Exploring Location-Based Augmented Reality Experience in Museums

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Abstract. Augmented reality and beacon technology have gradually attracted considerable attention as the technology has matured, and is now applied in many areas, including museums. This study uses AR and beacons to develop a new museum tour guide app and then design the content and functions of the app based on media richness theory. The tour guide app is expected to provide immediate information guiding service and various education and entertainment functions that are more interactive. Finally, the present study measured the usability of the system by a mobile-specific heuristic evaluation checklist.

Keywords: Augmented reality · Beacon · Media richness theory · Mobile-specific heuristic guideline · Tour guide app · Museums

1 Introduction

Since smartphones have become popular, humans' lives have been closely related to apps (applications). Everything becomes more convenient via apps. Mobile devices are not only generally used in formal educations [1] but also in informal situations such as touring a museum [2]. Mobile guiding decreases the limits of visiting. Users can learn anytime they want by using their mobile devices because mobile learning is free from time and space, is low cost and is easy to access [3]. Also, mobile guiding can provide personal information according to different users' needs. Therefore, mobile applications have become a mainstream guiding technique today. For example, the "My visit to the Louvre" app developed by the Museum Du Louvre [4] contains 3D museum models, suggested itinerary, cultural events, 600 comprehensive descriptions of artworks and 600 audio commentaries on the artworks. The "British Museum Guide" app was developed by the British Museum [5], which contains HD images, the history of exhibits and an interactive map. The "Explorer: The American Museum of Natural History" app was developed by the American Museum of Natural History [6], which contains the function of sharing on social network, testing your knowledge and purchasing tickets. "The Metropolitan Museum of Art, NYC" app developed by The Metropolitan Museum of Art [7] contains the function of saving favorite art. The "Discover NPM" app developed by the National Palace Museum (Taiwan) [8] contains traffic Information, location services and funny games.

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1.1 Taking Advantages of Augmented Reality Technology in Museum Visiting Experience

Digital media definitely provides a lot of convenience, but sometimes people focus too much on the interaction between the human and the device and ignore the interaction between the human and the context. This has occurred in many museums with mobile guiding [2, 9]. For these situations, it is important to lead users' attention during the guiding process. Augmented reality technology that bridges the gap between the digital and physical connects the virtual objects created by computers and the real scenes [10] and improves the interaction between audiences and exhibits, and the knowledge becomes more expressive and interesting. The AR technology has been widely used in education, for example, to show the collision effects in a physics class [11] and the chemical reactions in a chemistry class [12]. Research found that the attractive method, such as an AR learning game for children, seemed to have a positive effect on children's long-term knowledge, as demonstrated by Zarzuela et al. [13]. Sommerauer and Müller [14] found that using AR technology in a museum can efficiently improve the audience's knowledge and considered that AR is a valuable technology in museum exhibitions. AR technology connects the real exhibits and the information from the past to the future, allows the museum visitors to be immersed in the exhibition via virtual objectives and environments, turns education into entertainment and creates different visiting experiences. Also, the AR apps can let museum visitors check the visual tour guides and information they need by using their everyday mobile devices.

1.2 Using Beacons to Enhance Location-Based Interactivity in Museums

In addition to the AR technology, museums have begun to use micro-location technology beacons to provide visitors new experiences. Instead of searching through an audio tour for the right section, with beacons providing accurate locations, an app can detect users' exact location and then offer them static or dynamic information about the exhibits. So beacons are very appropriate for museum guiding and can be used to create experiences that are more convenient [15]. Besides, compared with other indoor location technologies, beacons have the advantage of low energy and low cost [16]. Beacon technology has been used to set up an interaction system between users and exhibits in a recently study [17] in order to develop different interaction systems [18] and to promote learning or consumption by providing personal guiding information based on users' locations. The National Slate Museum in England developed the Slate Museum| Amgueddfa Lechi app in 2014 [19] and applied beacon technology to the museum so that visitors can use the guiding app to sense 25 beacons located in different places and then experience the information guiding service immediately via their mobile devices, and it is the first organization to use beacons in a museum.

1.3 Media Richness, Interactivity and Retargeting to Mobile Devices

Since museums improve the visiting experience through various digital technology nowadays and provide rich interactive education and entertainment functions, it is

important to clarify whether the rich information is correctly and effectively transferred to users and achieves the expected result. Media richness theory (MRT) is widely used to investigate the communicating ability of information. Media richness theory emphasizes that information and knowledge transferred by media can help the receiver understand information and new knowledge. It was used to investigate the communication between the members of a business organization and to evaluate the communicating effect of media with varying degrees of media richness. Recently, digital media and mobile devices have become common. MRT has been used to investigate the actual benefit of the Internet applied in organization communication [20], evaluate the learning effect of digital media and improve the satisfaction [21], use MRT and TAM to evaluate the usability of multimedia messaging service [22] and integrate MRT, TAM and flow theory to investigate the acceptance of students' digital learning by using streaming media [23]. In addition, the Formosa Plastics Group Museum (FPGM) applied MRT to build a digital museum (www.fpgmuseum.com.tw) in 2014, which prompted the museum to become a resource website that efficiently transfers education information and achieves the effect of distance learning [24]. Therefore, the present study will use augmented reality and beacon technology to develop a new museum tour guide app and then design the content and functions of the app based on media richness theory. The tour guide app is expected to provide immediate information guiding service and various education and entertainment functions that are more interactive. Finally, the present study measured the usability of the system by a mobile-specific heuristic evaluation checklist.

2 FPGM Pocket Navigator App Design and Development

The Formosa Plastic Group Museum chose 24 special exhibits from numerous exhibits on different floors in 2015 and developed 24 independent guiding apps that can be downloaded by a QR code to help visitors learn and better know the Formosa Plastic Group. But scanning the QR code to get the app is not intuitive enough today. Since new technology appears, such as AR and beacons, we would like to create a more instinctive guiding process via these new technologies. The Chang Gung University Digital Media Lab combines the AR and beacon technology, builds a new guiding system (FPGM Pocket Navigator) based on the digital context used in apps that the Formosa Plastic Group Museum created in 2015 and designs the guiding functions according to the media richness theory. The initial guidance will be triggered through image recognition or sensor beacons. The FPGM Pocket Navigator supports the official version of Android 4.4 or higher for all Android operating systems. It was published in May 2016 on Google Play for consumers to download (https://play.google.com/store/apps/details?id=com.fpgm.ibeaconguide&hl=zh_TW), and it is updated and modified constantly (Fig. 1). The system architecture of the FPGM Pocket Navigator is shown in Fig. 2.

Fig. 1. FPGM Pocket Navigator on Google Play

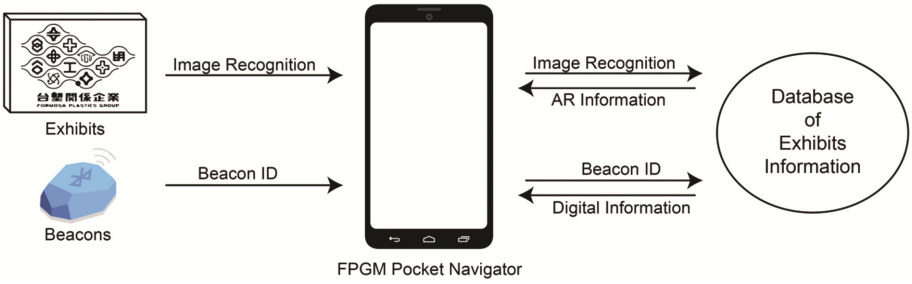

Fig. 2. System architecture.

The FPGM Pocket Navigator designs the functions of the guiding app based on four items of the media richness theory: Immediate Feedback, Multiple Cues, Language Variety and Personal Focus. It allows visitors to use the app in an intuitive way during their personal visiting, and the information will be conveyed more correctly and rapidly in order to approach the goal of education learning in museum.

2.1 Immediate Feedback

In order to strengthen the initiative hint and the interaction during the guidance, we integrate the AR and the micro-location beacon technology. We use different forms according to the exhibitions with different features. Users can use the AR camera aim for specific exhibits, and then the system will start the image recognition and show available information (Fig. 3). The beacons are used in those regional exhibits. When users are in range of the beacons' signal with the FPGM Pocket Navigator, the systems

will know which region the users are located and then immediately provide the exhibits' digital information to users (Fig. 4).

Fig. 3. Image recognition.

Fig. 4. Beacon locations.

2.2 Multiple Cues

The FPGM Pocket Navigator takes advantage of the initiative notification of beacons to provide the most intuitive guiding service. We set up beacons at the location of 24 special exhibits, the elevators on every floor and the main entrance (Fig. 5). The system will provide the available digital information right there and show where the user is on the map in a different color when he/she is in range of the beacons' signal. Besides, the system will automatically offer a map of the current floor each time a user reaches a different floor. Every time a beacon is triggered, the FPGM Pocket Navigator not only provides a clear hint on the user interface but also makes a sound to instruct users that something is available now. For every exhibit, the system provides text commentary, audio commentary, Facebook links, interactive questions and the unique buttons of each exhibit (Fig. 6). It allows users to contact the exhibits in many different ways.

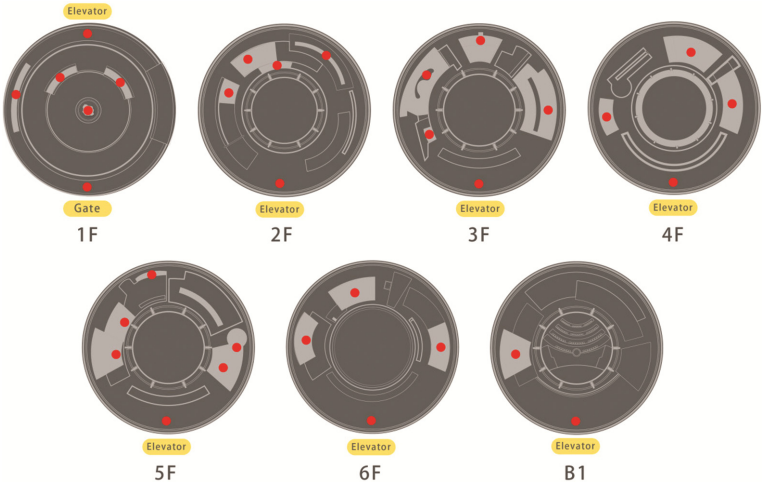

Fig. 5. Beacons in every floor.

2.3 The Audio Function Based on Language Variety

Language variety can be conveyed via signs. For instance, numbers can provide clearer meaning than natural language, and natural language can help the understanding of concepts and ideas. Therefore, the FPGM Pocket Navigator not only provides texts, images and realism, but audio commentary functions are also used in the system (Fig. 7). Through the guide's real speaking tone, the listener will be immersed in the situation and have a feeling of listening to a story, and learning will be more interesting in this way. In addition, the system has the function of interactive questions. It will ask users some questions and let them seek the answers on their own during the visit.

Fig. 6. Text commentary, Facebook link and independent button.

Fig. 7. Audio commentary and interaction question.

2.4 Leading Users by Personal Focus

Personal focus means that the message will be conveyed more completely when a person includes his/her own feeling or emotion. Some messages can be conveyed according to different users' needs or current situations. The FPGM Pocket Navigator can offer exhibit introductions according to users' current location. Besides, the system provides

introductions of each floor (Fig. 8). The user can rapidly understand the theme of each floor and quickly approach the region he/she would like to visit.

Fig. 8. Floor guides.

3 Validation

In the present study, we use 10 Usability Heuristics [25] for the User Interface Design, as proposed by Nielsen as the heuristic evaluation (HE) method because it is low cost, accurate and fast. HE is generally used to measure the usability of system user interfaces. However, with the continuously updating technology and devices, the traditional HE method is necessary to adapt to today's generation. Yáñez Gómez et al. [26] proposed a mobile-specific heuristic guideline according to today's generation, and they developed a modified version of heuristic evaluation checklists for mobile devices. We use the heuristic evaluation checklists for mobile devices to validate our tour guide system, but functions of the FPGM Pocket Navigator do not contain some of the items. So some subheuristics were removed from the original 13 heuristics in this study. We invited four experts: two of them are interactive interface designers and the other two are very senior museum staffs who work in the group of education promotion. The two interactive interface designers have the background of digital media design and the experience of interface design of mobile apps. One of the museum staff members has worked in FPGM more than 10 years, and the others have the experience of being guided for 8 years. The experts used the heuristic evaluation checklists for mobile devices to test the usability of the FPGM Pocket Navigator, exchange opinions and identify/discuss the weakness of the system. The results of the evaluation, based on 12 usability heuristics, were as follows:

(1) Visibility of the system's status: The FPGM Pocket Navigator can allow the user to understand the system's current status and which step is easier for the user.
(2) Match between the system and the real world: The visual element used on the buttons conforms to people's cognition. The users can understand it well without additional explanation, and it conforms to their logical thinking.
(3) User control and freedom: Users can use the functions for free, which are instinct and unlimited. They can check information they need whenever they want.
(4) Consistency and standards: The color, font and icons displayed in the system are consistent. The buttons with the same function will be located in the same position on the screen. Also, the texts, images and buttons perform in a fixed way.
(5) Error prevention: The size and the space between the buttons are appropriate. Users can easily tap the buttons, and the user interface design allows them to correctly understand the meaning without making mistakes.
(6) Recognition rather than recall: It is very intuitive to use the FPGM Pocket Navigator. Users don't need to perform special operations.
(7) Flexibility and efficiency of use: The functions in the systems are easy to operate and can be recognized easily.
(8) Aesthetic and minimalist design: The graphical interface design is clear and beautiful. Also, the system will not provide unnecessary information.
(9) Helps users recognize, diagnose and recover from errors: The system has some weaknesses in this part when the sensor is not working very well. Experts suggest that the system should inform the user about the interface when this occurs.
(10) Skills: Everybody has the operational abilities for this system.
(11) The help and documentation: The system offers the tutorial only once at the beginning. Experts noticed this situation. A good system should allow the user to receive tutorial information whenever he/she does not clearly understand all the functions.
(12) Pleasurable and respectful interaction: The interaction is interesting during the guidance so that the user can enjoy it.

4 Conclusion

Since new technologies also appear, the guiding method is also under constant innovation. New technologies provide various guiding methods but prevent the users from becoming confused after receiving too much information. It is important to lead users during the guidance. In this study, we currently use two popular technologies in museum guiding: AR and beacons are used to make guidance more intuitive and then investigative and measurable items are used from the media richness theory to design guiding functions. The usability of the system was tested by experts in the HE method. Experts affirmed the design of the FPGM Pocket Navigator and provided some valuable advice. The result demonstrated that the FPGM Pocket Navigator conforms to the usability standards and can provide a positive experience during people's visit with the FPGM Pocket Navigator. In the future, we will conduct further usability evaluations with audiences after fixing some issues according to experts' advice.

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