An Augmented Reality Mobile Navigation System Supporting Indoor Positioning and Group Communication Functions

Ching-Sheng Wang, Meng-Lung Lin, Ding-Jung Chiang, and Yen-Kui Yin

***Abstract*—**In recent years, with the increasing popularity of smart mobile devices, more and more famous museums and scholars have actively thrown themselves into the research of mobile navigation systems. However, the functions provided still limited. In this paper, a mobile navigation system combined with augmented reality, RFID indoor positioning and group communication functions is proposed. This system is able to use a mobile device to provide real-time analysis on exhibits, demonstrate various multimedia and 3D navigation information, and utilize an active RFID indoor positioning mechanism to enable the user to determine their real-time position, which is convenient for finding interesting exhibits or exhibition areas. In addition, this system supports group communication and information sharing functions, allowing the user to simultaneously communicate and share navigation information with group members without the need to talk loudly to achieve an efficient group navigation mode.

***Keywords*—**Augmented Reality, Mobile Navigation, Indoor Positioning, Group communication.

I. Introduction

IN most traditional exhibition sites, the guide introduction, printed maps, or simple information of exhibits, are provided for reference by visitors; however, they lack complete and systematic information of exhibits. Although varied services, such as explanations by personnel or voice navigation, are provided in some exhibition sites to increase the visitors' understanding of exhibits; the navigation form is very limited, as the tour guide can only introduce exhibits in a verbal manner. In addition, tour explanations by personnel are usually conducted in the form of group navigation due to the large difference in the proportion of visitors and tour guide, which renders tour guides unable to meet the needs of individuals, except for at certain visiting times. Moreover, in the case of visiting groups, loud explanations or conversations often occur between the tour guides and group members, often destroying the serenity of exhibition sites and affecting other visitors. Although smart mobile devices and GPS are very popular, due to building masking, GPS will not function when the user moves to an indoor space. Therefore, though some museums use a digital museum navigation system, most do not have an indoor navigation function. Because of indoor exhibition sites have the characteristics of vast, crisscrossed, and indirect spaces, which render it difficult for a user to clearly know their position among the exhibition sites and exhibits, leading to group members wandering and losing each other, thus, wasting the precious visiting time allocated for the tour. In light of the above issues, a group mobile navigation system supporting augmented reality, indoor positioning, group communication and information sharing functions is proposed in this paper. This system is able to present rich 3D and multimedia navigation information in a diversified augmented reality exhibition mode, which facilitate both virtual and real-time modes to provide the indoor positioning function that allows the user to know their position and those of other group members. In addition, this system supports information sharing functions for fast, quiet communication and tour information among group members thus, achieving a more efficient group navigation mode.

The remainder of this paper is organized as follows: section II provides a brief introduction and comparison of researches related to this paper; section III describes the system architecture and navigation functions; section IV presents the system implementation and related explanations; the section V shows the results; and finally, section VI provides the conclusion of this paper.

II. Related work

In recent years, with the increasing popularity of smart mobile devices, more and more famous museums and scholars have actively engaged in the research of mobile navigation systems. Among which, the Brighton Museum App [1], as rolled out by Brighton's Royal Pavilion Museum in the U.K., has incorporated the collection information of five museums, which helps tourists to plan their itinerary, in addition to providing museum maps, historical pictures, featured activities, and latest news of the museums. Another App designed by the American Museum of Natural History [2], is capable of

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reminding visitors of their positions and guiding visitor flows in the exhibition areas by importing an Wi-Fi indoor positioning function, which can also provide the pictures and text introductions of exhibits. The "Discover NPM " App [3], as launched by the Taiwan National Palace Museum in 2014, provides varied functions, such as traffic information, visitor's guide, and itinerary planning, and supports a GPS positioning function in the museum area, which allows users to determine their real-time position. French scholars Weis et al. [4] also designed a set of museum navigation system using passive RFID positioning, which utilizes a RFID Reader held by a user to sense passive tags arranged within the exhibition halls of museums, which can further remind visitors of their positions. However, the aforementioned system only supports outdoor positioning or has very limited indoor positioning range and accuracy, which limits the positioning function application.

In addition, with the efficiency improvements of smart mobile devices, some navigation systems have incorporated an augmented reality application in order to add diversity to navigation information. Among which, the Street Museum App [5] rolled out by the Museum of London can superimpose the museum's historical pictures onto the corresponding streetscapes to present a special effect of interlacement of history, which is presented through the GPS positioning function of a smart cell phone. Moreover, Taiwan National Palace Museum also rolled out a "Diplomatic credentials AR" App [6] in 2014, which can identify antique images through a mobile device, present the related 3D models of historical figures, and select the figure models to explain the related historical stories, which is quite novel.

Moreover, Chou developed a mobile navigation system [7] by taking Taipei Longshan Temple as the background and combining augmented reality technology. This set of system takes the QR code as the basis for identification. When a visitor approaches a target scenic spot provided with a tag, and focuses a mobile device on the tag of the QR code, the related text descriptions and pictures could be obtained. In the paper by Chang et al., an augmented reality mobile navigation system [8] is established to create an exhibition by way of storytelling and game playing. The user gets a better understanding of historical sites, such as the famous Tamsui Old Street and Fort Santo Domingo, by acting as the lead role in the story and relating the story specified by the system. In addition, Lin developed a set of augmented reality navigation system [9] able to be executed on a smart Android mobile device by taking the scenic spots in the famous Anping District of Tainan, as an example, which combines augmented reality and 2D bar code technologies, and introduces gaming concepts of exploring behaviors to increase the fun of a tour.

Compared with the above-mentioned related studies, a group augmented reality mobile navigation system supporting indoor positioning and information sharing functions is proposed in this paper. The function comparison of this system and other systems is as shown in Table I. In addition to supporting common text, picture, and video exhibition, our system supports the diversified augmented reality exhibition method. Moreover, by adopting marker-less image identification technology, this system is able to realize the augmented reality exhibition function without needing to change the exhibition site environment. Regarding the aspect of indoor positioning, the active RFID indoor positioning of this system is able to consider both range and accuracy. In addition, this system supports group communication and information sharing functions lacking in other systems, which attains a group navigation mode with more interaction to realize varied functions, such as advanced interaction and multi-people interaction, as specially recommended by Aoki [10] and Hou et al. [11].

TABLE I
TABLE OF FUNCTION ANALYSIS AND COMPARISON

Function / System/Paper	Text & Picture Exhibition	Video Exhibition	AR Exhibition	Group Communication & Information Sharing	Indoor Positioning
Brighton's Royal Pavilion [1]	Yes	No	No	No	No
American Museum of Natural History[2]	Yes	No	No	No	Yes (Wi-Fi)
National Palace Museum - Discover NPM App[3]	Yes	No	No	No	No (GPS, outdoor only)
Weis, etc.,[4]	Yes	No	No	No	Yes (Passive RFID)
Museum of London [5]	Yes	No	Yes	No	No (GPS, outdoor only)
National Palace Museum - Diplomatic credentials AR App [6]	Yes	Yes	Yes	No	No
Chou [7]	Yes	No	Yes	No	No
Chang [8]	Yes	Yes	Yes	No	No (GPS, outdoor only)
Lin [9]	Yes	No	Yes	No	No
Our System	Yes	Yes	Yes	Yes	Yes (Active RFID)

III. SYSTEM ARCHITECTURES AND FUNCTIONS

The system architecture, as shown in Figure 1, mainly includes a multimedia navigation information management system, RFID indoor positioning system, and a real-time navigation information sharing mechanism. Our system adopts marker-less augmented reality image identification technology in the multimedia navigation information management system. In the case of a visitor identifying an image through a mobile device, if there is navigation information at the mobile device end corresponding to the identified image, the related navigation information would be presented; if there is not such multimedia navigation information in the mobile device, due to the coincidental updating of exhibits or other factors, the system would automatically send a request to the multimedia navigation information management system, which would send the related data to the mobile device, and then exhibit the corresponding multimedia data.

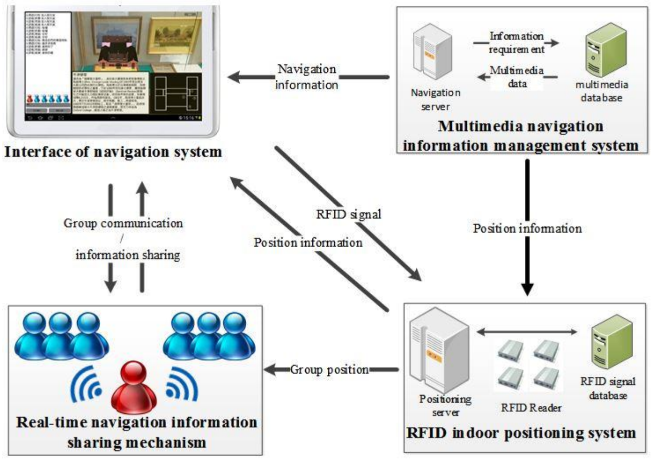

Fig. 1 Diagram of system architecture

In the RFID indoor positioning system part, this system collects the signal strength of the RFID Tag worn by a visitor through the RFID Readers arranged within the navigation space; sends the signal strength data back to the RFID positioning server to calculate the user's position through cross comparison; and summarize and transmit the positions of members in the same group to the user's mobile device. Figure 2 shows the diagram of the group position map, in which the user can identify their position, and other group members' positions, according to the tags of ❶, ❷, ❸,❹ and ❺.

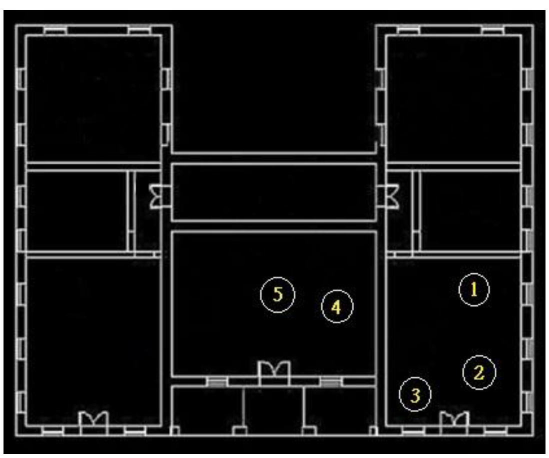

Fig. 2 Diagram of group position map

In addition to displaying the group positions, the real-time navigation information sharing mechanism supports group text communication and image sharing functions to allow group members to share the tour process and experience with each other in a real-time manner, thus, effectively promoting interaction between group members. The interface of the real-time navigation information sharing function is as shown in Figure 3. Initially, when the system is used, the system would give group members the serial numbers of 1, 2, 3... and show a welcome message. At any time during the visit, the user can select another member (the red one is the user) to communicate with, input a text message to be communicated in the message box, and then click the [Text Communication] button to send the message to a certain member. Moreover, the user can transmit the screen image he/she is viewing to other members by clicking on the [Image Sharing] button.

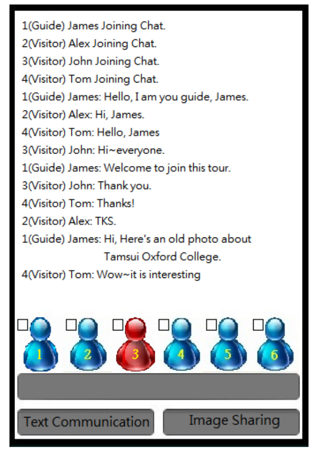

Fig. 3 Diagram of group communication interface

IV. System Implementation

The implementation of this system mainly includes augmented reality, indoor positioning service, and group communication, as well as augmented reality items of marker-less image identification and exhibition functions on a mobile device, the design and implementation of active RFID indoor positioning service and the implementation of text communication and image sharing functions for group communication.

A. Augmented Reality

In this paper, the exhibition pictures of Tamsui Oxford College site, a second-level national historical site, are used as the basis for augmented reality identification. The processing procedure mainly includes 5 major steps: (1) tracking the image, (2) calculating the three-dimensional coordinates of the image, (3) identifying the feature points of the image, (4) corresponding to the navigation information of the image, and (5) integrating reality with navigation information. When the camera of a mobile device captures an image with augmented reality information, the recognition program would first process the image into a gray-scale image, detect the features and distribution of the image under identification, , simultaneously analyze the tilt angle and distance of the image and lens to normalize the 3D coordinates of the image, and take them as the basis for developing the rotation and scaling events and displaying 3D objects. Finally, the corresponding virtual objects, and their multimedia navigation information, would be searched by the feature distribution and 3D or multimedia navigation information of an image captured by a mobile device would be presented.

This system adopts Unity as the main development platform of the mobile navigation system, and imports Vuforia SDK of the QualComm Company and the mobile-device augmented reality development kits supporting the cross-platform development environment of Mac/PC/Linux. The implementation procedure is as shown in Figure 4. First, the features of the target image are analyzed using Vuforia AR SDK, which are saved in a Unity package format able to identify images; then, the corresponding tour information can be immediately accessed according to the records in the database. In addition, in the real-time imaging stage, the 3D or multimedia navigation information corresponding to an image is presented at the correct position and angle, as based on the angle and distance parameters of the image and lens, and OpenGL for Embedded Systems (OpenGL ES) integrated with a real-time image captured by a camera, is presented on the screen, thus, achieving the effect of the interlacement of virtual and reality, as shown by the final presentation result at upper right in Figure 4.

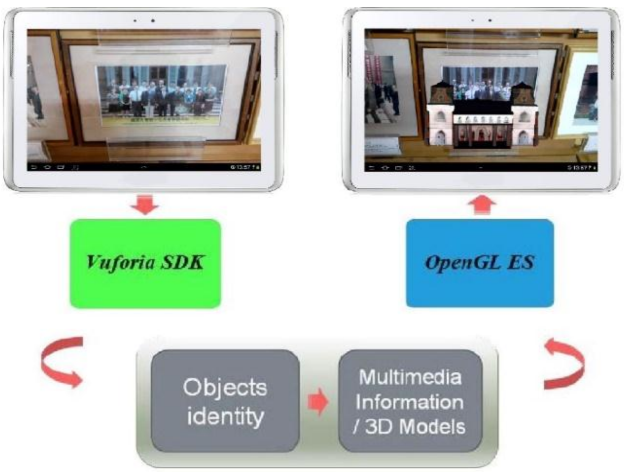

Fig. 4 Diagram of augmented reality implementation procedure

B. Indoor Positioning

The active RFID positioning function of this system mainly refers to the SLM positioning principle, as proposed by Wang et al. [12]. The Tamsui Oxford College is used as the testing location. The positioning mode is as shown in Figure 5. In the diagram, the yellow rectangles represent RFID Readers affixed within the exhibition space, and the red circles represent visitors equipped with RFID Tags.

First, the positioning environment must be arranged before conducting positioning, where the reference signal strength values of individual tags at different distances must be analyzed and set; then the SLMs of all positioning blocks are established, as based on the reference signal strength values, and stored in the database. During real-time positioning, the RFID Reader would upload collected signals to the server end in a real-time manner, where they are calculated into SLMs, search for the most similar SLMs in the database in order to fulfill positioning, and then, summarize and transmit the positions of members in the same group to the user's mobile device. Thus, the visitor is able to learn their and visiting group members' positions.

Fig. 5 Diagram of the indoor positioning mode

C. Group Communication

The group mobile navigation mechanism would provide varied functions, such as real-time communication among group members, exhibit information and position sharing. The procedure of identity verification would be run before the navigation system is operated in order that members of the same group could know each other's identity when entering a chat room for communication. In the process of navigation, if a group member sends a message, it would be first uploaded to the server end before being broadcasted to all visitors in the same group, thus, achieving the purpose of others not affecting the group conversation.

In the group message exchange server implementation part, this study used C# to write multi-threads in order to solve the problem regarding message passing in the case of a connection with multiple people. The message exchange server would record the users entering the chat server, and send the messages to all users connected to the same chat room in order to fulfill message exchange among group members. The mobile device end is connected to the server's IP and port, via a wireless network, for text message and image transmission. In the text message transmission part of this system, implementation is conducted by direct transmission of character strings to the server for re-broadcasting to all members. In addition, a user can share an image being currently visited to other group members. In implementation, an image displaced on a mobile device is directly captured and transmitted to the server in the form of encoded streaming, which is re-broadcasted to all members, and the members can decide whether to open the pictures shared by other people.

V. DEMONSTRATION

The development and demonstration platform of this system is Samsung Galaxy Note 10.1, with an Android operating system. The main interface of system is as shown in Figure 6. The red block on the left side of the interface is the group communication and information sharing area; the yellow block in the lower middle part is the navigation information display area; the blue block on the upper right side of the interface is the camera image and augmented reality navigation information exhibition area; the green block on the lower right side is the group position display map, where member positions and numbers are marked with yellow dots for identification convenience of group members. Moreover, group members can send the images of the blue, yellow, and green blocks to other group members, via the sharing function, in order to achieve a more effective group interaction mode.

Fig. 6 Diagram of main interface

Visitors can use the mobile device to identify certain pictures. Once identification is successfully completed, the 3D model (as shown in Figures 7 and 8) or video navigation material (as shown in Figure 9), which is related to the display item, such as antique’s name and introduction text, would be displayed, thus, allowing the visitor to learn more about the background data related to the antique.

Fig. 7 Example of on-site testing result

Fig. 8 Example of AR-3D model exhibition

Fig. 9 Example of AR-video exhibition

Moreover, the current positions of all group members would be continuously updated in the map information section of the lower right side. When intending to communicate with others, one can send a text or a current image on the mobile device to other group members through the text communication or image sharing functions on the left side. The message received by another group member would be displayed in the navigation information area, and that group member can choose to open the image or not (as shown in Figure 10).

Fig. 10 Example of information sharing

VI. Conclusion

A group augmented reality mobile navigation system supporting indoor positioning and group communication functions is proposed in this paper. In combination with varied technologies, such as marker-less image identification, active RFID indoor positioning, and group communication, this system allows visitors to directly capture and analyze exhibit pictures with a mobile device, further exhibit various multimedia and 3D navigation information, and determine all group members’ real-time positions through the map interface, which is convenient for finding group members and exhibition areas. In addition, this system supports text communication and image sharing functions to achieve a quiet and efficient group navigation mode. In the future, this system would attempt to combine multi-object augmented reality image identification and navigation recommendation technologies in order to further achieve a more diversified and elastic mobile group navigation system.

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