., Yasumoto, K. and Ito, M.: A personal tourism navigation system to support traveling multiple destinations with time restrictions, *Advanced Information Networking and Applications, 2004. AINA 2004. 18th International Conference on*, Vol. 2, IEEE, pp. 18–21 (2004).
- [29] Vansteenwegen, P., Souffriau, W., Berghe, G. V. and Oudheusden, D. V.: The city trip planner: an expert system for tourists, *Expert Systems with Applications*, Vol. 38, No. 6, pp. 6540–6546 (2011).
- [30] Kurata, Y. and Hara, T.: CT-Planner4: toward a more user-friendly interactive day-tour planner, *Information and Communication Technologies in Tourism 2014*, Springer, pp. 73–86 (2013).
- [31] Crandall, D. J., Backstrom, L., Huttenlocher, D. and Kleinberg, J.: Mapping the world’s photos, *Proceedings of the 18th international conference on World wide web*, ACM, pp. 761–770 (2009).
- [32] Chen, S. F. and Goodman, J.: An empirical study of smoothing techniques for language modeling, *Proceedings of the 34th annual meeting on Association for Computational Linguistics*, Association for Computational Linguistics, pp. 310–318 (1996).
- [33] Navarro, G.: A guided tour to approximate string matching, *ACM computing surveys (CSUR)*, Vol. 33, No. 1, pp. 31–88 (2001).
- [34] Ricci, F.: Travel recommender systems, *IEEE Intelligent Systems*, Vol. 17, No. 6, pp. 55–57 (2002).
- [35] Zheng, V. W., Zheng, Y., Xie, X. and Yang, Q.: Collaborative location and activity recommendations with gps history data, *Proceedings of the 19th international conference on World wide web*, ACM, pp. 1029–1038 (2010).
- [36] Baus, J., Krüger, A. and Wahlster, W.: A resource-adaptive mobile navigation system, *Proceedings of the 7th international conference on Intelligent user interfaces*, ACM, pp. 15–22 (2002).
- [37] Shiraishi, T., Shibata, M. N. N., Nagata, M., Shibata, N., Murata, Y., Yasumoto, K. and Ito, M.: A personal navigation system with a schedule planning facility based on multi-objective criteria, *Proc. of 2nd Int’l. Conf. on mobile computing and ubiquitous networking*, Citeseer (2005).

- [38] Mizoguchi, T.: Japanese cities' approaches for acquiring MICEs, *NRI Public Management Review*, Vol. 110, pp. 8–13 (2012).
- [39] Amano, K., Kato, G., Kitada, A., Takahashi, K. and Harada, H.: Manifold problems on the study tour in a high school (studies on extracurricular activities)(general researches), *Bulletin of Nagoya University School of Education Affiliated Upper and Lower Secondary School*, Vol. 19, pp. 16–21 (1974).
- [40] : Overseas School Excursion Manual, Japan Tourism Agency (2009). Japanese Ministry of Land, Infrastructure, Transport and Tourism.
- [41] Gómez, O. A.: Lessons from international students ' reaction to the 2011 Great East Japan Earthquake: the case of the School of Engineering at Tohoku University, *International Journal of Disaster Risk Science*, Vol. 4, No. 3, pp. 137–149 (2013).
- [42] Silventoinen, M., Rantalainen, T. et al.: Mobile station emergency locating in GSM, *Personal Wireless Communications, 1996., IEEE International Conference on*, IEEE, pp. 232–238 (1996).
- [43] Iwagami, R.: Positioning of students during school trip, *Electronics*, Vol. 43, No. 11, pp. 12–13 (1998).
- [44] Whipple, J., Arensman, W. and Boler, M. S.: A public safety application of GPS-enabled smartphones and the android operating system, *Systems, Man and Cybernetics, 2009. SMC 2009. IEEE International Conference on*, IEEE, pp. 2059–2061 (2009).
- [45] Nakamura, T., Kogo, K., Fujimura, J., Tsudaka, K., Wada, T., Ohtsuki, K. and Okada, H.: Development of emergency rescue evacuation support system (ERESS) in panic-type disasters: disaster detection by positioning area of terminals, *Parallel Processing (ICPP), 2013 42nd International Conference on*, IEEE, pp. 931–936 (2013).
- [46] Tsuji, J., Kawamura, H., Suzuki, K., Ikeda, T., Sashima, A. and Kurumatani, K.: An indoor positioning system based on probabilistic model with ZigBee sensor networks, *J Adv Comput Intell Intell Inf*, Vol. 14, No. 6, pp. 425–430 (2010).

- [47] Yamaguchi, K., Kato, T. and Ninomiya, Y.: Moving obstacle detection using monocular vision, *Intelligent Vehicles Symposium, 2006 IEEE*, IEEE, pp. 288–293 (2006).
- [48] Kondo, S.: Safety confirmation system for elderly single-person household with sensor systems, *IEEJ Transactions on Electronics, Information and Systems*, Vol. 131, pp. 1293–1297 (2011).
- [49] Dong, Y., Niimura, M., Kunimune, H. and Fuwa, Y.: AS-5-6 Development of safety confirmation system for elderly person using a wireless Ad-hoc network, *Proceedings of the IEICE general conference*, pp. S63–S64 (2010).
- [50] Nagai, K., Kitagata, G., Suganuma, T. and Shiratori, N.: A safety confirmation system for large-scale disasters based on multi-agent system, *IEICE Tech Rep*, Vol. 104, No. 273, pp. 113–117 (2004).
- [51] Lu, Y. and Yang, D.: Information exchange in virtual communities under extreme disaster conditions, *Decision Support Systems*, Vol. 50, No. 2, pp. 529–538 (2011).
- [52] Toriumi, F., Sakaki, T., Shinoda, K., Kazama, K., Kurihara, S. and Noda, I.: Information sharing on twitter during the 2011 catastrophic earthquake, *Proceedings of the 22nd international conference on World Wide Web companion*, International World Wide Web Conferences Steering Committee, pp. 1025–1028 (2013).
- [53] Yoshitsugu, Y.: Roles of social media at the time of major disasters observed in The Great East Japan Earthquake: twitter as an example, *The NHK monthly report on broadcast research*, Vol. 61, No. 7, pp. 16–23 (2011).
- [54] DoCoMo, N.: Area Mail Disaster Information Services. <http://www.nttdocomo.co.jp/english/service/safety/areamail/>.
- [55] Barnes, M., Leather, H. and Arvind, D.: Emergency evacuation using wireless sensor networks, *Local Computer Networks, 2007. LCN 2007. 32nd IEEE Conference on*, IEEE, pp. 851–857 (2007).
- [56] Fujihara, A. and Miwa, H.: Real-time disaster evacuation guidance using opportunistic communications, *Applications and the Internet (SAINT), 2012 IEEE/IPSJ 12th International Symposium on*, IEEE, pp. 326–331 (2012).

- [57] Nakajima, Y., Shiina, H., Yamane, S., Ishida, T. and Yamaki, H.: Disaster evacuation guide: Using a massively multiagent server and GPS mobile phones, *Applications and the Internet, 2007. SAINT 2007. International Symposium on*, IEEE, pp. 2–2 (2007).
- [58] Gelenbe, E. and Wu, F.-J.: Large scale simulation for human evacuation and rescue, *Computers & Mathematics with Applications*, Vol. 64, No. 12, pp. 3869–3880 (2012).
- [59] Hasegawa, R.: Disaster evacuation from Japan ’s 2011 Tsunami disaster and the Fukushima nuclear accident, *IDDRI Study No5* (2013).
- [60] Nozawa, M., Hagiwara, Y. and Choi, Y.: Indoor human navigation system on smartphones using view-based navigation, *Control, Automation and Systems (ICCAS), 2012 12th International Conference on*, IEEE, pp. 1916–1919 (2012).
- [61] Harle, R.: A survey of indoor inertial positioning systems for pedestrians, *Communications Surveys & Tutorials, IEEE*, Vol. 15, No. 3, pp. 1281–1293 (2013).
- [62] : Survey of internal exchange in secondary education in 2011 (2011). Ministry of Education, Cultural, Sports, Science & Technology Japan.
- [63] Kasahara, H., Mori, M., Mukunoki, M. and Minoh, M.: Business Model of Mobile Service for Ensuring Students’ Safety Both in Disaster and Non-disaster Situations During School Trips, *Information and Communication Technologies in Tourism 2014*, Springer, pp. 101–114 (2013).
- [64] : ALSOK safety confirmation. ALSOK.
- [65] Sumi, Y. and Mase, K.: Conference assistant system for supporting knowledge sharing in academic communities, *Interacting with Computers*, Vol. 14, No. 6, pp. 713–737 (2002).
- [66] Ardito, C. and Lanzilotti, R.: Isn’t this archaeological site exciting!: a mobile system enhancing school trips, *Proceedings of the working conference on Advanced visual interfaces*, ACM, pp. 488–489 (2008).
- [67] Stricker, D., Karigiannis, J., Christou, I. T., Gleue, T. and Ioannidis, N.: Augmented reality for visitors of cultural heritage sites, *Proc. of Int. Conf.*

on Cultural and Scientific Aspects of Experimental Media Spaces, pp. 89–93 (2001).

- [68] Pettey, C. and van der Meulen, R.: Gartner Says Free Apps Will Account for Nearly 90 Percent of Total Mobile App Store Downloads in 2012, *Gartner*, [Online] September, Vol. 11 (2012).
- [69] Kim, W. C.: Blue Ocean Strategy: How to Create Uncontested Market Space and Make Competition Irrelevant/W, *Chan Kim, Renee Mauborgne—Harvard Business Review* (2005).
- [70] RITCHIE, B. W. and Coughlan, D.: Understanding school excursion planning and constraints: An Australian case study, *Tourism Review International*, Vol. 8, No. 2, pp. 113–126 (2004).

List of Publications

Journal Articles

1. H.Kasahara, K.Kurumatani, M.Mori, M.Mukunoki, M.Minoh, Evacuation support and safety confirmation sharing in disaster situations for school trips by mobile information system, *Information Technology & Tourism*, Vol.14, No.3, pp.197-217, 2014.
2. H.Kasahara, M.Mori, M.Mukunoki, M.Minoh, Business Model and Market Strategy of Mobile Information Service for Educational Tour: from School Trip Case, *Society for Tourism Informatics*, Volume 11, Issue 1, pp.87-98, 2015.(Japanese)
3. H.Kasahara, K.Tamura, M.Iiyama, M.Mukunoki, M.Minoh, Tourist behavior model construction based on tracks of tourists using regional environmental factors and application, *Information Processing Society Japan* (Japanese) (Accepted)
4. H.Kasahara, M.Iiyama, M.Minoh, Transportation Mode Inference of Tourists' GPS Trajectories Under Environmental Constraints. (Prepare submitting)

Refreed Conference Presentations

1. H.Kasahara, M.Mori, M.Mukunoki, M.Minoh, Transportation Mode Annotation of Tourist GPS Trajectories under Environmental Constraints, *ENTER 2015*, Lugano, Swiss, In *Information and Communication Technologies in Tourism 2015* pp. 523-535.
2. H.Kasahara, M.Mori, M.Mukunoki, M.Minoh, Regression Analysis of Tourist Photographic Activity Using Geo-tagged Photos and GPS Trajectory, *TAECE*

2014, Kuala Lumpur, Malaysia, 2014-03 , Proceedings of the Second International Conference on Technological Advances in Electrical, Electronics and Computer Engineering , pp 116-123

3. H.Kasahara, M.Mori, M.Mukunoki, M.Minoh, Business Model of Mobile Service for Ensuring Students' Safety both in Disaster and non-Disaster Situations during School Trips, ENTER 2014, Dublin, Ireland, 2014-01, In Information and Communication Technologies in Tourism 2014, pp 101-114
4. H.Kasahara, K.Kurumatani, M.Mori, M.Mukunoki, M.Minoh A Tourism Information Service for Safety during School Trips, The 1st international conference on Serviceology (ICServ2013), Tokyo, Japan, 2013-10, In Serviceology for Services. Selected papers of the 1st International Conference of Serviceology, pp 319-326, 2014

Conference Presentations

1. H. Kasahara, M. Iiyama, and M. Minoh, Online Transportation Mode Inference from Tourists' GPS Trajectory Using Environmental Constraints MVE2015-10, Oct. 2015. (Japanese)
2. H.Kasahara, M.Mori, M.Mukunoki, M.Minoh, Tourist Status Estimation from GPS Trajectory using Environmental Constraints JSAI2015 Challenging Session, May. 2015. (Japanese) (Best Paper Award in challenging session)
3. H.Kasahara, M.Mori, M.Mukunoki, M.Minoh, Semantic Annotation of Tourists' GPS Trajectories Under Environmental Constraints PRMU2014-71. Dec. 2014.(Japanese)
4. H.Kasahara, K.Kurumatani, M.Mori, M.Mukunoki, M.Minoh, Utilization of Information Technology for School Trips and Future Direction - Introduction of Educational Travel Support Service "Ccry" - 8th Working Group of Society for Tourism Informatics Japan. Nov.2013. (Japanese)(Best Paper Award)

Technical Magazine Articles

1. H.Kasahara, K.Kurumatani, M.Mori, M.Mukunoki, M.Minoh, School Trip Support Based on Location Data. Institute of Systems, Control and Information Engineers. Vol 57-8. pp342-347. (Japanese)