PDR-based Adaptation for User-Progress in Interactive Navigation System

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Abstract
Recently, indoor pedestrian navigation systems have attracted attentions of people. We have been developing an interactive pedestrian navigation system and found that the navigation system could not provide enough sense of reassurance for a user according to our preliminary experiment. In this study, we propose a method to improve the user's sense of reassurance by notifying user's level of achievement sensed by their smart phone sensors and conduct the experiment in the Osaka underground city. According to the questionnaire survey that we conducted after the experiment, people who chose affirmative opinions on a sense of reassurance increased by 45% due to the proposed method.

Author Keywords
Pedestrian Navigation, PDR, Indoor Navigation

ACM Classification Keywords
H.5.1 [Information interfaces and presentation]: Multimedia Information Systems- Hypertext navigation and maps

Introduction
Recently, indoor pedestrian navigation systems have attracted much more attentions of people [1][2], we have been developing an interactive navigation system for

pedestrians [3][4]. In our system, a user interacts with the system on visibility confirmation of landmarks such as shops or facilities. In addition, the system was intended for using in the Osaka underground city as an example of indoor.

Since the system holds all and perfect information of landmarks in the area, it can identify the user's destination and current position through such interaction. As the system's UI is designed in a familiar time-line style shown in Figure 1, users have to select the given options except for inputing landmark description(name).

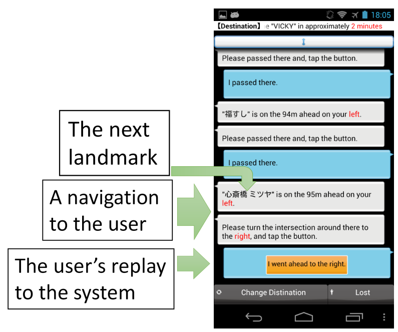

Figure 1: The screenshot of the interactive navigation system

After the development of the first prototype, we conducted a preliminary experiment on pedestrians indoor navigation systems. Through the preliminary experiment, we found that the prototype could not provide enough sense of reassurance for a user in such text-only time-lines. Among the negative cases, some users lost their way when they could not recognize the designated landmark even if they came across it.

In this study, as a method to improve the user's sense of reassurance, we propose two functionalities; support to find landmarks and "*Route Judgment*", and develop them into our navigation system. Support to find landmark functionality gives turn-by-turn instruction and estimated user's progress timely. The route judgment functionality is to determine whether the user is on the right way or not, and this navigation system notifies or alerts the user of the appropriate information timely. Those notifications can be generated using smart phone sensors in the pedestrians dead reckoning (PDR) technology. Thus we evaluated whether the method could influence a user's sense of reassurance when the user used the navigation system.

In the rest of this article, the details of our approach of two functionalities are explained, and performance evaluation of the functionality is presented. Finally the conclusion and future research directions are given.

Approach and Implementation

In order to improve a user's sense of reassurance, utilizing the route judgment functionality, the system notifies/alerts a user of the appropriate information according to a user's progress on the navigated route. This route judgment is implemented using smart phone sensors in the PDR technology. Route judgment estimates user's current progress of navigated route and relative location relation (distance) to landmarks judging the user is on the right way or not. After this, details of two functionalities are as.

Support to find the landmark

The system estimates the distance from the user's current location to the next landmark in real time and displays the distance on the smart phone panel all the time. Among our assumptions, spaces where users can walk are mostly limited to corridors especially in the underground city, which means more simple estimation is practically more effective rather than professional PDR approach. We just count user's walking steps and turning recognition is only focused on corridor's intersections area. This simplification might be considered too primitive but actually worked rather fine in Osaka underground city. Before each user begins to use the system, the length of a user's step is set in a fixed length. The number of steps are counted by detecting each extreme of three-axis-composite values of smart phone accelerometer. Utilizing real time counting of user's steps, the system notifies the user of messages concerning with the distance to landmarks. The distance to the landmark is estimated all the time in each turn, and user's walking distance is calculated by multiplying the number of steps by the length of a user's step. The navigation system notifies the user of a displayed message, "*You are approaching the next landmark.*" when the estimated distance is less than the threshold so as to be prompt to recognize it. Furthermore, the system alerts the user displaying a message, "*You might have passed the next landmark*" when the estimation tells that way. After user confirms the end of the turn, the system proceeds to the next turn and displays and update the estimated distance to the next landmark and map around the user.

Route Judgment

Since the width of the corridor is limited in the underground city that our system covers, the user does not turn except at the intersection area. Therefore, the system should activates the route judgment functionality only around the intersection where user might turn. Judging the traveling direction with the gyroscope and the accelerometer, we obtain the user's relative change of the traveling direction. The user's relative change of the traveling direction is calculated by integrating horizontal angular velocity while they are turning. The user's turn-period is estimated by utilizing features of horizontal angular velocity. If the system could know that user is walking the right way, it gives a message, "*You are proceeding on the right way.*" at some points like just after the proper turn is made. On the other hand, the system prevents user from making the situation worse, it warns by displaying a message, "*You might deviate from the route*", when it judges that the user does not turn or turn to the wrong way from instructed route and direction. The screenshot of the navigation application embedding these two functions is shown in Figure 2.

Figure 2: The screenshot of the interactive navigation system with the support functions

Evaluation

We evaluate if the two proposed functionalities contribute to reassure users while they are traveling with our navigation application on their smart phones. We conducted an experiment to check the PDR's estimation accuracy in advance. At first, we experimented 60 times on the estimated walking distance. As a result, the estimated walking distance was at the accuracy of almost 90$\sim$130% by the actual walking distance. Based on the

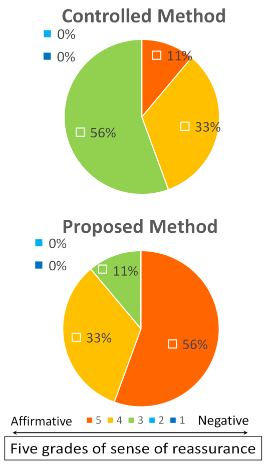

Figure 3: The sense of reassurance for Interactive Navigation System

result, we set the threshold so that the messages are notified to find the landmark at the appropriate timing. As for turning recognition in the route judgment functionality, 20 times trial on 90-degree-turning is done, and it was able to judge without a mistake. Finally, we experimented an evaluation on the real-field of the Osaka underground city in Japan. Nine users who were not familiar with the area were gathered to use our navigation application through the following two methods.

Method 1: Controlled Method

The controlled method consists of text-based time-line navigation system and displaying map around current position. User's current location in the map is not updated automatically, but only by their interactions with the system.

Method 2: Proposed Method

The proposed method consists of the controlled method above and the proposed notification/alert messaging based on PDR. User's current location is updated automatically by estimated walking distance in real time.

We conducted a questionnaire about a sense of reassurance while they were traveling. The result of questionnaires evaluation conducted after the experiments is shown in Figure 3. As is shown above, the controlled method has 44% affirmative opinions and there is not any negative opinions. Affirmative opinions of the result of the proposed method rose up to 89% and no negative opinions. Also, nine users lost the way seven times in all when they used controlled method. In comparison, they did not lose the way when they used proposed method. As a result, our method contributed to reassure the user using the navigation system.

Conclusion and Future Work

In this paper, we have developed the supporting feature to our interactive navigation system in order to give users a sense of reassurance concerning with their traveling in indoor environment. The proposed method consists of two functions estimating the user-progress; support to find the landmark and route judgment functionality. These two have improved a sense of reassurance by notifying the user of the appropriate messages timely. We experimented on the nine users with our interactive navigation application with/without the two methods, and took a questionnaire survey on a sense of reassurance while they were traveling. As a result, our method gave a sense of reassurance for 89% of the users whereas it is only 44% without it. However, we got the feedback that the notifying timing of the message was too fast, so we are aspiring to improve the navigation system by enhancing the accuracy of the estimated walking distance.

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