The Design and Experience Model of Mixed Reality Interactions in Museum

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Abstract
This study uses the display space in Li Tien-Lu Hand Puppet Historical Museum as the experimental field. By integrating iBeacon sensor technology and virtual reality technology into creation of a new experience of the hand puppetry culture, this study attempts to investigate the exploring behaviors and action strategies of visitors under the navigation of games. While seeking a balance between traditional display of artifacts and use of digital instruments, this study expects to facilitate two-way and spontaneous interactions between the museum and visitors. After implementation of the system, the ease of use of the system, user behaviors, and preferences are also analyzed. Finally, a gamifying museum with mixed reality experience design model is proposed.

Keywords：hand puppet; Gamifying museum; augmented reality; experience model

Introduction

Li Lien-lu Hand Puppet Historical Museum in Sanzhi District, Taiwan, was established in 1996 by the late hand puppet master, Li Tien-lu, with an objective to promote and preserve the traditional art of hand puppetry. (Lin, Shih, & Wu, 2015). Using technologies to provide interactive experiences has become a trend among major museums in the world that are seeking to create a stronger advantage through innovative operations (Ferrara & Sapia, 2013). The above examples manifest that development of mixed reality interactions in museums is currently based on application of technologies and multimedia. However, little research has probed into the appropriateness of integrating technologies into museum navigation or the value of new visitor experiences that can be brought by the integration (Davies, 2001; Pérez-Sanagustín, Parra, Verdugo, García-Galleguillos, & Nussbaum, 2016; Sylaiou, Mania, Karoulis, & White, 2010).

In this study, we will begin by designing a mixed reality exhibition environment to examine the interactive process of the navigation. Through measurement of system usability, observation of operational behaviors of users, and visitor preferences, we will further analyze the mixed reality experience model that integrates the concept of gamifying museum and evaluate visitors' experiences. The results can contribute to creation of new experiences of the hand puppet culture, continuous innovation of the museum, and better implementation of multimedia technologies in the future.

Literature Review

System usability scale (SUS) has been extensively applied to test of products, system programs, functional interfaces, and websites. Through quantitative analysis, it can produce reliable results with a sample of at least 12 people. It is a user experience-centered research method (Brooke, 1996). Consisting of 10 items, SUS can objectively evaluate a product or a system's performance on usability and learnability. Previous research has found among nearly 500 studies of consumption or business related issues that the average SUS score is 68. This suggests that a product or system with a SUS score above 68 ranks above at least 50% of all the products or systems compared. Hence, SUS can be used as an indicator of both user acceptance and usability (Bangor, 2009). However, the original wording of the SUS 10 items may be interpreted differently from individual to individual (Lewis & Sauro, 2009).

In addition to adding auxiliary explanations depending on participant needs, researchers are advised to use qualitative data such as behavioral observations and preference survey results while using the SUS. This can help them obtain substantive views and suggestions from subsequent modifications of the product or system.

Museum visitors' behaviors are mainly affected by the environmental factors of the museum. Even if museum visitors come from widely varying backgrounds, their behaviors generally conform to expectable models (Falk & Dierking, 1992; Nielsen & Landauer, 1993). In other words, if museum operators have better understanding of the expectable behaviors of their visitors, they can provide more satisfactory services. However, visiting route, lighting, content explanation, large interactive facilities, color, and atmosphere are still considered the primary environmental factors that

affect museum visitors' behaviors. As to the behaviors of visitors in museums that provide individualized multimedia-based navigation, more research is needed.

In today's museum exhibition practice, application of technologies is so prevalent that new display methods or devices are being invented from time to time (Hashim, Taib, & Alias, 2014). The goal is certainly to deepen visitors' impressions and induce their responses, and further recontextualize exhibits for audiences (Waidacher, 2001). Exhibit type is one of the important factors affecting visitor behaviors. Traditionally, museum exhibits are classified by text, post, cabinet size, lighting style, circulation route of the audience (Neal, 1976; Piccablotto, Aghemo, Pellegrino, Iacomussi, & Radis, 2015) or by presentation method (i.e. static or dynamic)(Miles, 1982). With increasing application of technologies, more and more museums classify their exhibits by presentation technology into lighting, audio, visual, and computer (Bell, 1991; Piccablotto et al., 2015). According to the Natural History Museum in London, the benefits of using multimedia to aid exhibition include (1) attract visitors, (2) retain visitors' attention, (3) arouse visitors' existing knowledge, (4) diffuse information to visitors, (5) encourage responses, and (6) provide feedbacks (Gosling, 1981). While traditional display methods have their irreplaceable value, using technologies to add value to museum exhibitions has become a trend (Eghbal-Azar, Merkt, Bahnmueller, & Schwan, 2016).

Research Design

In this study, the research site was the left exhibition hall on the second floor of Li Tien-lu Hand Puppet Historical Museum. There were about 30 display cabinets of different types in this exhibition area. After evaluation with our design concept and research needs, we selected only 12 cabinets to install iBeacon and designed the circulation route for visitors based on pre-arranged tasks.

The subjects were participants in a two-day Hand Puppet Workshop held on Aug 1-2, 2015. The participants included 8 students and 20 teachers at junior high or elementary school. They were taken to visit Li Tien-lu Hand Puppet Historical Museum, where the museum docent first gave them an introduction of the museum and basic skills of hand puppetry. Later, they were asked to fill out a pre-test questionnaire called "Preferences for Museum Exhibits". The survey result could provide an insight into their opinions about the types of exhibits in museum and be used for subsequent analyses. To minimize human interference, the number of visitors in each exhibition space had to be controlled.

The behavioral observation scale is intended to observe the types of behaviors that may arise during the system usability assessment (Lin & Fan, 2013). In this study, these behaviors were classified into "operational mistake", "misunderstand the question", "hesitate during operation", "fail to accomplish", "raise questions", "system problems", "failed trials", and "cabinet search model" which was added to record participants' performance in the mixed reality space.

The preference questionnaire was intended to understand participants' preferences for the "traditional display" model and the "digital interactions" model as well as expectations for services that a digital museum navigation system should offer. This questionnaire was designed based on the Interactive Experience Model proposed by

Falk & Dierking (1992) and previous research's views on traditional display and digital display of exhibits (Neal, 1976, Miles, 1982, James Bell, 1991, & Gosling, 1981).

Results

The overall SUS score was 68.8, or 52% after converted to a percentage. This suggests that the system's usability score was higher than the average 68 points (50%), and integrating mixed reality technology into Li Tien-lu Hand Puppet Historical Museum was acceptable by visitors.

Among the odd-numbered positive items, Item 7 (I would imagine that most people would learn to use this system very quickly) and Item 9 (I felt very confident using the system) received the highest average score, indicating using Tablet PC or other mobile devices as a medium of mixed reality interactive navigation is appropriate, because visitors can operate the APP based on their past experience of using the devices and become familiar with the gamifying museum model quickly. Using a familiar carrier device for navigation is critical to the SUS score. It can reduce anxiety and fear in users when using a new system and allow them to experience the system with confidence.

Among the odd-numbered positive items, Item 4 (I think that I would need the support of a technical person to be able to use this system) received the highest score, indicating that when integrating a technological innovation into the mixed reality space of museum, whether visitors can intuitively get involved in the interactions is important. The experience model should be self-descriptive. It should be designed in a way that allows users to know how to operate the system in their first use of the system. It should enable first-time users to identify or perceive through self-system the attributes, cultural factors, value, functionality, practicality, and other information the designers have intended to express by the system's design and interface (Almquist & Lupton, 2010). When the self-descriptive property of the system conforms to user perceptions, users will engage in voluntary exploration of the museum. Even without occasional or additional explanation or assistance, they can naturally gain the experiences that the mixed reality space is designed to offer.

Users' behaviors of operating the system were classified into 10 types. Each user might have multiple behavioral models in the mixed reality space. Through calculation of the frequency of each type of behavior, the strengths and weaknesses of the system could be identified. The result could fill the gap of the SUS in capturing the usability of each system function. From the 28 participants, it was found that "search by number" and "raise questions" occurred more frequently. Hence, the causes of these two types of behaviors had to be examined.

In the mixed reality exhibition space, the tasks were arranged with consideration of the locations of the cabinets. Users were expected to visit the cabinets according to the order of tasks. The mobile APP would provide users the number of the next cabinet to visit. Users had to find the correct cabinet before they could move on to the next game. This shows that users' decision over moving route and behavior of moving were affected many times by the instructions given by the APP. They unknowingly followed the circulation route we have originally designed for the gamifying museum.

This design of circulation route could be a reference for exhibition designers to overcome the difficulty of navigating visitors in large exhibition spaces or spaces without a specific movement direction. However, this model also reduced users' exploration of the museum. Users would habitually follow the instructions offered by the APP. They seldom had exploratory behavior or stopped at certain objects out of curiosity. In the future, the directions on circulation route should be progressively reduced to provide users an opportunity to choose exhibits to appreciate and explore on their own.

The question raising behavior occurred as many as 41 times. This is consistent with the relatively high score for SUS Item 4 (I think that I would need the support of a technical person to be able to use this system). This implies that the interface design is not intuitive enough or users were unfamiliar with iBeacon sensing technology. The loading time of data also affected users' experience and willingness to use. In Akamai and Gomez's research, nearly half of the users expected that data could be loaded within 2 seconds on their mobile device, and they might lose interest, patience and even become anxious when a site cannot respond in 3 seconds (Jacob, 2011). Therefore, it is necessary to let users have sufficient understanding of the system's operations so as to avoid repeated "question-raising" behaviors. One of the ways is to provide an introduction of the system design before they enter the mixed reality interaction space. Posters, unified verbal explanations or APP-embedded explanations can be used. The "user instruction" should be viewed as a part of the museum experience. This can prevent users from interacting with the museum in a state of confusion.

Presenting real objects in the exhibition can increase the value of attending a museum for visitors and shorten the distance between visitors and collections and even the entire museum. Hence, in application of mixed reality in museum exhibition, the focus can be placed on the core advantages of each exhibition model. The advantages of the traditional display model include "See the collections freely", "See the real collections", and "Intuitively understand the content of the exhibition". The advantages of the digital interactions model include "See the collections in interesting ways", "Novel experiences are available in the exhibition", and "The exhibition offers high interactivity". Exhibition designers can use these six items as a guideline to design an optimal combination of virtual and reality elements in the exhibition space and bring the best exhibition and services to visitors.

As to the digital museum navigation system, users' evaluation on a five-point Likert scale is as follows: 4.54 points for building a virtual map, 4.46 points for building a cross-domain platform, 4.18 points for recording data in the cloud. All the scores were higher than the average 3 points. For future developers of digital navigation systems, these items can be viewed as the required functions or the functions to be added in the systems.

Conclusion and Suggestion

In this study, we used the SUS, the behavioral observation scale, and a preferences questionnaire to explore the appropriateness of a mixed reality exhibition model implemented in a hand puppet historical museum. The findings are summarized as follows. These findings can be a reference for other museums when planning to implement the mixed reality navigation model.

(1) The SUS test showed that the gamifying museum navigation model implemented in Li Tien-lu Hand Puppet Historical Museum was a mixed reality navigation technology accepted by users.

(2) The gamifying museum navigation model affected users' decision over moving route. It could be used as a basis of circulation route design. However, it could also reduce users' spontaneous exploration of the museum.

(3) Before implementation of any technological innovation, it is necessary to inform users of how the system works first. Otherwise, users may raise questions repeatedly. Hence, it is advised to view "user instructions" as an integral part of users' museum experience. This can avoid them from interacting with mixed reality in a state of confusion.

(4) The traditional display model and the digital interactions model are complementary. Hence, the core advantages of the two models can be emphasized in the application of mixed reality in museum exhibition. The advantages of the traditional display model include "See the collections freely", "See the real collections", and "Intuitively understand the content of the exhibition". The advantages of the digital interactions model include "See the collections in interesting ways", "Novel experiences are available in the exhibition", and "The exhibition offers high interactivity". These advantages can be utilized to design an optimal combination of virtual and reality elements for visitors.

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