Exploring the Application of Serious Game Based on Augmented Reality: A Case Study on Tsingtao Beer Museum

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Abstract. This work aims to explore the feasibility and significance of serious game based on augmented reality in museums, and approaches its effect on the experience of visitors. Depending on the status of museums and the characteristics and advantages of AR serious game, the article demonstrates that the experience and the follow-up purchase intention of visitors can be enhanced by improving the interestingness, learning and interaction of visiting museums, and setting up personalized mechanisms. Taking Tsingtao Beer Museum as an example, we designed a game concept prototype and described the method of game development. Finally, the article proposes the prospect and significance of further study on the application of AR in museums.

1. Introduction

As a significant part of the national economy, tourism has unlimited potential while developing vigorously. The data issued by National Bureau of Statistics [1] has shown an annual trend of growth in the number of visitors of museums in China. In 2017, the number of visitors of historical relics institutions in China has reached more than 1.1 billion, including more than 0.9 billion of museum visitors. “We’re heading to a golden age of relics and museology,” said Dr. Jiang Hu, the vice curator of Shanghai Museum. [2] Meanwhile, the 21st century poses some challenges to the relevance of museums and museums have to strive hard to avoid coming across as inaccessible ivory-towers [3].

AR technology creates a blend between the real world and the digital, bringing the digital 3D objects literally in our hands [4].

Taking Tsingtao Beer Museum as an example, in this paper, the authors reviewed the previous studies in the field of cultural institutions to understand the application and development of AR in museums, investigated whether the use of serious games in museums can engage the experience of visitors transfer cultural knowledge as side effects to the visitors in the process. On this basis, combined with augmented reality technology, we designed a serious game prototype in Tsingtao Beer Museum, analysed and summarized the level of the game prototype to solve the problems in traditional museums and the ability to enhance visitor’s experience. Finally, we proposed the plan of game development and future work.

The remainder of the paper is organized as follows: section 2 provides a literature review of the application of AR in museums, the related experience and serious game based on AR; section 3 describes the investigation of Tsingtao Beer Museum; section 4 mainly introduces the flow and the development of our game; section 5 discusses the differences between traditional visit and visit with the game in 6 factors; section 6 outlines the conclusion and section 7 discusses the future work.
2. Literature review

In recent years, the construction of museums in China has developed rapidly. In 2017, the Cultural Technology Innovation Plan [5] presents that “fully facilitate the integration of scientific technology into the cultural sector”. In order to conform with the trend of times and alleviate problems in the construction of museums, an increasing number of museums begin to use new media to reform and innovate [6]. AR is the practice of dis-playing digital information over people's real-time view of objects, people, or spaces in the physical world [7]. It has become an efficient, automatic, and playful method towards the appreciation and understandings of tangible and intangible cultural heritage [8]. The use of AR was found to not only bring history to life, but also actively engages visitors and facilitates the gathering of new information [9]. However, there are also some important restrictions in the use of AR be found. For instance, the special conditions of museums (e.g. artificial markers cannot be used, small, crowded rooms, etc.) and the limited computational capacity of smartphones [10]. Thus, there is a need to study areas relating to the application of AR in museums and find a way to combine museums with AR.

Museum tourism, like heritage tourism, is viewed to a great extent as an experiential consumption [11]. Though the combination of AR and museums has been put into practice, study indicated that museums in China are overall in an early transitional period in terms of the adoption of, and the development of cultural technology appropriate for visitor access [12]. Study showed that AR has the potential to influence the experience of museum visitors significantly and positively [13] Besides, in terms of the subsequent impacts, AR-enriched user experience produces higher perceived value [11], and user satisfaction [14]. Thus, Chen et al. [11] establish a relationship “experience quality / perceived value / satisfaction / behavioral intentions”. It is noticeable that individuals have different approaches in the way they forage, retrieve, process, store and recall information, so the adaptive and personalizing mechanisms should be proposed [15].

Investigations reveals that participants often have a preference for, and expectations of “interactive games” and “Interactive Exhibit Design” [12]. In addition, serious games have been proven to be a source of enjoyment and, if well-made, are a powerful tool to communicate knowledge [16]. The study pointed out that the game facilitated a wider exploration of the museum [17]. Therefore, serious games may be a good way to combine AR with museums, which can also enhance the experience of visitors.

3. Investigation of Tsingtao Beer Museum

3.1. Tsingtao Beer Museum

The investigation is based on the case of Tsingtao Beer Museum, which is a comprehensive topography museum of history and art. The museum is the only beer museum in China. Its exhibition area is more than 6000 square meters which is divided into three parts: history and culture, production technology and multi-functional area. The museum is located in the old workshop and with old equipment of Tsingtao Beer a hundred years ago. It concentrates the historical development of beer industry in China, based on the centuries' history and techno-logical process of Tsingtao Beer, integrating cultural history, production process, entertainment, creative shop- ping and catering, which is intellectual, entertaining and engaging.

For matching up the visiting process of production technology, we understand the current information and process of the museum with the guide map (see Fig. 1). There are two topographical problem can be summarized from the map: some spaces are narrow, and the processes are too many and confusing.
3.2. Online comments
In order to gain a preliminary understanding of visitors’ experience in Tsingtao Beer Museum, the online comments from several digital travel platforms were collected and translated from Chinese to English. Here are some of the online comments on the touring experience in Tsingtao Beer Museum which can represent many other similar comments (see Table 1).

| No. | Comment |
|-----|---------|
| 1   | “We were deeply impressed by the cold beer and beer beans in Tsingtao Beer museum, everyone received and ate them. The museum provided beer twice, but the second time we don’t want to drink without beer beans. But the beer crafts and exhibits were a little boring and the arrangements are jumbled.” |
| 2   | “Visitors rarely stopped to understand and appreciate the beer history or equipment. And there were many people so that it’s crowded. I can’t remember an exhibit that brightened my eyes in the journey. However, it was the beer that made me feel fresh.” |
| 3   | “I like travelling, especially the ones about history and this is my second time to Tsingtao Beer Museum. I’m here to have a glass of beer at 10 degrees Celsius, and to make some like-minded friends. The Tsingtao Beer Museum introduces a lot of knowledge about the production of beer. It’s great, but I haven’t found difference from the first time I came here. I think it’s time to change.” |
| 4   | “The introduction of cultural relics in the museum is too rigid. At last, I want to buy some souvenirs, but the expensive price stopped me. It’s a pity that I haven’t understood the whole production flow of beer after visiting.” |
| 5   | “Tsingtao Beer Museum is famous for the production of beers. And the most happiness thing is that my family came here to have a glass of beer. We understood the raw material and process of beer together, and the instructions of the exhibits were easy to understand, but the words are so boring that I didn’t want to read.” |

Summarizing these online comments, we can extract some common words that the visitors have used to describe Tsingtao Beer Museum: crowded, boring, narrow space, cannot remember, jumbled arrangements and expensive price (if the visitor pay for it). It is worth noting that most visitors
mentioned the free beer pleased them. Therefore, there are both advantages and frequently mentioned problems on the experience of Tsingtao Beer Museum.

3.3. On-site investigation

In order to examine the needs of visitors in Tsingtao Beer Museum further, we went there to interview both the visitors and the stakeholders of the museum (see Fig. 2). A questionnaire is designed to investigate visitors’ needs and their experience in Tsingtao Beer Museum.

![Figure 2. The on-site interview with several visitors and an on-site staff in Tsingtao Beer Museum.](image)

100 questionnaires (adapted from Fenu and Pittarello [18]) were sent out in total at the exit of the museum (where is a bar for visitors to drink), and 91 questionnaires were finally collected.

From the analysis of the survey we can obtain an overall idea of the profiles of the users who engaged in the experimentation. Most of the visitors (70%) were between 18 and 45. Many people (about 55%) visit the museum for entertainment and viewing, 75% of them spent 2 hours or less visiting the museum. Based on existing exhibition form, visitors showed little interests in history and technology.

The latter questions were designed on problems in most museums, and the feedback has been collected. The experience of visitors in the museum has been analyzed, and based on these data, factor analysis is carried out with SPSS. The result of factor analysis is shown in the table. (see Table 2)

| Factors |
| --- |
| F1 |
| F2 |
| F3 |
| F4 |
| F5 |

| Factors | Communality | Mean value of factor load | Name |
| --- | --- | --- | --- |
| F1 | 0.625~0.684 | 0.527~0.729 | Interestingness |
| F2 | 0.567~0.632 | 0.554~0.735 | Transmission efficiency of knowledge |
| F3 | 0.568~0.649 | 0.583~0.676 | Satisfaction degree of personalized service |
| F4 | 0.577~0.610 | 0.566~0.763 | The science and technology in exhibition |
| F5 | 0.516~0.565 | 0.558~0.692 | Immersion |

According to the results of factor analysis, the cumulative contribution rate of these five factors is 56.01%. Therefore, we can conclude that the main problems of visitors exist in these aspects. The main requirements of visitors for the exhibition in museums are interestingness, transmission efficiency of knowledge, satisfaction degree of personalized service, the science and technology in exhibition and the immersion. The results provide the data basis for the next design.
3.4. Exploration of technology
Based on the literature review and the actuality of Tsingtao Beer Museum, the authors find three key problems.

Firstly, the difference between Tsingtao Beer Museum and other historical museums is that visitors can observe closely as well as touch the tools to understand the production flow, however, most visitors cannot emerge with a full-fledged concept of the production flow after visiting. Visitors can’t experience a complete process because of the limitations in the museum. However, the problem can be solved by using AR. Therefore, it is necessary to present the production flow that these visitors want to know in an appropriate context, and recreate a cognitive and emotional link with the author and the place they visit [19].

Secondly, the exhibition in the museum lacks personalized service. Due to the museum is rebuilt from the old factory building of Tsingtao Beer, it is difficult to solve the problems about the settings of exhibits and topography in the museum by existing technology. Tsingtao Beer Museum has a large number of visitors, it is necessary to set the display in the open, but the practical halls are narrow (because the equipment was not built for visiting, but for the production in the old days). Thus, there is a possibility to design personalized tour route by using AR to solve the problem.

Thirdly, the guide in the museum is not clear enough. Visitors are difficult to know their positions as well as the progress of the visit. In this situation, visitors can’t remember and classify the contents in the museum. Thus, it is in accordance with the rules of people’s memory if location information can be added in the process.

3.5. Conclusion
In conclusion, here are the needs of visitors in Tsingtao Beer Museum which are most important: better interaction and more interesting, learning in an enjoyable and relaxing process, a clear and appropriate system for guiding.

4. A serious game based on AR
Aiming at the result of our investigation, we designed an augmented reality serious game prototype based on mobile devices in order to find a way to address the needs of visitors in Tsingtao Beer Museum and improve the overall touring experience.

4.1. Game prototype flow
“Finding” is a serious game prototype based on augmented reality. The equipment and tools displayed in the production flow hall can be recognized by the user's camera to carry out the game, which encourages them to collect relevant clues and knowledge from the exhibition. After getting the definite information, visitors can interact with the game and get real-time feedback. After their tour, they can get some coupons for souvenirs which engage their experience and intentions to purchase. Hence, the game meets the needs of visitors for interestingness, as well as learning effect.

Visitors should choose the tags they are interested in first to determine an appropriate game them (there are five different game routes in total, system will match the latest similar one with the tags according to the user's choice). After that, visitors can explore the museum according to the hints, which gives them a lot of space where both interestingness and knowledge can be reflected. What’s more, visitors may work together when meet problems which creates opportunities to interact with others in reality.

In order to design a complete AR game, the logical flow between the main pages is shown as follows. (see Fig. 3)
Fig 3. Low-fi prototype illustrating the game flow of the mobile augmented reality game Finding.

Tags selection: In order to meet to preferences and needs of different visitors, five different game routes in the prototype are designed in the background (For example, there are differences in the number of checkpoints and the content displayed on each page between users who choose history and learning and users who choose technology.), and a most appropriate game will be chosen by system according to the tags that visitors choose.

Scanning: After selecting the interest tags, users can visit the museum and enter the scanning page, which will prompt users to find the target. According to the real production process of beer, visitors need to complete the game items which are set in each process step (Scanning in each exhibition hall). Each step in the overall process is shown at the top of the page. Users can know their real-time location and progress according to the status bar, and enjoy the game and memory better.

Dragging: A pop-up tip will be displayed if users scan the specific equipment, which shows the required material or conditions of the corresponding tool. Users can complete the task by dragging and pulling the correct material (barley is the material needed in fig. 3) or conditions onto the equipment. Visitors can experience the pleasure of brewing and create an environment-friendly interactive experience by throwing in the mock raw materials.

Animation of beer: When user drags the materials or conditions onto the corresponding equipment, the collider on the equipment will be triggered, then corresponding animation will be displayed. The wort rolling in the equipment is showed in fig. 3. At the end of each operation, users will gain real-time feedback, which simulates the changes of raw materials in beer brewing process.

Scanning: After the displaying the animation, users will receive the next task (scanning the next equipment).

Finally reward: Ultimately, users can get some reward when they complete all the tasks based on their completion accuracy.

4.2. User journey map
A user journey map illustrating the visitor’s experience with the mobile augmented reality game in Tsingtao Beer Museum was drawn (see Fig. 4). With the game, visitors can learn in a relaxing and interesting way. Due to the personalization design, they can visit with their own touring route and interest. Besides, the different experience engages and rewards can influence their intentions to purchase.
4.3. Game prototype development mode

In order to develop our design into a mobile application in the future, we have learnt and mastered the necessary technology, and then chose EasyAR SDK Pro (an augmented reality engine that supports 3D object tracking and generates dynamical tracking targets from standard .obj model files) to achieve AR features. We need to obtain the .obj model files of the equipment firstly to identify the equipment in the museum as a 3D Object Target (the object that be detected and tracked). And the models are got by Maya. What’s more, at least one material image should be imported to the models so that the 3D objects can be identified the tracked in the hall, which is different from most existig image Target recognitions. Ultimately, we'll develop demos in Unity in the future, the model is as follow (see fig. 5).

![Fig. 5. High-fi prototype illustrating a main part of the game flow.](image)

4.3.1. Interaction. We have made many comparisons on how to realize the interaction between AR objects and visitors. And we chose to use the Lean Touch plug-in finally, which allows visitors to control the position, size and rotation of the objects in the game better. In this way, the game elements can interact with visitors well and have rich interestingness. Visitors can achieve the goal easily by habitual gestures in daily life. In Blender, we will build the prototypes (such as hops, barley and so on) which we need to use as sub-objects of 3D Object Target. What’s more, we need to add some C# scripts to realize some UI attributes such as drag and zoom to be used by visitors.

4.3.2. Award mechanism and data collection mechanism. After the game, according to the setting of award mechanism, system will compare the materials and equipment chosen by users with the standard process. Different number of coupons (from 20% to 50%, which will be obtained from the museum) in souvenir shop will be presented to users based on the consistency of the data. The aim is
to test the intentions of visitors to purchase the cultural and creative products, for the psychology to take advantages. Every visitor's game data will be transmitted to us through mobile network or wireless network, so as to iterate and update in the later stage.

5. Discussion
We extracted and analysed the factors related to visitors in the game prototype. They are: 1. Degree of knowledge about craft exhibits; 2 The interestingness and entertainment of visit; 3 Degree of personalization; 4 Interaction experience with exhibits; 5 Intention to purchase souvenirs; 6 Desire to advertise (share with others) the museum. Based on these factors, comparing with the existing museum visiting mode, it can be found that visitors can interact with exhibitions joyfully through AR game. Besides, the immersion and experience of visitors will be greatly improved. For the benefits of museums, the application of AR games will increase the sales of souvenirs and attract a number of visitors. In the future, the application of AR games will have a better situation.

6. Conclusion
This paper describes the design and evaluation of a serious game prototype in museums based on augmented reality. Depending on the results of previous research in the field of cultural institutes and the investigation of Tsingtao Beer Museum, we discussed the key problems that can be solved by AR and the effect on visitors' experience with serious games based on AR.

In the game prototype we designed, the traditional visiting mode in museums has changed, which has opportunity to enhance the visitor's experience in many ways. Visitors can explore while learning knowledge in an interesting process (different from imparting knowledge). What’s more, visitors can reach the peak of emotional experience in stages (getting real-time feedback when interacting with exhibits). In this process, visitors play with their own personalized routes to ensure that each visitor gets the best experience as far as possible. People can also communicate and cooperate with others at the same level, which can promote potential social interaction.

Nevertheless, there are some key factors that we must pay attention to. For example, the limited time and energy to engage in virtual games to some visitors. Hence, in order to avoid the unpleasant misunderstandings and troubles which may reduce the travel experience when using AR, the design should be more intuitive and relatively simple to attract more visitors.

7. Future work
Due to the constraints of resources, we have only designed the concept prototype of the game for the time being. In the future, we will continue to explore technology and develop the game as a complete augmented reality game based on mobile devices. Because of the uniqueness of each museum, this paper can only be used as a reference for other museums. The future game mechanism will be more intuitive and easy to understand. The on-site test will be conducted to bring greater improvement to the experience of visitors. At the same time, the con-ten-t of Tsingtao Beer Museum will be better combined with augmented reality games, so that to play the role of theory and games in other fields. Next-generation technologies such as Augmented Reality are fast permeating many society sectors. Their market is projected to reach $95 billion by 2025, representing a large portion of the economy within the next decade [20]. With the coming of 5G era, high-speed and low-latency data transmission methods will give rise to more applications of augmented reality. Thus, it is of great significance to study augmented reality in museums.

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