Usability Study of Indoor Mobile Navigation System in Commercial Facilities

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ABSTRACT
In this paper, we describe a field experiment of an autonomous mobile system to navigate users and to estimate the self-position indoors, where it is impossible to receive a GPS signal. Many users utilize positional information systems of GPS. However, because positional information computed using GPS signal is available only in the locations with satellite signal reception, it is difficult to use GPS for positioning in indoor environments. Therefore, we have developed an indoor navigation system to provide ubiquitous information service like that of a portable navigation system that can be used inside commercial and office buildings. The navigation system can display user's position that is estimated by beacon signal using license-free radios. We carried out a field experiments in large-scale commercial facilities to evaluate the usability of the navigation interface and availability of the indoor navigation service on a smart phone. As a result, we found that the users would like to have some functions of indoor navigation systems.

Author Keywords
Positioning, Position estimation, Indoor navigation, Smartphone, Cell phone, Wireless beacon

ACM Classification Keywords
C.5.5 [Computer System Implementation]: Services

INTRODUCTION
When considering various services for mobile terminal using systems like our indoor positioning system, we must consider what services the users' preference, functions of the service, the operation interface, and the screen view. For instance, human-navigation services in outdoor environments rarely require notice to users about vertical movements or positions. However, in indoor public spaces, where it is impossible to use GPS, such as commercial facilities, users might use elevators and escalators to go to the target location.

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For a usability study of indoor navigation services, we conducted a field experiment in large-scale commercial facilities to investigate the usability of the indoor navigation service on a mobile terminal. Our indoor navigation system might be developed so that it can guide a user around commercial facilities. Moreover, the system must be evaluated by typical users.

We describe the usability of an indoor navigation system on a smart phone to use position information in an indoor environment, and results of the experiment. Furthermore, we discuss effective indoor navigation functions and the interface considering users' opinions obtained through the experiment.

FEATURES OF THE INDOOR NAVIGATION SYSYTEM
We have developed an indoor navigation system considering usability. The indoor navigation system service has the following features.

- Showing the current position of the user in a floor map.
- Changing the floor map according to the user's position.
- Showing routes from a current position to a destination.

Figure 1 shows a user's current position expressed using a circle in the center of the display screen. As the user moves from left to right on a floor, the user's position in the screen is updated by the navigation system. Moreover, when the user moves to another floor, the system automatically recognizes the current floor and changes the user terminal map to the floor map.

Usually, a navigation route is displayed on a floor map on the terminal screen as shown in Fig. 2(a). When the user reaches the points of navigation events, such as an intersection on the route or in front of an escalator or elevator, a guidance picture like that shown in Fig. 2(b) is displayed on the screen along with a beep sound. The screen presents guidance to lead the user to the destination. The guidance is shown using multimedia: natural language, pictures (e.g., icons, arrows), and photographs of the location. Consequently, the user can reach the destination merely by following the guidance. Advice by the screen announcement includes right turn, left turn, floor changing via escalator or elevator, and destination arrival.

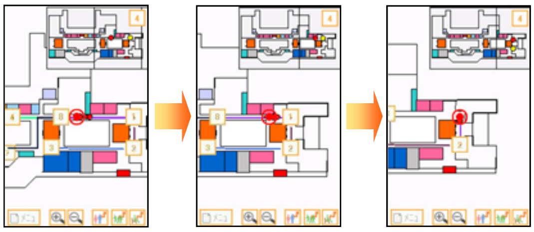

Figure 1. Example of Positioning Result.

(a) Map View. (b) Navigation View. (c) Arrival Guide.

Figure 2. Example of Routing Guide Screen.

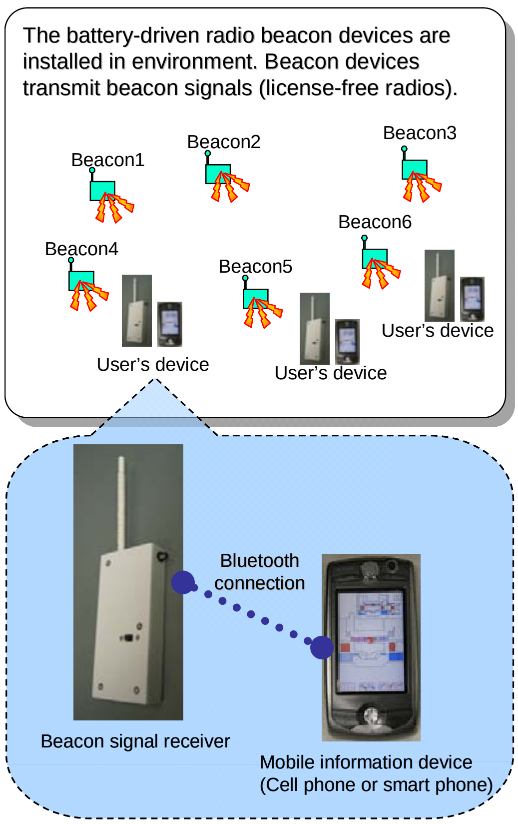

Figure 3. Architecture of Positioning System.

As depicted in Fig. 3, the position is estimated on a smart phone with a beacon receiver that receives signal data transmitted from radio beacon devices installed in indoor environments. The radio beacon device is small and lightweight. Therefore, it is possible to attach it in an inspection door on the ceiling. A beacon receiver to be carried with the user is small and cable-less.

EXPERIMENT IN COMMERCIAL FACILITIES

In this experiment, we intend to collect diverse opinions from ordinary users. The users actually operated the user terminal of the indoor navigation system in the building and reported widely various opinions about the navigation system.

Experiment Environment

We conducted an experiment to investigate users' demands for the service in a large-scale commercial building. The building is known as not only as a shopping center but also as a sightseeing area in Yokohama City. We selected the building so that the participants in the experiment would be able to seek and obtain various services in the real world.

To guide the users to various destinations, we created a database of locations in the building, e.g., stores, bathrooms, sightseeing spots, and so on. A smart phone with a touch pen interface (FOMA M1000; NTT docomo Inc.) was selected as the target terminal with which a user can input many destinations graphically. The interface is highly interactive; the user merely pushes the intended image on the screen, such as a picture of a store, using the touch pen.

The field experiment was conducted at Yokohama Landmark Plaza building, which is adjacent to the Yokohama Landmark Tower[1]. As shown in Fig. 4, Yokohama Landmark Plaza has five floors; each floor in the building has shops, restaurants, hair salons, and so on. The floor area is about 10,000 [m^2]; the center part of a floor is the blow-by. Therefore, the user can receive the positioning signal sent by the radio beacon devices installed on each ceiling on other floors.

Radio beacon devices were installed in the second floor, the third floor, and the fourth floor: the user can use the navigation system from the second floor to the fourth floor. The radio beacon devices were installed at a ratio of one unit for about 200 [m^2] on those floors. It is not necessary to install the radio beacon devices uniformly because the user can specify a self-position if the beacon receiver carried by the user can receive one or more beacon signals.

The field experiment was carried out for five days during November 2007. Several kinds of participants took part in the experiment. The disaggregated data are of 37 participants: 5 students, 27 homemakers, and 5 elderly people. The participants in the experiment move inside the building, using the smart phone and beacon receiver, as shown in Fig.

[1] Mitsubishi Estate Co. Ltd.: The Landmark Tower Yokohama 2-2-1, Minatomirai, Nishi-ku, Yokohama, Japan.

5, and operate the indoor navigation system by referring to the user manual.

The participants experienced one or more scenarios among 11 scenarios prepared in advance. Each scenario assumes a situation and purpose of the navigation, e.g., shopping with young men and women, sightseeing with the family, and so on. Users chose scenarios that were suitable to their own attributes, and moved around in the building according to the scenario using the navigation system.

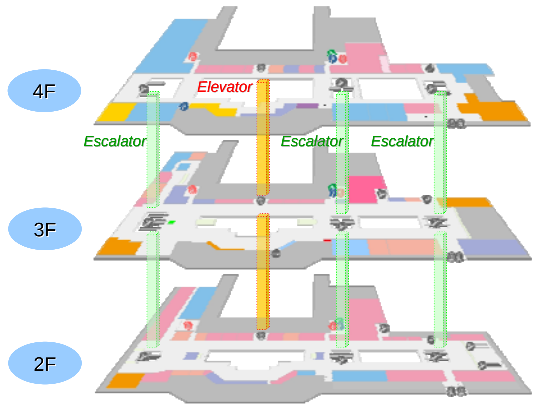

Figure 4. Floor Map of Yokohama Landmark Plaza.

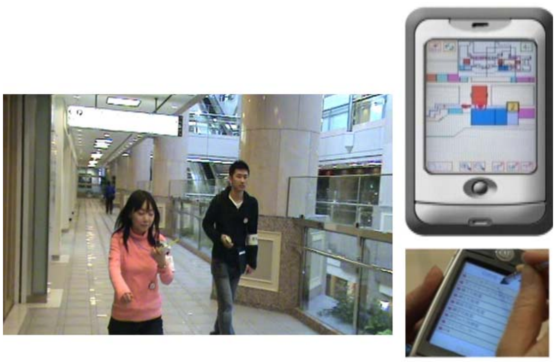

Figure 5. Indoor Navigation Image in Experiment.

Experimental Results

To investigate the usability of the indoor navigation system, we administered the following questions to solicit opinions about the experiment.

A) *A question about whether the user understood that they were led in some direction by watching the map and guidance picture on the screen of the smart phone.*

B) *A question about whether the guidance picture was displayed at the right time; in other words, the user was able to watch the picture immediately before encountering a cross over points on the displayed route, before riding an elevator or before riding on escalators.*

C) *A question about whether the user was able to input easily a setup of the destination shown by the navigation menu.*

D) *A question about whether the indoor navigation service with the user's cellular telephone would be useful—whether the user would like to use the service.*

The questionnaire results in the experiment are shown in Fig. 6.

(a) Navigation screens.

Regarding the questionnaire result (Fig. 6(a)) about guidance of the navigation displayed while the user moves to a destination, about 30% of participants responded that the indicated direction can be recognized by comparing the photograph image of the screen and the surroundings. More than the half understood by comparison several times.

That is, we understood that 80% or more of the participants were able to reach to the destination without becoming lost; it was possible to select a correct passage by the navigation system. Therefore, it is considered that guidance to a destination using the navigation system indoors was effective.

(b) Display timing of guides.

As shown in Fig. 6(b), from the questionnaire related to the viewing timing of the guidance advice, about 60% of participants answered that the displayed screen showed timing neither good nor bad.

We considered the following as factors of the result.

1) In our system, a guidance picture is displayed at a point that is distant from a fixed distance, immediately before an intersection, near an elevator or an escalator. Therefore, when the guidance picture is shown at a location with no turning point, it is also true that the users might have difficulty recognizing the point. We are developing a technique for adjusting the guidance points to resolve this problem.

2) As another factor, it is considered that each user has different timing to watch the smart phone screen; the timing changes from moment to moment. For example, although a user stopped to check the guidance screen, in subsequent guidance, the user checked the screen for subsequent guidance while walking. In such cases of a walking check, the user felt that the guidance screen was shown later than when they stopped to check because the user had moved forward several meters by the time they recognized the guidance screen. Moreover, a fast walker might be shown the screen much later. To solve that problem, we consider appending function that modifies the timing for the guidance according to the walking speed acquired in real time by another sensor.

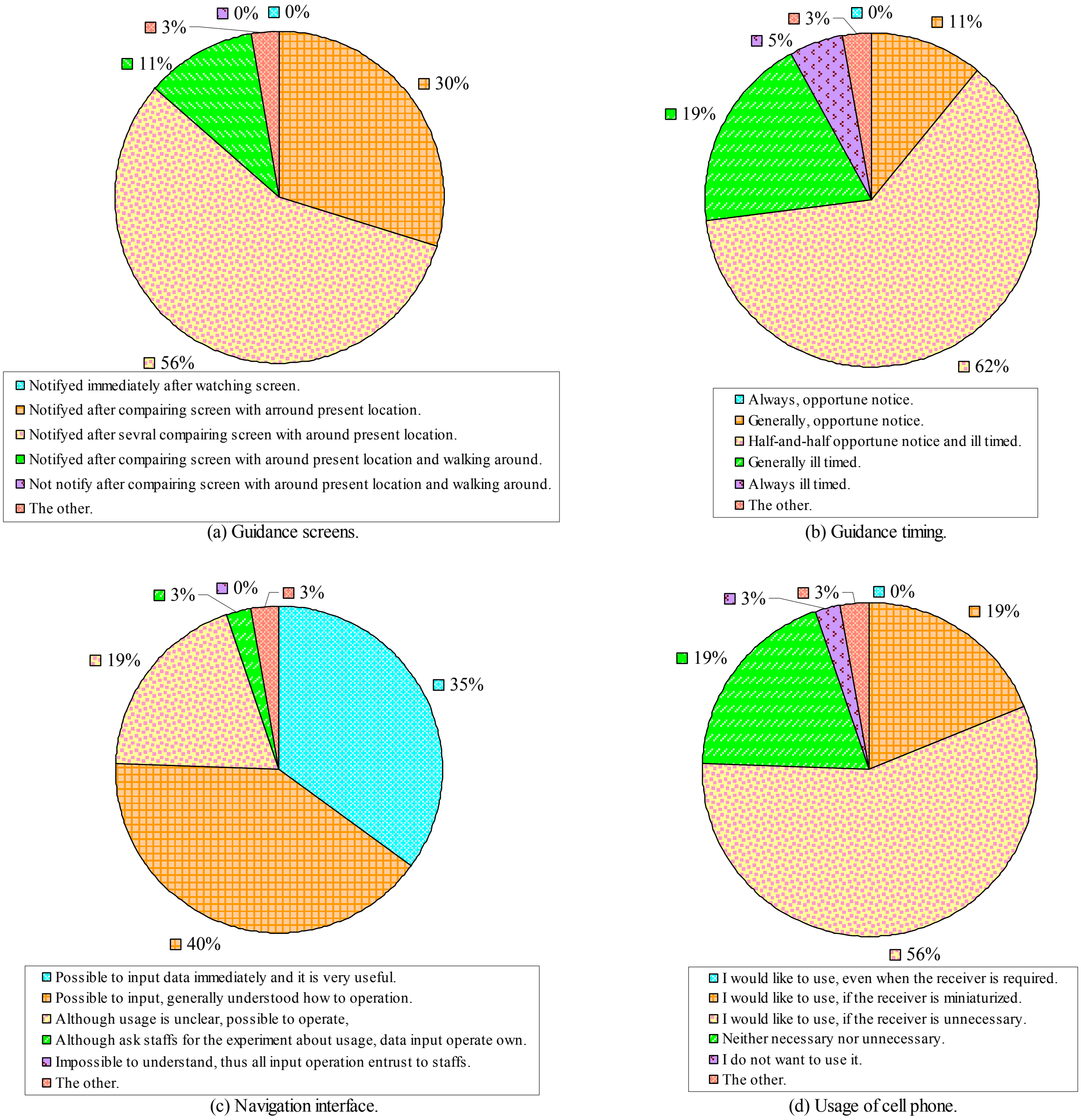

Figure 6. Result of Questionnaire in the Experiment.

3) The difference of guidance timing also occurs from precision error. The error results from the difference between a user's position and estimated position in the system. Although the precision of location estimating changes according to number of radio beacon units installed in the environment, not many units can be installed in a building as a practical consideration. For that reason, other sensors can be attached to the user's device to enhance the positioning precision.

(c) User interface.

In the questionnaire about an input to smart phone of the destination of the navigation in experiment, almost all participants responded that they were able to understand the operating instructions and used the navigation function (Fig. 6(c)).

We consider that anybody can use the input interface easily because the interface of the smart phone design is easy to understand. For instance, the destination is chosen by touching a picture images and illustrations of shops, restaurants, and so on.

(d) Users' needs for cellular telephone services.

Although users utilized the smart phones prepared for us in the experiment, we found users' preference use of the service by which the indoor navigation service is also carried out in a cellular telephone. The questionnaire results depicted in Fig. 6(d) show that about 74% of participants answered that they would like to use such a system if the beacon receiver were miniaturized, or if the beacon receiver were unnecessary.

Conversely, it is a minority view that the user would not like to use the service in a cellular telephone. Therefore, although users' needs for indoor navigation are high, for popularization of services, it is important that usage conditions also include the device configuration.

Discussion

Based on the result of the experiment conducted at Yokohama Landmark Plaza, we can discuss users' needs for indoor navigation services. Results of the questionnaire to participants provided feedback that the users desire use of the indoor navigation service if the service can operate in popular, practically used devices such as cellular telephones.

Moreover, in the opinions of participants, users were unsure whether the walking direction matched the map aspect on the smart phone's screen when the user was walking using the indoor navigation service, after moving to another floor by escalator or elevator, after turning a corner, and so on.

The disorientation occurred because the map screen display aspect on the user's terminal is fixed. Although the sense of direction depends on the person, in some situations, the users noticed no difference between a self-direction in the real environment and the aspect of map displayed on the small screen. Also, the floor design of Yokohama Landmark Plaza has similar architecture throughout the entire area. To reduce loss of motion by disorientation, heading up of the map through self-direction using an electronic compass sensor in the cellular telephone must be effective, which is our future work for this system.

We were acquired users' opinions about the advantages and disadvantages of our indoor navigation system because evaluated the system by the several kinds of users. The system was evaluated by two survey methods, that is, one is description format and the other is group discussion. Although group discussion can hear the detailed opinions of the users, the survey method takes much time and energy. In the feature, we would like to consider how to effective interview methods.

REATED WORK

In recent years, position information services such as navigation services have received much attention in the context of civil life, home life, industry, and so on. In outdoor situations, car navigation systems that specify self-position and which provide directions to the destination are useful as a substitute for human navigators to such locations. Moreover, when advanced traffic information systems [1][2] are applied to car navigation systems, it is also possible to show a route with consideration of traffic and accident information related to the present.

However, because the systems have difficulty receiving signals of Global Positioning System (GPS) in indoor environments, some alternative positioning systems are proposed to use GPS in the locations where it is impossible to receive a GPS signal from real satellites. The Pseudolite-GPS [3] and GPS Re-radiation [4] Systems are well known as alternative systems to utilize GPS.

Pseudolite-GPS is a system using a transmitter that emits the pseudo-GPS signal generated by simulations. However, the system has difficulty receiving signals at close distance and at distant locations from the transmitting antenna. Moreover, it is difficult to obtain correct time synchronization accurately between the system and GPS satellites. The GPS Re-radiation System receives real GPS signals in open field areas, then forwards them with a cable, and transmits them to indoor environments. The system cannot be used in areas that cannot also receive GPS signals outdoors. Additionally, it is necessary to install many GPS receiving antennas outdoors to raise the position tracking precision.

Therefore, various non-GPS methods are often applied to indoor positioning systems. Active Bats [5] and Cricket [6] are techniques that can detect positions by receiving signals sent from transmitter devices. Typically, these systems increase the number of installed devices if the areas to recognize the user's position become broad.

In practice, RADAR [7], PlaceLab [8], EKAHAU [9], and AirLocation II [10] are methods using the strength of radio electric field of Wi-Fi signals. Improving these methods' positioning precision is difficult because the electric field strength becomes unstable for changing of Wi-Fi radio transmission power. Ubisense [11] uses ultra wideband technology (UWB) for positioning, but it is impossible to recognize the self-positions of users on their own portable devices.

We have developed an indoor positioning system in consideration of the shortcomings of the systems described above. The system can operate on a portable information terminal such as a cellular telephone by receiving radio beacon signals from beacon devices installed in the environment. The system operates autonomously without server access; the installed beacon devices can be driven using batteries attached to the devices. Consequently, our system also preserves user privacy.

FUTURE WORKS

In our system, a guidance picture is displayed at a point distant from a fixed distance. Therefore, we are developing a technique for adjusting guidance points to resolve this problem. Moreover, to show guidance pictures with optimized timing on the screen, we consider an appending function, which modifies it according to walking speed, which is acquired in real time by another sensor. Furthermore, we are considering enhancement of the positioning precision to attach other sensors in the user's device [12]. Future systems might incorporate miniaturization of the beacon receiver, integration as IC of the device, and integration with cellular telephones.

CONCLUSION

For this study, we have developed a system for an indoor navigation service that is intended for implementation not only on smart phones but also on cellular telephones. Moreover, we presented results of an experiment in Yokohama Landmark Plaza for an indoor navigation system conducted using beacon devices.

Yokohama Landmark Plaza has a blow-by in the center of each floor above the ground floor, which means that it is difficult for users utilizing the service to recognize motion to another floor. In the building, many customers come to shops and restaurants; the people are passing through using the passages. We carried out the experiment to investigate this indoor navigation service in such a realistic environment.

In the experiment, we administered questionnaires to elicit comments related to experiences of indoor navigation in the commercial building. Consequently, we acquired useful opinions related to the navigation system and position information services, such as the interface, its operation ability, and the screen information. Moreover, we confirmed the possibility of correct function for navigation service using indoor position information in this real environment.

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