Study on Mobile AR Guide System to Enhance User Experience in Cultural Heritage Sites

Jiamin Ping, Yue Liu, and Dongdong Weng

***Abstract*—An outdoor mobile Augmented Reality (AR) system that integrates location-based navigation and puzzle game as an auxiliary tool for user experience in cultural heritage sites is designed. The proposed system is developed to provide learning information about cultural heritage sites and allow participants to interact with both virtual and physical objects. To evaluate the performance of the proposed system, an experiment is conducted in an actual cultural heritage site. The experiment is to compare the performance between the AR group and the non-AR group of participants in terms of learning effectiveness, focusing time, direction awareness, and the performance of the system. The performance factors include navigation accuracy, easiness of system, interaction naturalness, attraction, immersion and participants' attitude towards the AR system. The evaluation results show that the AR system can enhance participants' learning effectiveness and extend focusing time comparing to the non-AR system. Besides, it can improve participants' direction awareness in visiting cultural heritage sites. The AR guide system is more interactive and participants in the AR guide group can comprehend more content about the physical environment. The AR guide system is proved more attractive and interesting. Most of the participants think that the AR guide system is a better approach to navigation.**

***Keywords*- mobile AR; user experience; AR guide; cultural heritage.**

I. Introduction

Yuanmingyuan was an imperial summer resort in recent China, which was built continuously by several emperors of the Qing Dynasty for more than 150 years. It consists of three parks and occupies about 350 hectares. Unfortunately, it was looted and burnt down by the Anglo-French forces in 1860 and suffered from continual damages later on [1].

Due to its special significance in Chinese history, the reconstruction of Yuanmingyuan has been argued for a long time and visitors can barely get the historical information of the sites. The existing guided system in Yuanmingyuan only adopts traditional audio introduction about the sites and are designed with no entertainment and interactivity. Thus, an auxiliary tool to enhance user experience in such a situation is needed. The synergy of new mobile devices, AR and context-awareness have the potential to enhance users' experiences [2].

The significant of the background of Yuanmingyuan is very important in history learning. The immediate need for attractive and interactive emerges, as the sites seem very poor for users. Games have the potential to build effective learning environments [3]. The importance of exploring meaningful learning has been elaborated and active learning games can be played in the real world with the support of digital devices. Digital Game-based Learning (DGBL) has widely been used in learning. It is perceived as a potentially engaging form of supplementary learning that could enhance the educational process and has been adopted at all levels of education [4]. Research on mobile game-based learning tends to focus on the motivational effects, and found that it provides highly motivating learning experiences [5].

Users usually shuttle back and forth in different scenic spots in Yuanmingyuan to gain more information. Navigation plays an important role while touring. A mobile guided system can save time on the road between two scenic spots. Location-based augmented reality system has been developed for specific real-world locations which include historical or geographical sites [5]. Location-based technologies provide opportunities to embed learning in authentic environments and thereby enhance engagement and learning outside traditional formal educational settings. Mobile AR guided systems have been widely used in tourism in the field of city view [6], cultural heritage [7], or other large public activity areas such as shopping mall [8], art museum [9]. They can provide interactive annotations which are integrated with map-based services and additional information, and provide access to location-based information, relevant to the immediate surroundings of users [2].

Considering the historical background of cultural heritage sites, this paper introduces the development of an outdoor mobile AR guide system combined with the form of a puzzle game. The AR guide system aims to enhance the user experience by interacting with several represented scenic spots. It can not only guide users to different scenic spots, but also present more information about Yuanmingyuan while they are using the game based mobile AR guide system. Users are confronted with the problem that they have

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no idea about how to view the scenic spots efficiently because of the uncertain route plan when visiting a park. The task design in the puzzle game is based on a traditional story, inserted the story plots into the scenic spots to enhance the understanding of the historical information. A user study is conducted to evaluate performance factors of the mobile AR guide system, including learning effectiveness, focusing time, and direction awareness. Besides, navigation accuracy, easiness of system, interaction naturalness, content comprehension and users' attitude towards the AR system are also evaluated in the user study.

II. Literature Review

The proposed system combines the factors of mobile AR guide and DGBL, and then the user study is conducted to evaluate the performance of information acquisition and the system itself. The literature review is described in terms of these areas.

The research on AR has so far mostly focused on the development such as display technology [10, 11], and algorithms for identifying and tracking real-world objects to integrate the real and the virtual [4]. The advances in mobile computing, computer graphics, wireless and sensor technologies allow for the fast development of Augmented Reality (AR) applications on mobile phones [2]. There have been corresponding developments in mobile entertainment media, with numerous projects aimed specifically at creating GPS-based tour guides for historic locations [7]. Mobile AR guide systems have been used in many areas, such as cultural heritage [7, 12, 13], art museum [9, 14-17], shopping center [8] and types of outdoor AR game [14, 18, 19], safety and emergency [20, 21], education [5, 22, 23], AR view and navigation [1, 6, 10, 24-26].

The studies on applying mobile AR technology to navigation system in the context of a tour, while the tourists moving within a cultural site are emerging. The findings in [9] show that augmented reality technology applied in the navigation system can not only improve the motivation and participation of the tourists, but also create a realistic and novel learning environment via the combination of the real and the virtual. An AR guide system is installed in historical sites in Portugal and in Belgium's Ename Center, helping visitors to visualize how an actual site have once looked like [12]. City View AR is a mobile outdoor augmented reality application for providing AR information visualization about destroyed buildings and historical sites that are affected by the earthquakes on a city scale [6]. A mobile navigation system that combines a linear tour with in-depth information exploration for cultural tours is built in [7].

DGBL is widely used in learning. Many types of researches explore if learning in games can enhance user experience using mobile AR technology. In [5] the effects of a mobile city game called Frequency 1550 are investigated in terms of pupil engagement in the game, historical knowledge, and motivation for history in general and the topic of the Middle Ages in particular. DiedricAR aims at the learning of Descriptive Geometry and allows students to learn in an autonomously way by using their own mobile devices. This work explores the potential benefits for students' spatial ability, the relationship between application design and user experience [22]. A mobile application using visualization and AR technology is designed to learn multimedia models of objects and astronomy [23]. The pilot study shows mobile AR application is a suitable tool for learning in terms of students' interest, cognitive activity and learning effectiveness.

The most frequently studied effects outcome with games for learning are knowledge acquisition and content understanding, followed by the perceptual and affective and motivational skills and perceptual and cognitive skills [4]. There are three categories of desired outcomes: learning outcomes, motivational outcomes and efficiency outcomes [27]. The learning outcomes include increased interests in the subject matter and improvement in performance. The motivational outcomes include enjoyment and increased motivation to learn. Time management is one of the important factors of efficiency outcomes.

User experience takes a broad perspective on the user's interaction with a system [8]. The foremost goal of user study is to enhance and enrich user experience, knowledge acquisition, content understanding, user task performance or other usability-related aspects, or to provide usability-oriented guidelines for design. Another goal of user study is to evaluate the performance of the system such as the technical demonstrators, the ease of use, content effectiveness, and then provide live feedback for the design of such system [28]. The main evaluation method includes a pre-test, training before experiments and video recording during the experiment, questionnaire and interview after the experiment.

Many studies focused on how the mobile AR system enhances user experience and satisfaction [7] [9] [8] [19] [12] [29] [5] [30]. A quasi-experiment is adopted to evaluate the knowledge acquisition [5]. The RTC experiment is performed to assess the learning effectiveness and student motivation using pretest and posttest, questionnaire and observation [30]. Several learning performance factors of the museum visitors who are aided with AR and non-AR guided modes is evaluated. The factors include learning effectiveness, flow experience, the amount of time spent focusing on the painting, behavioral patterns, and attitude of using the guided system [9]. A user study is conducted in [8] to catalyze users' sense of efficiency, empower them with novel context-sensitive and proactive functionalities and raise their awareness of the information related to their surroundings with an intuitive interface. W. Woo [7] gains an understanding of how sharing information during visits to cultural heritage sites by socially related people influences the visiting experience; differing mutual eavesdropping and content control behaviors emerged according to group types.

To evaluate the performance of AR system, most researches focuses on the task error, task time, test score, and designed questionnaires [6] [15] [10] [11] [18]. Users response to AR viewing and non-AR viewing are compared [6] using a mobile tourism system to demonstrate that the AR view helpes to understand the changes due to the earthquakes through online survey and questionnaires. The accuracy, effectiveness, efficiency and usefulness of an AR micro aerial vehicles fly system are evaluated using questionnaires and recorded video, which supported navigation and flight planning by augmenting the users' view relevant information [10]. A user study about the AR guide prototype in the museum is conducted through questionnaires and video recording, which showed that the navigation and content are effective [15].

III. Methods

AR technology can be created by utilizing and connecting various innovative technologies (e.g., mobile devices, wearable computers, and immersion technologies). Similar to many innovations, the educational value of AR is not based on the use of technology. Instead, it is closely related to how AR is designed, implemented, and integrated into formal and informal learning settings [31].

A. System development

The mobile AR guide system is designed to integrate tour navigation in a cultural heritage park with a puzzle game. The system description of the system has been shown as a poster in VR 2016 [32]. The puzzle links in the game are presented through AR technology, GPS based navigation and sensor-based interactive technology. Six scenic spots are chosen in the tourist route which is marked with stars and red numbers as shown in Fig.1.

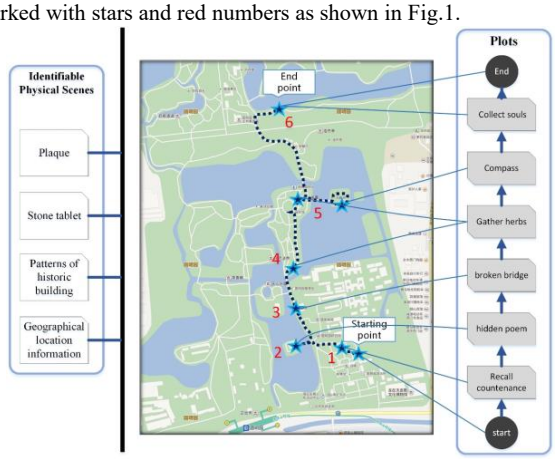

Fig. 1. The design scheme of the mobile AR guide system.

The application takes advantage of built-in sensors on mobile phones such as camera, the gyroscope and GPS to recognize an image, identify the direction and get geographical location information. The system shows information using different visualization methods as shown in Fig.2, including AR and interactive digital map. There are 6 interactive modes, i.e. 2D interaction of touch, 2D/3D interaction of gyroscope, 2D/3D interaction of AR, the interaction of information between physical and virtual scene.

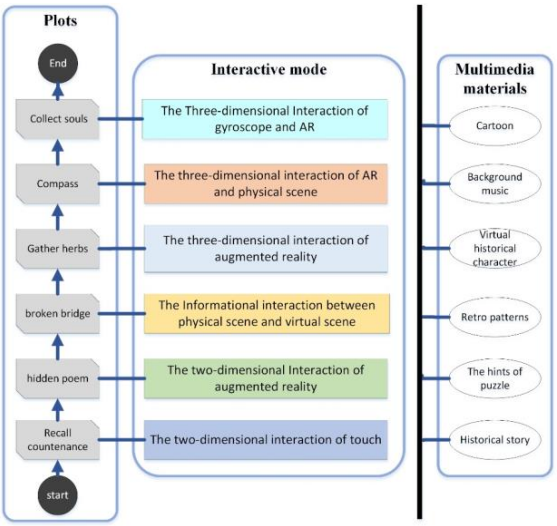

Fig. 2. Interactive mode and multimedia materials.

The proposed mobile AR guide system is developed in Unity 3D, when the plugin named Vuforia is employed to implement the AR functions. And the participants play the game in a mobile phone carrying Android system developed by Google Inc. The physical objects which are chosen as a marker are recognized by the mobile camera, and then the virtual information and objects are added to the physical objects. The proposed system contains six tasks distributed in six scenic spots shown in Fig.1. Participants are required to find out the hints in scenic spots step by step according to the tourist route in the park. The hints are presented with visual and audio information.

B. Scheme design of the system

1) AR design

Task 1: Face features

Hua, the protagonist of this love story, once fell in love with a prince named Tang during her lifetime. Now Hua forgets Tang's face, the first task is helping Hua recall Tang's countenance according to certain hints of facial features. Participants are guided by the proposed system to the first scenic spot with the map as shown in Fig.1, accept the task and change the eyes, nose, mouth as shown in Fig.3. Task 1 is designed to strengthen participants' impression of information using 2D touch interaction.

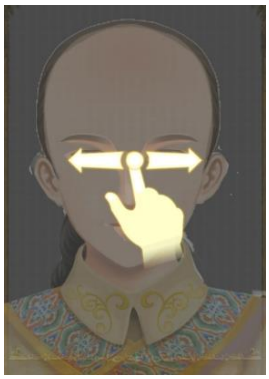

Fig. 3. The facial feature in task 1.

Task 2: Hidden poem

Tang writes a poem for Hua to ensure the dating place, which is on one door of a pavilion in the third scenic spot. Participants need to help Hua find out the poem by scanning every door. After participants scan the right door, an image will be shown on the screen to indicate the dating place as shown in Fig.4. The puzzle in task 2 is designed based on a poem, which aims to strengthen the impression of the scenic spot using 2D AR interaction.

Fig. 4. The hidden poem in task 2.

Task 3: Broken bridge

While dating in the park, Hua falls into a pool accidentally on a bridge. Tang gathers herbs in two places to save Hua. Participants

move to the scenic spot 4 and are expected to find out the broken bridge to evoke Hua's memory. Meanwhile, they should solve a number puzzle as shown in Fig.5b according to the hint on a stone tablet on the bridge as shown in Fig.5a, which contains background information of Yuanmingyuan. Task 3 is designed to divert conventional learning to innovative learning through informational interaction between physical and virtual scene. If participants want to solve the number puzzle, they must interact with the tablet.

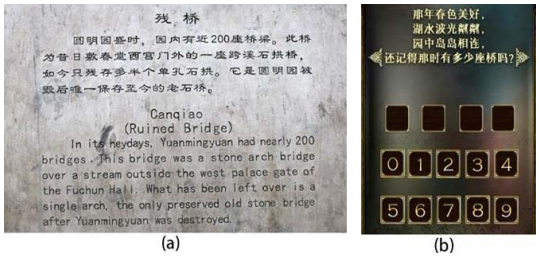

Fig. 5. The stone tablet and number puzzle in task 3.

Task 4: Gathering herbs

In this task, participants help Tang to gather various herbs scattering in two scenic spots which are located in red number 5, 6 as shown in Fig.1. We choose several representative stone tablets as the physical markers as shown in Fig.6, allowing participants to collect herbs through 3D AR interaction. A 3D model of herb will grow up on the screen while participants scan the corresponding stone tablet with a mobile camera as shown in Fig.6a. Task 4 is designed to enhance physical information in scenic spots using 3D AR interaction while solving the problem of gathering herbs.

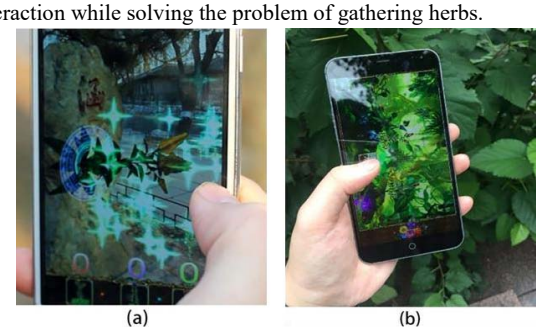

Fig. 6. The physical marker and virtual herb in AR game (a) and non-AR game in task 4.

Task 5: Compass

Participants need to find numerical hints in scenic spot 7 in Fig.1 to solve the puzzle of the compass as shown in Fig.7a. Task 5 is designed to collect physical information and comprehend deeply about scenic spot using 3D AR interaction while solving the puzzle.

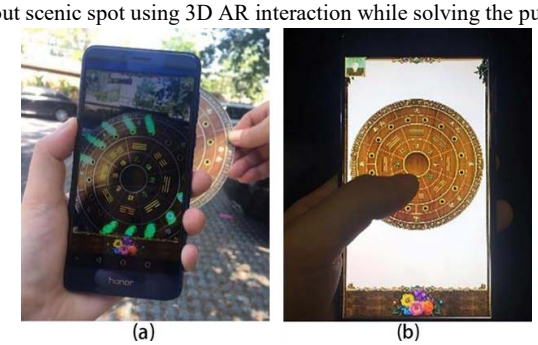

Fig. 7. The compass puzzles in AR game (a) and in the non-AR game (b) in task 5.

Task 6: Collecting soul fragments

Since Hua's memory is fully recovered, participants need to collect the fragments of the soul in the last scenic spot as shown in Fig.1. The movement of the mobile phone can help to find the images of the soul, which are distributed randomly as shown in Fig.8, then the game is completed successfully. Task 6 is designed mainly to explore participants' direction awareness using 3D AR and gyroscope interaction, which motivate participants to interact with innovative learning method and learn about knowledge of scenic spot.

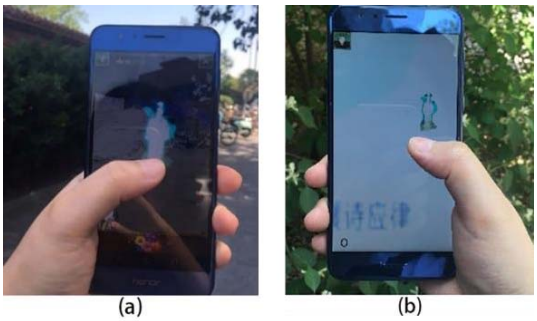

Fig. 8. The fragment of soul in AR game (a) and in the non-AR game in task 6.

2) AR design

To explore the mobile AR guide system influence on participants' experience of the AR game we also develop a non-AR edition, which removes the AR effects in task 2, 4, 5, 6. The AR interaction in task1 and the number puzzle in task 3 are the same as the AR system because these two tasks do not involve AR technology.

In task 2, the poem would not appear on the screen unless participants scan the featured window in the AR game. In contrast, in the non-AR game as soon as participants find the right place, the poem is displayed on the screen directly. After removing the AR effect, the herbs would appear, and then participants need to click the screen to choose the right herbs in task 4 as shown in Fig.6b. The compass appears on the screen in task 5 as shown in Fig.7b. In task 6 the fragments distribute randomly on a 2D map, participants drag the screen to find out the four fragments as shown in Fig.8b.

IV. User Study

We conduct a between-subject experiment to evaluate the performance of the mobile AR guide system and compare user experience under two different conditions: AR guide system and non-AR guide system.

A. Hypotheses

We are interested in the performance of the AR guide system and the user experience of using it. Thus, we propose the following hypotheses:

H1: the AR guide system can enhance participants' learning effectiveness compared to the non-AR guide system.

H2: the AR guide system can extend participants' focusing time on the scenic spot.

H3: the direction awareness of participants in the AR group is better than the non-AR group.

H4: the AR guide system is more interactive and participants in the AR guide group can comprehend more content about the physical environment.

H5: the AR guide system is more attractive and interesting than the non-AR guide system.

B. Participants

24 participants are invited to take part in the experiment (12 females, 12 males, age ranging from 21 to 27, with different backgrounds), which are divided into 2 groups of 12 and referred to as AR group and non-AR group. Of the participants using the AR guide system, over 75% have experience with outdoor AR system.

C. Procedure

The task of our study focuses on finding hints and completing the puzzle game. We therefore ask each participant to tour around the Yuanmingyuan and the procedure is as follows:

After a brief introduction to the study, participants visit the park with the AR guide or non-AR guide system, in which a video record software is installed on the mobile phone. The tour lasts about 40 min. After the tour, participants are asked to answer a questionnaire composed of 26 questions divided roughly into six parts. In addition, we conduct random interviews with the participants focusing on their experience. Finally, they need to take part in a test on the scenic spot including 8 questions.

D. Research tools

1) Test after the visiting

The aim of the test for scenic spots visiting is to determine whether it can improve participants' comprehension of the scenic spots after using the different guide system, and hence to ascertain their learning effectiveness. The test questionnaire includes 8 questions divided into four topics which are relevant to the impression of the content, the location of the certain representative scenic spot, direction awareness, comprehension of the scenic. The contents of the items are as shown in Table 1.

Table 1 Test questions

No.	Question items	Corresponding task
T1	the feature of the protagonist's face	Task 1
T2	the location of dating place	Task 1
T3	the direction of dating place	Task 1 2
T4	the location of hidden poem	Task 2
T5	the content of the stone tablet	Task 3
T6	scenic spot of gathering the herb	Task 4
T7	scenic spot of the compass	Task 5
T8	the distribution of the fragments	Task 6

2) Time recorded by the system

In order to obtain the participants' focusing time on each scenic spot, the time spent on the scenic spots and on the road is recorded and then used in the analysis to determine the amount of focusing time on the scenic spots.

3) Questionnaires

We use the following questionnaires to measure the overall satisfaction, which is consisted of 6 items: system performance, navigation, immersion, interaction, interest, user behavior and psychology. The questions are inspired by the questionnaire of the mobile phone guide applied to cultural heritage [7], the mobile phone AR based puzzle game in the campus [18] and the mobile guided application at the museum [15].

4) Interviews

The interview questions are inspired by the questionnaire of the mobile phone guide applied to cultural heritage [7]. It aims to explore the participants' attitudes and acceptance of the navigation, as well as the advantages and disadvantages of AR guided system. The interviewers use neutral phraseology throughout the interviews so as not to interfere with the views and ideas of the interviewees.

V. Results

The data of the experiment is collected from the test scores, recorded time and questionnaires. We analyze the learning effectiveness, focusing time, direction awareness and the performance of the system.

A. Analysis of learning effectiveness

The learning effectiveness is mainly analyzed by the test score of participants after they visit the scenic spots in Yuanmingyuan. For each question, if the participant gives the correct answer he can get one point. The results of ANOVA analysis of the test score reveal that the different navigation modes exerted significant effects on the participants' learning effectiveness, with a significant difference between the two groups $F(1, 22) = 24.569$, $p = 0.000 < 0.05$. It is significantly better for the AR guided group than that for the non-AR guided group.

A comparison of the accuracy of the responses to each question is shown in Fig.9. For all questions except T5, the AR guide group response more accurately, indicating that these participants have more impressions about the scenic spots, a clearer understanding of the content, and a better direction awareness than those in non-AR guide group. Thus, the learning effectiveness of the AR guide group is superior to those in the non-AR group.

For the aspect of the impression in T1 and T5, 92.3% participants remember the representative scene in the AR guide group compared to the 83.3% in non-AR guide group.

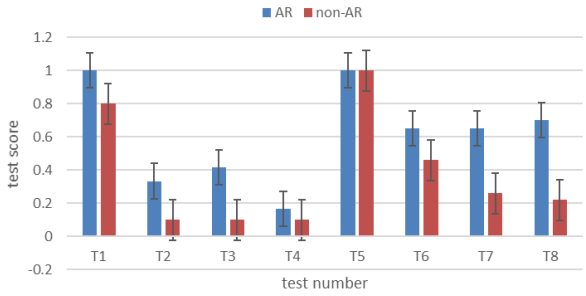

Fig. 9. Comparison of the learning effectiveness between AR and non-AR group.

B. Analysis of focusing time

The focusing time is mainly analyzed by the focusing time on scenic spots. The total time during which the participants' attention focused on the scenic spots included the time spent on viewing and interacting with the scenic spots [17]. The ANOVA analysis result of focusing time reveals a significant difference between the AR guide group and non-AR guide group $F(1. 22) = 24.941$; $p = 0.000 < 0.05$. The time spent focusing on the scenic spots is significantly longer in the AR guide group (mean=22.46min) than for the non-AR guide group (mean=16.17min). It is obvious that the participants in the AR group spend more time viewing and interacting with the scenic spot.

C. Analysis of direction awareness

The improvement of participants' direction awareness is important for a guide system. It is analyzed by the combination of test score and questionnaire. The accuracy of test results in T2 and T4 shows that participants can perceive scenic spots location more accurately in the AR guide group (50.00%) than those in non-AR guide group (16.67%). Moreover, participants in the AR guide group (41.67%) perform better in direction awareness than those in non-AR guide group showed by the result of T3 (8.33%).

In task 6, participants need to collect fragments of soul around a bridge, which also shows participants' ability to direction awareness. The ANOVA analysis reveals that the time participants spent on finding fragments have a significant difference between the two groups $F(1,22) = 11.832$; $p = 0.002 < 0.05$. Participants in the AR guide group spend less time collecting fragments than those in the non-AR guide group. Meanwhile, the ANOVA analysis shows that the score of task 6 has a significant difference between the AR and non-AR guide group $F(1, 22) = 4.939$; $p = 0.037 < 0.05$, which reveals that participants in AR guide group perform better than those in non-AR guide group. Obviously, participants in the AR guide group spend less time collecting the fragments and still possess a higher score than those in non-AR guide group.

The result of the navigation part in questionnaire also reveals that participants in the AR guide group agree that AR guide system is helpful in direction awareness as shown in Fig.11b.

D. Analysis of questionnaire

The questionnaire includes 26 questions about participants' visiting experience in terms of system performance, navigation, interaction, interestingness, immersion and user behaviors and psychology. The questionnaire is used a 5 points scale, the score of each question is from 1 to 5 points. As shown in Fig.10, participants favor the AR guide system than non-AR system especially in navigation and interaction.

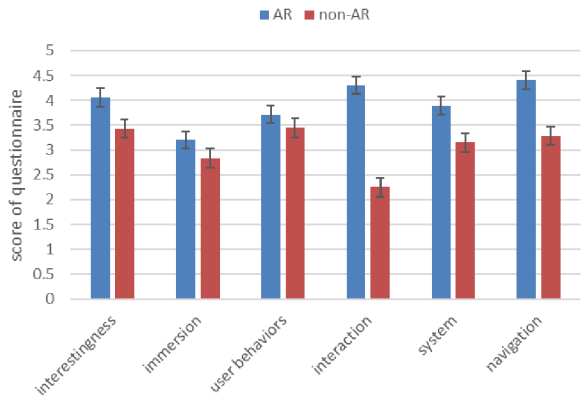

Fig. 10. The result of overall satisfaction.

1) System performance

In the aspect of system performance, participants hold the view that AR guide system has the advantage of overall easiness and the interface when visiting the park, which can enhance the visual effect of the experience as shown in Fig.11a. There is no significant difference in the easiness of operation and quality of video/audio between the two groups since we design the AR and non-AR guide system to be the same except the AR effect as a contrast.

2) Navigation

Analysis of the questionnaire shows that the navigation accuracy of the AR guide system is significantly higher than that of the non-AR guide system especially in the localization and spatial ability as shown in Fig.11b. AR guide system can guide participants to the next scenic spot more efficiently. The result of the questionnaire reveals that AR guide system is easier to use and thus can be chosen as a better approach in navigation.

3) Interaction and comprehension

In the interaction part of the questionnaire, participants in the AR guide group are more interactive as shown in Fig.11d. The participants in the non-AR group have no score in tracking precision since the non-AR guided system has no AR effect and artificial marker.

Besides, the ANOVA analysis results of test score in T6 and T7 show that there is a significant difference between the two groups on the items of interaction with information and comprehension about content $F(1,22) = 4.652$; $p = 0.042 < 0.05$. AR guide system can enhance the interaction with the real world and comprehension about the physical environment (60.77%) compared with the non-AR guide system (38.33%).

As for the user behaviors and psychology, there is no significant difference between the two groups as shown in Fig.11e.

4) Interestingness and immersion

The interestingness and immersion parts of the questionnaire shows that AR guided system is more attractive for the participants and more coherent between two scenic spots as shown in Fig.11c. There is no difference between two groups about the links design and eagerness to the next scenic spot since the links design are the same between the two guide systems.

Analysis of the questionnaire shows that the AR guide system is more immersive for participants as if they are the protagonist of the story and detached from reality as shown in Fig.11f. Two groups have the same attitude toward enjoying the scenic.

E. Analysis of interviews

To explore the attitude and acceptance of AR guided system, an interview is conducted randomly among participants.

Regarding the attitude toward the use of different guided systems, the analysis of the interview reveals that the AR guided system is more attractive and can motivate participants to visit. Participants can gain more knowledge about the scenic spots when visiting the cultural heritage sites.

Analysis of the interviews reveals that most participants credit the AR guided system with 5 advantages: more attractive, better visual effects, more interactive, better location identification, more expressive. They also mentioned the points that the system design could be improved such as a variety of content, adequate interface design, detail introduction and location sensitivity. It is further mentioned that they hope to visit the park using our proposed AR guide system with friends.

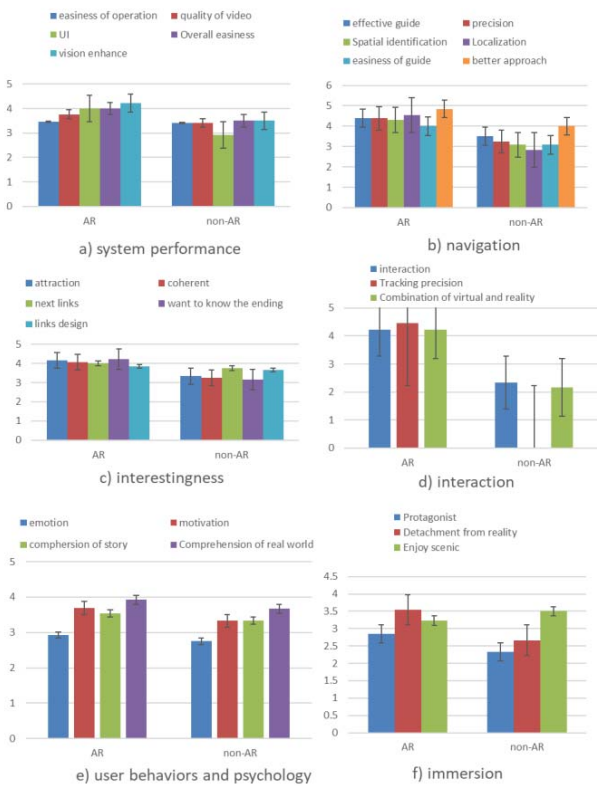

Fig. 11. The result of the questionnaire.

VI. Discussion

The mobile AR guide system aims to help participants to obtain the historical background knowledge and information about a scenic spot in Yuanmingyuan. All of the experimental results are discussed based on the underlying research purposes, and the participants' visiting effectiveness, focusing times, direction awareness, interaction naturalness, content comprehension, the accuracy of navigation and overall performance during the visiting are evaluated.

The ANOVA result of test score reveals that using AR technology can improve participants' learning effectiveness significantly. As shown in Fig.9, the result of T3 and T4 shows that 2D AR interaction in the proposed system is efficient. The result of T1 shows that 2D touch interaction can improve participants' learning effectiveness to a certain degree. The result of T5 shows that physical interaction pattern can help participants get the knowledge about the real-world information, and the combination of 3D AR interaction and physical information interaction can improve participants' learning effectiveness as shown in the result of T7. The result of T8 shows that 3D AR interaction and gyroscope can help to learn effectiveness.

The ANOVA analysis of focusing time reveals that participants in the AR guide group spent more time viewing and interacting with the scenic spots significantly than those in the non-AR guide group. Participants need to find some hints in the physical environment as designed in the system, so they must pay more attention to the scenic spots. Therefore, they pay more attention in viewing and interacting with the scenic spots rather than spend time on the road with the help of AR technology.

The results of test and questionnaire reveal that AR guide system can improve participants' direction awareness. The interface of the AR guide system using 3D interaction through the mobile camera in accordance with human's visual habits and mode of perception. The relationship between the location in the AR system and the location in the real world is clearer so that participants' direction awareness is better in task 2 and 5. In task 6, participants in AR guide group collect the soul fragments by moving the mobile phone along with the physical movement using gyroscope technology while the participants in non-AR guide group dragging 2D map on the mobile screen. The result of T8 in Fig.9 shows that participants in the AR guide group performed significantly better than those in the non-AR group do. Thus, the proposed system facilitates participants' performance on the direction-sense task.

The results of test and questionnaire reveal that the AR guide system has an advantage in system performance, navigation, interaction and interestingness according to the questionnaire. In the part of system performance, the effect of vision enhancement is outstanding. Because of the seamless fusion between the interface and the real world, participants prefer the UI of the AR guide system and they consider it is more interactive. The AR guide system can guide participants to the next scenic spot more accurately and is easier to use.

The results of the questionnaire and interview reveal that AR guided system is more attractive and immersive in general. Participants in AR guide group choose task 5 and 6 as the most interesting part, which is AR designed links and provides more interactivity, while participants in non-AR guide group choose task 3 because in task 3 they need to interact with physical information and find hints in the real world.

However, some participants of the AR guided group state that certain aspect of the proposed system needs to be improved. For example, more details of the scenic spots are not shown in the AR guide system because of the design of the puzzle game. Moreover, the activity arrangements also affect participants' attitudes toward the usefulness and acceptance of guided systems, such as insufficient visiting time and a large crowd of visitors.

VII. Conclusion

This paper aims to explore how the outdoor mobile AR guide system influence user experience during the visit of a historical park, and conducts a user study on the evaluation of the proposed system. The performance factors include learning effectiveness, focusing time, direction awareness and the performance of the system, which includes navigation accuracy, easiness of system, interaction naturalness, attraction, immersion and participants' attitude towards the AR system.

The result of data analysis shows that the AR guide group can improve participants' learning effectiveness and extend participants' focusing time. It can enhance the visual effects using AR technology, as well as the memory about the scenic spots more vividly. The result also shows that the AR guide system can help to improve participants' direction awareness in visiting cultural heritage sites. The AR guide system is more interactive and participants in the AR guide group can comprehend more content about the physical environment. The participants consider that the AR guide system is more attractive and interesting. In addition, the participants in the AR guide group have a better experience on navigation, immersion and hold a positive attitude of using the AR guide system.

Some participants proposed that they hope to use the AR guided system with friends in the park. It is also important to study users' behaviors and psychology using the AR guide system in the aspect of group awareness, communication and experience sharing in the future.

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