

User Experience of Virtual Reality in Lieyu Bunker Tours: Case Studies of Jiangjun Bunker and Shaxi Tunnel

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Abstract

This study examines how an image-based virtual reality (VR) tour platform can enhance young adults' interest in visiting Lieyu Island, Kinmen, a former military buffer zone between Taiwan and mainland China. Following the end of military administration in 1992, Lieyu has developed tourism around its natural scenery, cultural heritage, and wartime landscapes. Based on local characteristics and site accessibility, two coastal defense sites—the Jiangjun Bunker in the northeast and the Shaxi Tunnel in the southwest—were selected for platform development. The platform integrates panoramic bunker scenes with interactive markers presenting architectural, military, and historical information. The study proceeded in four stages: panoramic image capture and field documentation; platform construction with thumbnail-based navigation and hotspots; usability testing with 45 participants aged 19–28 using the System Usability Scale (SUS), the Questionnaire for User Interaction Satisfaction (QUIS), and focus group interviews; and integrated analysis. Results showed an SUS score of 84.6 (Grade B), indicating high usability and user confidence but limited intention for repeated use. QUIS results confirmed smooth system operation, while interviews suggested that simplified interactive games and two-dimensional (2D) scenic visual elements could improve engagement. The findings provide design recommendations for VR-supported heritage tourism targeting younger visitors to Lieyu.

Keywords: Lieyu bunkers, tourism interpretation, virtual reality, user experience

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Introduction

Research Background and Motivation

Lieyu Township in Kinmen County contains numerous wartime bunkers and tunnels originally constructed for military defense. However, the existing tour-guidance information on the Kinmen tourism website mainly consists of brief textual descriptions and static image lists, offering limited contextual interpretation and lacking an immersive experience. Consequently, the current presentation may be insufficient to attract younger visitor groups or stimulate their travel motivation.

In the contemporary digital environment, virtual reality (VR) technology enables tourist destinations to be presented through panoramic and immersive visual experiences, allowing users to develop a stronger sense of presence. Zhu (2014) indicated that image-based virtual reality provides high-quality visual representation and offers a more complete depiction of real environments than computer-generated virtual reality. Jiang (2019) further demonstrated that VR platforms integrating panoramic photography with embedded textual and visual information can effectively enhance learning outcomes and user satisfaction in tour-guidance contexts.

Based on these findings, this study focuses on wartime bunkers as a distinctive tourism feature of Lieyu Island. By applying the concept of an image-based VR tour platform to coastal defense sites in Lieyu, this research examines the feasibility of using VR for tourism interpretation. Through users' navigation and experiential interaction, the study aims to explore the potential of VR applications to enhance user experience and promote travel motivation toward Lieyu Island.

Research Objectives

This study designed an image-based virtual reality (VR) tour platform featuring two military heritage sites in Lieyu Township, Kinmen County: the Jiangjun Bunker and the Shaxi Tunnel. Panoramic images of both sites were captured on location in Lieyu using an Insta360 X4 camera. Relevant literature and historical materials were then collected and organized to develop textual and visual interpretive content related to former military facilities, including machine guns, firing ports, and bunker structures. The platform was designed to present Lieyu's wartime heritage in a more immersive and accessible manner, with the aim of attracting younger audiences.

After the platform was completed, usability testing and subjective evaluations were conducted based on users' interaction with the system. Young users' satisfaction and experiential responses toward different aspects of the platform were analyzed to identify potential directions for design improvement. Based on these findings, this study further proposes recommendations for applying VR-based tour guidance to enhance travel motivation among younger visitor groups to Lieyu Island.

The specific objectives of this study are as follows:

1. To evaluate the usability and user experience of the image-based VR tour platform through subjective usability assessments.
2. To examine users' satisfaction with the VR tour platform and identify aspects of the tour content requiring improvement.

3. To propose design recommendations for using image-based VR to promote young visitors' travel intention toward Lieyu Island.

Literature Review

Applications of Virtual Reality in Tourism Interpretation

Previous studies have examined the relationship between virtual reality (VR), destination image, and travel motivation. Guo (2013) conducted a questionnaire survey to investigate the effects of personal characteristics, VR experiences, and destination image on travel motivation. The findings indicated that VR significantly influenced users' perceptions of destination image and effectively enhanced their motivation to travel. Similarly, Zappia (2016) used questionnaire-based evaluation criteria, including simplicity and usability, to analyze users' subjective and objective impressions of VR systems. The results confirmed that viewing information and videos through VR could strengthen visitors' engagement with heritage sites.

Jenny (2017) developed an application integrating VR and augmented reality (AR), in which tour routes were dynamically adjusted according to users' ratings of attractions. The findings suggested that combining user interests with tourism-related commercial activities could increase users' willingness to use tourism applications. Jiang (2019) further examined platform stability, interface usability, and tour content through questionnaires and interviews. The results demonstrated that VR tour platforms could improve users' understanding of tourist attractions and increase overall satisfaction with the tour experience.

Background of the Lieyu Area

Following the cross-strait division in 1949, military forces retreated from mainland China to Taiwan and its offshore islands, including Kinmen and Lieyu. After the Battle of Guningtou, Lieyu became a frontline military outpost during cross-strait tensions and played a critical role in the defense of the Taiwan Strait. The island also endured prolonged artillery bombardment. Major military events associated with Lieyu include the Battle of Guningtou in 1949, the Dadan Island Incident in 1950, the September 3 Artillery Battle in 1954, the August 23 Artillery Battle in 1958, and the June 17 Artillery Battle in 1960. The fortifications and commemorative facilities constructed during these periods have significantly shaped the historical and spatial development of Lieyu (Battle Heritage Records, 2010).

In recent years, policies returning military land to civilian use have led to the gradual release of former military sites in Lieyu. As a result, some historically significant military structures have been demolished, while many wartime bunkers remain concealed in forested areas and are often overlooked even by local residents. Limited public awareness of military heritage preservation has contributed to the gradual disappearance of Lieyu's wartime cultural identity. Therefore, documenting and reinterpreting these military landscapes has become an important issue in the preservation and promotion of Lieyu's local heritage.

Usability Evaluation

Nielsen (1993) identified five key factors for evaluating product usability: learnability, efficiency, memorability, errors, and satisfaction, as shown in Table 1.

Table 1
Usability Factors

Usability Factor	Description
Learnability	The extent to which users can quickly understand system operations during initial use, reflecting interface intuitiveness.
Efficiency	The speed and effectiveness with which users complete tasks after becoming familiar with the system.
Memorability	The ability of users to regain proficiency after a period of non-use without relearning the system.
Errors	The number and severity of errors encountered during use, as well as the system's tolerance and recovery mechanisms.
Satisfaction	Users' overall pleasure, sense of accomplishment, and psychological comfort during system use.

Note. Adapted from “Usability 101: Introduction to Usability,” by J. Nielsen, 2012, Nielsen Norman Group.

In addition, Nielsen (1993) proposed contextual inquiry as a method for identifying usability issues by examining users' behaviors in their natural work environments. The primary technique, contextual interviews, involves discussions between users and researchers regarding work practices, goals, and usage problems. Data collected through notes or video recordings are subsequently analyzed collaboratively by researchers and users to derive usability insights (Gao, 2004).

Research Design

Research Method and Design

System Usability Scale (SUS)

The System Usability Scale (SUS), developed by Brooke (1996), is a subjective usability questionnaire designed to measure users' overall perceived usability after interacting with a system. The SUS consists of 10 items, including five positively worded statements and five negatively worded statements. Participants respond to each item using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

In this study, the wording of the original SUS items was slightly modified to better correspond to the characteristics of the image-based virtual reality (VR) tour platform. The revised items emphasized platform-related tasks and adopted wording appropriate for younger user groups, while maintaining the original structure and measurement purpose of the SUS. These modifications were made to ensure that participants could clearly understand each item and provide responses that accurately reflected their experience with the VR tour platform.

Questionnaire for User Interaction Satisfaction (QUIS)

The Questionnaire for User Interaction Satisfaction (QUIS), developed by Chin et al. (1988), is a subjective evaluation instrument designed to assess users' satisfaction with interactive systems from a human–computer interaction perspective. The questionnaire evaluates multiple interface-related dimensions, including users' overall reaction to the system, screen

presentation, terminology and system information, learning, system capabilities, and usability and user interface.

In this study, the QUIS was structured according to these six dimensions and adapted to focus on the functions and interactions of the image-based virtual reality (VR) tour platform. The questionnaire items were modified to reflect platform-specific interface features, informational content, and navigation requirements. This adaptation enabled a more comprehensive assessment of users' perceived usability, interface satisfaction, and overall experience when interacting with the VR tour platform.

Focus Group Interview

Focus group interviews are a qualitative research method originally introduced by Bogardus (1926), involving group-based discussions to collect in-depth qualitative data. Following the recommendations of Stewart and Shamdasani (2001), this study conducted focus group interviews with 4–6 participants per session. A total of five sessions were held, involving 24 participants, and each session lasted approximately 30 minutes.

The participants were selected from the 45 questionnaire respondents. Selection was based on participants' level of engagement during the platform evaluation and their ability to provide detailed and meaningful feedback during discussion. Through these interviews, this study further explored users' perceptions of the image-based virtual reality (VR) tour platform, including their experiences with navigation, information presentation, interaction design, and overall travel motivation.

Research Participants

Young adults aged 20–29 have been identified as one of the least frequent visitor groups to the Kinmen region, while also demonstrating potential for increased travel intention. Therefore, this study recruited undergraduate and graduate students aged 19–28 years as research participants, maintaining an age range within a 10-year span to ensure relative consistency in demographic characteristics.

All participants first interacted with the image-based virtual reality (VR) tour platform. After completing the platform experience, they were invited to complete subjective usability and satisfaction questionnaires, user experience evaluations, and focus group interviews. This procedure enabled the study to examine participants' perceptions of the platform from both quantitative and qualitative perspectives.

Research Procedure

The research procedure consisted of four stages: preparation, design, evaluation, and analysis and conclusion. In the preparation stage, panoramic images were captured at the Jiangjun Bunker and the Shaxi Tunnel in Lieyu Township, Kinmen County, using an Insta360 X4 panoramic camera. Both the exterior and interior routes of the two bunkers were documented. Field investigations and a literature review were also conducted to examine the wartime context of the sites in greater depth and to develop the tour information content and interaction design for the virtual reality (VR) platform.

In the design stage, the panoramic images were imported into the Kuula virtual tour software. Viewing points, visual navigation markers, and informational text windows were configured for both the interior and exterior spaces of the bunkers. Photographs of historical weapons were overlaid onto gun platforms, and audio narration was added to complete the image-based VR tour platform with panoramic navigation.

During the evaluation stage, 45 undergraduate and graduate students participated in hands-on interaction with the VR tour platform. After using the platform, participants completed the System Usability Scale (SUS) and the Questionnaire for User Interaction Satisfaction (QUIS). Focus group interviews were then conducted to obtain in-depth qualitative insights through group discussion.

In the final stage, quantitative and qualitative data were analyzed to examine users' perceived usability and experience when interacting with the VR tour platform. Based on the findings, directions for design optimization were identified, and recommendations were proposed for using VR to enhance travel motivation among younger visitor groups to Lieyu Island. By synthesizing users' preferences and expectations, this study provides design references for future research and supports the cross-disciplinary application of VR in promoting tourism destinations.

Operation Flow of the Virtual Reality Tour Platform

The virtual reality (VR) tour platform comprises 30 tour viewpoints. When users launch the platform, an instruction interface appears to explain the basic operation controls, as shown in Figure 1. After reviewing the instructions, users can click the circular play icon to begin panoramic navigation and interact with elements within the bunker environment.

Figure 1
Platform Operation Instruction Interface



Note. Screenshot captured from the image-based virtual reality tour platform developed in this study.

Figure 2 presents panoramic view of the Jiangjun Bunker as the homepage of the VR platform, where the image is the entrance gate of the Jiangjun Bunker. Users can click the tour information panel to view explanatory content related to the site. The “NEXT” indicator allows users to move to the next tour viewpoint, while the panoramic navigation indicator reminds users that the viewing angle can be adjusted to explore environmental details. In addition, users can scroll the mouse wheel along the bottom thumbnail bar to preview and access other tour viewpoints.

Figure 2
Jiangjun Bunker Tour Homepage Interface



Note. Screenshot captured from the image-based virtual reality tour platform developed in this study.

At other tour viewpoints, users can interact with interface elements such as the tour information panel, weapon information panel, and overlaid weapon images. Figure 3 presents a tour viewpoint located at the machine-gun embrasure area of the Shaxi Tunnel. The upper Chinese characters explain that the machine-gun in this figure is an M1919A4 Browning machine gun, which is broadly used in Lieyu during the 1950–1980.

Figure 3
Shaxi Tunnel Tour Viewpoint Interface



Note. Screenshot captured from the image-based virtual reality tour platform developed in this study.

When users select the tour information panel on the left side of the interface, a textual explanation window appears over the panoramic scene of the current viewpoint. After reading

the description of the bunker layout in that area, users can close the window by clicking the close icon in the upper-right corner.

Users may also select the weapon information panel located above the tour viewpoint to open a weapon description window. As shown in Figure 4, the window displays an image of the wartime weapon at the center of the screen, accompanied by explanatory text.

Figure 4
Weapon Image and Text Description Window Interface



Note. Screenshot captured from the image-based virtual reality tour platform developed in this study

Results and Analysis

SUS Analysis

The overall System Usability Scale (SUS) score for the platform was 84.6, corresponding to a Grade B rating. This result indicates that the platform was generally acceptable to users and demonstrated a high level of subjective satisfaction during operation.

Based on the five-point scale used for each SUS item, the results in Table 2 show that Item S1 yielded the lowest mean score among the positively worded items, with an average of 3.93. This suggests that users expressed a relatively limited intention to reuse the same platform, indicating a need for further interface optimization. In contrast, Item S9 received the highest mean score among the positive items, with an average of 4.64, indicating that users generally felt confident in operating the platform and were able to quickly become familiar with its interaction methods.

Table 2*Overall Platform Usability (Positive Items)*

Item	N	Min	Max	Mean
S1. I would like to use this platform frequently.	45	3.00	5.00	3.9333
S3. I think the platform is easy to use.	45	3.00	5.00	4.5778
S5. I think the platform is well designed, allowing me to use it smoothly.	45	3.00	5.00	4.2444
S7. I think most people could learn to use the platform very quickly.	45	4.00	5.00	4.6222
S9. I feel confident using this platform.	45	4.00	5.00	4.6444

Note. From the author's SUS experimental data results.

QUIS Data Analysis

The overall mean score of the Questionnaire for User Interaction Satisfaction (QUIS) was 6.21 out of a maximum score of 7, indicating that users generally had a positive experience with the platform. High satisfaction was reported across multiple dimensions, including audio narration, interface design, learning, system performance, and ease of use.

The QUIS consisted of 20 items, each rated on a seven-point scale. Among these items, Item Q5 received the lowest mean score, with an average of 5.51. This result suggests that users perceived the platform's method of presenting site information as relatively less engaging, and the experience did not fully meet their expectations. Detailed results are presented in Table 3, which summarizes users' overall perceptions of operating the virtual reality platform.

Table 3*Overall User Perceptions of Operating the Virtual Reality Platform*

Item	N	Min	Max	Mean
Q1. I think this virtual reality platform is good.	45	4.00	7.00	6.04444
Q2. I think operating this virtual reality platform is easy.	45	3.00	7.00	6.35556
Q3. I am satisfied with this virtual reality platform.	45	3.00	7.00	5.88889
Q4. I think using this virtual reality platform helps me understand the site.	45	4.00	7.00	6.22222
Q5. I think the way this virtual reality platform presents the site is interesting.	45	4.00	7.00	5.51111

Note. From the author's QUIS experimental data results.

In the QUIS results, Item Q17 received the highest mean score, with an average of 6.62. This indicates that users were generally able to operate the virtual reality platform with ease and clearly understand the functionality of the interface. In addition, the system was perceived as stable and responsive during operation. Detailed results are presented in Table 4, which summarizes platform performance.

Table 4*Platform Performance*

Item	N	Min	Max	Mean
Q15. The system performance of this virtual reality platform is smooth.	45	4.00	7.00	6.48889
Q16. The system of this virtual reality platform is stable.	45	4.00	7.00	6.55556
Q17. I can operate this virtual reality platform easily.	45	3.00	7.00	6.62222

Note. From the author's QUIS experimental data results.

Focus Group Interview Analysis

Findings from the focus group interviews provided further insight into the low intention for repeated use reflected in SUS Item S1. Participants indicated that their willingness to reuse the platform could be enhanced by incorporating simple, story-driven non-player character (NPC) interactions, in which game characters introduce site narratives and guide users to subsequent scenes.

Participants also suggested linking the Jiangjun Bunker and Shaxi Tunnel tours to other distinctive bunkers in the Kinmen area to enrich the content. Such expansion was perceived as likely to increase user engagement and encourage repeated use of the virtual reality (VR) tour platform. The following excerpts illustrate participants' perspectives on repeated use of the platform:

Interviewer: Would you want to use this platform again?

Participant SA3: No, but I would be more willing to reuse it if the experience were more story-driven. For example, if users were positioned as tourists visiting Lieyu and encountered NPC characters who introduced the site through narratives, the platform would feel more like a game and encourage reuse.

Participant SA1: I would not use it again either. Whether I would reuse the platform depends on the content. If game-like features were added, the experience would be less monotonous, and I would be more likely to use it again.

Participant SA4: I think the platform could be linked to other bunkers. Kinmen has many bunkers, and they are quite similar. Including images and brief explanations of other bunkers would enrich the content.

Regarding QUIS Item Q5, which reflected users' perceptions that the platform's method of presenting site information was relatively unengaging, participants expressed a desire for more in-depth introductions to the historical context and daily life associated with the bunkers. They suggested incorporating two-dimensional (2D) scenic illustrations, archival photographs, or simple line drawings to provide visual references for bunker locations and spatial relationships.

Participants also recommended designing a dedicated mascot to introduce site narratives. A character with a friendly appearance combined with lively audio narration was perceived as an effective approach to enhancing user engagement and increasing interest in exploring the platform. The following excerpts further illustrate participants' views on the presentation of tour content:

Interviewer: Do you find the way the tour information is presented interesting?

Participant SA5: Not particularly. The interaction flow feels repetitive, and toward the end it becomes tiring because I have to keep reading text, which constantly shifts my attention.

Interviewer: How do you think the design could be more engaging?

Participant SA2: Since this is about coastal defense bunkers, I think it would be more interesting to include more information about past living conditions. Adding old photographs or scenic images around the environment, where clicking them reveals the complete space, would be helpful.

Participant SA6: Yes, I agree. Adding small stories would help. When entering a scene, a mascot could start speaking and introduce the area. That would be more engaging, because the current audio narration simply reads the text in a very straightforward way.

Conclusion

Research Conclusions

This study examined the usability and user experience of an image-based virtual reality (VR) tour platform applied to the Jiangjun Bunker and the Shaxi Tunnel in Lieyu by integrating the System Usability Scale (SUS), the Questionnaire for User Interaction Satisfaction (QUIS), and focus group interviews. The results showed an overall SUS score of 84.6, indicating strong performance in perceived usability, ease of use, learnability, user satisfaction, and system stability. Users were generally able to become familiar with the platform quickly and operate it smoothly, confirming that the platform achieved a high level of usability and provided a positive user experience.

However, the questionnaire findings also revealed relatively lower ratings for users' intention to reuse the platform and for the perceived enjoyment of the tour presentation. The focus group interview analysis further suggested that the uniform tour flow and prolonged reliance on text and audio narration led to user fatigue, which reduced users' sense of immersion and willingness to revisit the platform.

By synthesizing the quantitative and qualitative findings, this study identified several directions for platform optimization. First, narrative-driven and scenario-based design could be incorporated through virtual character-guided tours to attract younger users. Second, simple interactive mini-games and non-player characters (NPCs) could be integrated to increase engagement and reuse intention. Third, archival photographs, two-dimensional (2D) spatial reference images, and illustrative graphics could be added to reduce reading load and strengthen visual interpretation. Finally, the tour content could be extended to include other distinctive bunkers in Lieyu, thereby enhancing the depth of the platform content and the tourism value of the virtual tour experience.

Overall, the findings suggest that image-based VR has the potential to support the interpretation and promotion of military heritage tourism in Lieyu. Although the current platform demonstrated favorable usability and interaction quality, future development should place greater emphasis on narrative design, interactive mechanisms, visual enrichment, and content expansion. These improvements may further enhance young users' engagement with wartime heritage sites and increase their travel motivation toward Lieyu Island.

Future Recommendations

Based on the quantitative questionnaire analysis and focus group interviews, this study found that users generally perceived the platform as easy to use and stable in system performance.

However, further optimization is still required. Participants indicated that the tour content mainly focused on the Jiangjun Bunker and the Shaxi Tunnel, while the interaction patterns and tour flow were relatively uniform. In addition, the heavy reliance on text and audio narration limited narrative depth and interactive context. These limitations may reduce long-term engagement, intention for repeated use, and the platform's overall effectiveness in tourism promotion.

Future research is recommended to incorporate narrative-driven and scenario-based design supported by virtual characters that guide users through the experience. Simple interactive mini-games may also be integrated to increase younger users' engagement and intention to reuse the platform. In addition, visual elements such as archival photographs, scenic images, and two-dimensional (2D) spatial reference maps should be added to reduce the textual reading load and enhance users' understanding of the surrounding environment.

Moreover, expanding the tour scope to include additional distinctive bunkers in Lieyu could support the development of a series-based virtual tour. This approach may foster greater awareness of Lieyu's wartime cultural heritage among younger audiences and strengthen the tourism value of former military sites. The findings may also support cross-disciplinary applications of virtual reality (VR) in tourism interpretation and serve as a digital reference for enhancing travel motivation in future VR design practices.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The authors declare that ChatGPT, an AI-assisted writing tool developed by OpenAI, was used to refine sentence structure and correct English spelling in the manuscript. The use of ChatGPT was limited to language polishing, spelling correction, and improving clarity and readability. Apart from ChatGPT, no other AI or AI-assisted technologies were used in the writing process. The ideas, research design, procedures, findings, analyses, and discussion presented in the manuscript are the authors' original work and were derived from a rigorous and systematic research process.

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