A Pilot User Study on 3-D Museum Guide with Route Recommendation Using a Sustainable Positioning System

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Abstract: We describe our 3-D museum guide system and the pilot study we did to evaluate it. The prototype system used in the pilot study uses a human positioning system based on dead reckoning, active RFIDs, and map matching. The system manages content consisting of 3-D maps, recommended routes, and Flash files to provide appropriate navigation information based on estimated user position, azimuth, and history. The pilot study was conducted at the Science Museum. We got useful feedback from participants about 3-D maps, recommended routes, etc.

Keywords: 3-D indoor guide, route recommendation, content management, log visualization

1. INTRODUCTION

There are now a lot of web and cell phone services that provide content related to a user’s position on a map of a building or facility using position and azimuth information [1][2]. These services are mainly used for outdoor navigation with 2-D maps. There are also 3-D viewers that can show users the simulated sights of urban areas [3][4][5]. A 3-D guide service that combines these fundamental technologies would be very useful, especially in facilities with a 3-D structure such as museums. We describe a 3-D museum guide system with route recommendations using a positioning system based on dead reckoning. Then we report the results of a pilot study of the system conducted at a science museum.

2. 3-D INDOOR GUIDE SYSTEM

In this section, we outline our prototype system, describing how the system worked at the Science Museum. The system consists of a positioning subsystem that acquires a user’s position and azimuth, a content management subsystem that retrieves and visualizes content, and a user terminal that displays the provided content. The following subsections describe each part of the system’s parts.

2.1. Sustainable Positioning System

Kourogi et al. have shown that it is possible to accurately estimate a human’s position and orientation by a dead-reckoning method that detects and tracks a user’s steps using a self-contained sensor module that consists of three-axis accelerometers, gyro sensors, and magnetometers [6]. Accumulation error is a common problem for dead-reckoning methods, so a method that combines dead reckoning with absolute positioning using active RFIDs or GPS has been proposed [7]. Our prototype system uses a positioning system that combines the method proposed in ref. [7] with a Wi-Fi-based positioning method (PlaceEngine [8]) and map matching. This positioning system can be placed as a pioneering system to construct a sustainable ubiquitous information society because it can determine the user’s position and orientation for information services over a wide area without excessive dependence on infrastructure-side sensors.

2.2. Content Management System

Our system runs a database on a user terminal that contains histories of the user’s position and orientation, terminal battery level, Flash content, such as time-scheduled exhibits, and recommended routes. The content management system retrieves content appropriate to the user’s position and orientation as acquired by the positioning system. Then, two kinds of display subsystem present the retrieved content. One presents content such as Flash content via a web browser. The other visualizes the position of content around the user and retrieves and visualizes the recommended route based on the user’s position on a 3-D map on Google Earth.

In the guide system for the Science Museum, a startup screen, a play button, and explanations of events and exhibits were prepared as the Flash content. This content explains events and exhibits and consists of a still image including a photo, descriptive text, and about 15 seconds of voice data that reads the text. Each bit of Flash content was placed on the 3-D map using our original content-authoring tools. The position where Flash content is placed is visualized as a place mark. When a user sees the event or exhibit corresponding to
the content, it is played. The content is also played when the system begins to navigate to the exhibit.

The system also presents the user with recommended routes. Four courses were given for the Science Museum, and information on scheduled events and exhibits was input to the database and used to calculate routes. Figure 1 shows an example of visualizing a recommended course from the start point on the 1st floor to the first several exhibits on the 5th floor.

2.3. Wearable User Terminal

We prepared hand-held and head-mounted-display (HMD) wearable user terminals for the guide system (Figure 2). The common components were a belt bag that stored positioning system equipment, a hand-held PC (SONY VAIO Type U), and a voice recorder for conversation analysis. The HMDs were monocular (Mitsubishi Electric SCOPO), and users who wore them kept the hand-held PC in a shoulder bag. A button on the outside of the shoulder bag was used to control the PC. This type of configuration enables users to keep their hands free.

The positioning system equipments can operate for more than two hours with a battery pack. However, the hand-held PC can operate for about an hour with a standard battery.

2.4. User Interfaces

Because of the small display size, displaying a 3-D map and Flash content simultaneously is not practicable. Therefore, Flash content is presented full-screen when it is needed; otherwise the 3-D map is displayed full-screen.

For the safety of the users, we decided to use a monocular HMD placed over the user’s dominant eye. Moreover, to make it easier for users to handle the terminal, the system was designed to be adaptive to the user’s position, azimuth, and time the user is not moving. The user only had to push the button when he or she wanted to cancel navigation to scheduled events and to replay Flash content that had been played before.

3. PILOT STUDY

To evaluate the usability of the 3-D indoor guide system and the effect of the different types of display on usability, we conducted a pilot study to evaluate the system from various viewpoints including robustness and operability. We focused especially on qualitative evaluation of the system based on users’ subjective responses.

3.1. Task and Procedure

The pilot study was conducted at the Science Museum, which has five 2500~2700 m² floors over a total of four days. Two sessions were done per day. We prepared three separate system trials, so three participants could do the experimental task simultaneously. A support staff person followed each participant to ensure the participant’s safety, to record the actions of the participant, and to maintain the system during the study.

Each participant used both types of display, except for participants under 16 years old, who were only allowed to use the hand-held device for safety reasons. Each participant looked around the museum using the experimental system for two hours. The participants returned to the support desk to change the battery and the display setting about one hour after the session started.

Each support staff wore a movie-audio logging system and recorded participants’ activities from behind them. When a participant went up and down stairs, the support staff ensured their safety. Each support staff helped the participant put on/take off the system when it impeded the participant’s experience of hands-on exhibits. Moreover, the support staff dealt with system trouble.

The experiment was explained to each participant before the session began. The participant was told that a recommended route would be shown on the 3-D map but that he or she would not need to follow the route.
The purpose of this explanation was to avoid creating the impression that the system enforced activities in the museum. After each session, participants answered a questionnaire and attended a group interview. The group interview was recorded on two cameras: one for participants and the other for the interviewers.

After the first half of the study period (the first two days), we had several days to prepare for the latter half (the third and fourth day), so we were able to incorporate information from participants’ comments on the first half of the experiment. To do this, we had to do a careful quantitative analysis of the responses to the questionnaire because experimental conditions had changed. However, we were able to see the effects of our improvements in the latter half.

3.2. Participants
We had a total of twenty-two participants: twelve females and ten males. Three were in their teens, four in their 20’s, eight in their 30’s, four in their 40’s, and three in their 50’s, providing for feedback from various generations.

3.3. Results and Discussion
In this section we discuss typical comments from the questionnaire and the group interview as subjective results, and discuss the causes and their meanings. The questionnaire consisted of 17 questions answered on a seven-point scale.

3.3.1. The 3-D map and grasp of current location
We got both positive and negative feedback about the 3-D map through the group interview. Some participants reported that the 3-D map was interesting and helped them understand where they were in the museum. Others reported they were not able to understand how the map corresponded to the buildings. The comparable result was seen as for the questionnaire (See Figure 6).

From these results, we think that there were some participants who were confused by measurement error. Thus, there were two types of participants. One type is participants who were able to understand that, due to measurement error, a displayed position may be different from an actual position. The other is participants who were not able to recognize this and are confused by it. Some participants who commented that the 3-D map was difficult to understand reported that the visualized position was different from their actual position. It is impossible to understand the difference between actual and displayed positions without understanding the correspondence. To sum up, the 3-D map gave useful visual cues to understand the correspondence between actual positions and positions on a map. However, measurement error of the positioning system confused participants and possibly gave a bad impression of the 3-D map.

Some participants reported that they wanted to see text information such as room numbers on the 3-D map. This indicates that symbolic information other than shape and appearance was also important in understanding the correspondence between the map and the buildings. Therefore, we showed room number information on the 3-D maps in the later sessions.

3.3.2. Navigation and recommended route
We received a lot of negative feedback on the recommended route such as “I was not able to follow the route” or “I didn’t follow the route.” Such feedback can be grouped into two categories. One concerned confusion regarding the direction of the recommended route. For example, “I wasn’t able to grasp the direction to go, so that I wasn’t able to follow the route”; and “The route looked like my trajectory.” The other was concerned with providing navigation information. For example, “I didn’t understand where the route was leading to, so I decided not to follow the route.”

The reason for the confusion regarding direction originated from the visualization of the recommended route as connected lines, rather than as connected arrows. Actually, the connected line started at the participant’s current position and ended at the goal of the route, so the participant could see the direction but misunderstood it. In addition, only the parts of the route that were on the same floor as the participant were visualized, so connections to different floors were not clear. These problems were solved before the later sessions started. The route was shown by connected arrows and connection to the different floors was displayed in the later sessions.

As a result, there was less misunderstanding of the direction of the recommended route, and later sessions participants understood better.

The meanings of comments like “I didn’t understand where the route was leading” were classified into two types concerning short-term and long-term goals. The reason some participants did not understand where the route went in the short term was due to the virtual camera settings of the 3-D map. We mainly focused on
the correspondence between the museum and the map, so the area immediately around the participant’s position was zoomed and the viewing angle was almost perpendicular to the horizontal plane. As a result, things in the direction the participant was meant to go were not clearly visible. The virtual camera settings were also improved for the latter sessions. That is, for ten seconds the cameras were set near the participant’s position to show the details of the 3-D map and the virtual camera position was set far enough that the whole floor could be seen for the following five seconds. The viewing angle also changed to show the direction the participant was intended to go.

To indicate the long-term goal, the system played the Flash content as next goal information. However, participants could not easily understand it. Visualizing the whole route to the next goal might be more impressive and make the next goal position clearer.

3.3.3. Hand-held vs. HMD devices

Figure 5 shows a comparison of the results for the hand-held and HMD displays. Overall, participants tended to be able to see displays easily, got tired, and experience and concentrate on the exhibits easily with the HMD. In the interview, many participants were curious about the HMD because they had never used it before. However, participants reported that they needed to concentrate on the monocular HMD to see content, and that they had to adapt themselves to the HMD. Some participants pointed out that the HMD was not a good device for facilities such as the Science Museum because children visit such facilities. Some participants reported that they felt it was easier to experience hands-on exhibits with the HMD than with the hand-held display. Other participants reported that the hand-held display was comfortable when they were just looking at the exhibits. It was interesting that a participant pointed out that the hand-held devices allowed sharing of information when the system was used by a group of people. Many participants also said the hand-held system was too heavy.

3.3.4. Better evaluations due to improvement in the system

To figure out how changing experimental conditions affected outcomes, we focused on how responses changed over time. As we changed the system, favorable answers to the questionnaire tended to increase. Figure 6 shows average scores for questions for which this tendency was especially prominent: how easy 3-D maps and Flash content were to understand (Q1, Q2) and how useful announcement of events in ten minutes was (Q8).

3.3.5. Other comments

The participants requested certain functions and services. Representative examples are: “I wanted to input my own goal instead of just seeing the recommended exhibits,” “Announcement of the time-scheduled events was really useful. Please add more announcements.”, “We’d like to know where our children are rather than where we are”. In the stage where the first specification was decided, we tried to reduce as much as possible what users had to do. Therefore, we didn’t prepare the functions to input the users’ goals. This should be added to the system.

4. CONCLUSION

There has been no study of 3-D indoor guide systems comparable in scale to this pilot study. All feedback from participants and operational experience in this pilot study are valuable and will have a great impact on future strategy for research and development.

A lot is left to future work, such as stabilization of whole systems, improvement in positioning systems with map matching methods and RFID, and rules for displaying content. Further experiments with improved systems based on experience and feedback from participants in this pilot study are also left to future work. We made sure to evaluate many issues that
depend on user age such as weight and robustness of the equipment, usability of user interfaces, and generation differences in response to the HMD. We must design a system usable by people of all ages or a system that can be adapted to users of all ages.

Statistical analysis of questionnaire results, recorded conversation analysis, and analysis of group interviews are also left to future work. We are currently developing the experimental log-visualization tool shown in Figure 7. This tool can retrieve a participant’s trajectory, recorded voice, and recorded movie using participant ID, time, position, etc. Query results are visualized and simultaneously played on the 3-D map and web browser. This enables us to see movies, hear recorded voices, and know the position and orientation of the participant at any time. Therefore, we expect to be able to analyze highly realistic experimental logs.

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REFERENCES