Research Article

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Evaluation of an Online 360° Virtual Reality World Heritage Site During COVID-19

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Abstract: This study developed a framework to evaluate, in the context of COVID-19, the performance of an OVRWCHT (online 360° virtual reality world cultural heritage tourism) system created by the authors for the purpose of heritage interpretation and presentation. The research framework was based on the seven main principles of the ICOMOS Charter for the Interpretation and Presentation of Cultural Heritage Sites, and evaluation criteria were established for each. This framework was used to evaluate an OVRWCHT for the Hailongtun Tusi World Heritage Site in Guizhou Province, China. Data were mainly based on 1,062 questionnaires and analyses of the developed system. The findings indicated that, whether in terms of user experience or the interpretation of the UNESCO criterion “outstanding universal value,” Stakeholders agreed that OVRWCHT has played a positive role in heritage interpretation. Yet, more data support is needed to improve both technology and theory – especially the transferability of OVRWCHT to countries other than China. Based on the findings, it is suggested that the International Council on Monuments and Sites should continue to issue charters on how emerging technologies can support heritage site interpretation and presentation.

Keywords: online virtual reality, archaeology, heritage, COVID-2019

1 Introduction

The various travel restrictions and isolation policies imposed during COVID-19 forced most cultural heritage tourists to change or cancel their travel plans in 2020. In this regard, technologies such as artificial intelligence and 3-D visualization have provided ways to experience heritage sites without the need to travel. OVRWCHT (online 360° virtual reality world cultural heritage tourism) is one such technology that can help people remotely discover the value of cultural heritage sites. In particular, OVRWCHT has been playing an increasingly important role in heritage tourism in China.

The concept of online 360° virtual reality presentation is not new, nor is its application to cultural heritage sites. Such technology has satisfied the desire of many Chinese people to explore heritage sites during COVID-19. However, this has raised questions about the role of cultural heritage site interpretation and presentation during COVID-19. How can heritage site interpretation and presentation promote the

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recognition of “outstanding universal value” (the UNESCO criterion for World Heritage Sites) under the conditions of COVID-19? Could emerging technologies perform better than traditional approaches?

This paper proposes that the improvement of cultural heritage services should focus on not only the technological aspects but also the interpretation and presentation of cultural heritage sites. This study aimed to evaluate the performance of such interpretation and presentation via OVRWCHT during COVID-19. To this end, a theoretical framework was established to analyze OVRWCHT’s effectiveness based on the seven principles of the ICOMOS Charter for the Interpretation and Presentation of Cultural Heritage Sites (hereafter, the Charter). An OVRWCHT was established to present and interpret the Hailongtun Tusi World Heritage Site in Guizhou Province, China. A questionnaire survey was undertaken from May 28 to June 2, 2020, to assess the effectiveness of this OVRWCHT. A total of 1,062 valid responses were collected, which verified the effectiveness of this OVRWCHT for presenting and interpreting the Hailongtun Tusi site.

2 Literature Review

2.1 Research on Cultural Heritage During COVID-19

Various heritage organizations published statements related to cultural heritage during COVID-19. For example, the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM, 2020) proposed ways to support cultural bearers, artists, and craftspeople during COVID-19. Bénédicte de Montlaur of the World Monuments Fund expressed concerns about the safety of those engaged in heritage work around the world and the need for economic support for such sites (Montlaur, 2020). Noting that education, heritage, and culture did not cease to exist during the pandemic, the Council of Europe (2020) expressed support for applying emerging technologies to the heritage sector.

Despite such concerns, there is relatively little research specifically focused on cultural heritage sites and COVID-19. Yet, COVID-19 has clearly reformulated global lifestyles with regard to accessing cultural heritage sites. Kuzelewska and Tomaszuk (2020), for example, examined the question of online access to heritage sites during COVID-19 in the context of case law under the European Court of Human Rights.

2.2 Interpretation and Presentation of Cultural Heritage

The Charter for the Interpretation and Presentation of Cultural Heritage Sites (hereafter, the Charter) was ratified by the sixteenth General Assembly of ICOMOS on October 4, 2008. It aimed to define the basic principles of interpretation and presentation as essential components of heritage conservation efforts (Silberman, 2008). Numerous studies have focused on various aspects of heritage interpretation, with some arguing that the Charter can be a useful tool for cultural conservation, protection, and management (Continenza, Redi, & Trizio, 2017; Costa & Carneiro; Lee & Hyun, 2019). Other related studies have investigated the Charter’s application to the museum community, the effect of tour-guide interpretation on perceived heritage value (Ababneh, 2018; Weng, Liang, & Bao, 2020), the satisfaction and attitudes of site visitors (Kimjuyeon & Ahn, 2011; Pignaton, Santos, & Tavares, 2019), heritage and hermeneutics (Ablett & Dyer, 2009), visitors’ interpretation preferences (Oh & Cho, 2017; Poria, Biran, & Reichel, 2009), interpretation and city heritage (Bajec, 2019; Felicidade & Silva, 2019), geoheritage interpretation (Scriven, 2019), and heritage tourism interpretation (Hristov, Naumov, & Petrova, 2018; Raimundo, Sarti, & Pacheco, 2019).

Van Den Dries (2016), meanwhile, argued that doctrines such as the Charter can often fail in implementation. As a result of large gaps between theory and practice, the Charter might fail to be generally accepted by local heritage professionals (Van Den Dries, 2016). Similarly, Asfaw and Gebreslassie (2016) noted that the Charter’s principles are hardly practiced at all in the case of the Wukro Tourism Cluster as a

result of various unfavorable factors. There is a need, therefore, to develop appropriate interpretation systems and presentation infrastructures based on local settings (Asfaw & Gebreslassie, 2016). Villasante (2019), meanwhile, redefined the concept of heritage interpretation using a stakeholder-based approach for use in educational contexts.

Along with technological development, new methods have been adopted for the interpretation and presentation of cultural heritage, including approaches based on virtual reality (VR), augmented reality (AR), artificial intelligence (AI), 3-D printing, and panoramic cameras. Rahaman (2018) proposed a conceptual framework for digital heritage interpretation and tested the framework on an online platform to assess its effect on user interpretation.

Since the Charter only provides broad principles related to heritage, there is a need for more detailed indicators to assess approaches to heritage interpretation and presentation. The Charter's seven principles pertain to (1) access and understanding, (2) information sources, (3) attention to setting and context, (4) preservation of authenticity, (5) planning for sustainability, (6) concern for inclusiveness, and (7) importance of research, training, and evaluation. Despite the increasing application of technology to cultural heritage interpretation and presentation, there is insufficient research on standards, guidance, and ethics for assessing practices under the Charter.

2.3 Virtual Reality and the Tourism Experience

The application of VR/AR technology is not a new topic. Chung, Han, and Joun (2015) focused on applying AR to a heritage site in terms of tourists' intention to visit; they found that technology readiness was a predictor of perceived usefulness. However, AR can assume various forms and that study only used 145 cases, which might not provide a comprehensive picture of this emerging technology. Examining the opportunities VR offers for tourism, Tussyadiah, Wang, Jung, and Dieck (2018) found that the sense of being in a virtual environment increased the enjoyment of the VR tourism experience and had an effect on tourists' attitudes and behaviors. Gonzalez-Rodriguez, Diaz-Fernandez, and Pino-Mejias (2020), meanwhile, used 119 online responses to evaluate tourists' VR experiences at a cultural heritage destination. Their findings highlighted the importance of tourists' desires, which might play a stronger role in VR tourism than VR design itself. However, only 119 samples in that study may not be good enough to support its conclusions.

2.4 Application of 360° HD Technologies

Integrating 360° panoramic photos into virtual heritage environments could support heritage conservation and education. For example, the Edeta 360° virtual tour used multiple photographic images with overlapping fields of view to produce a segmented panorama. Given the relative ease and low cost of using 360° HD technologies, other studies have supported applying such approaches to heritage interpretation.

China has been using panoramic technologies for the interpretation and presentation of cultural heritage sites for some time. For example, the virtual visit service for the 2008 Beijing Digital Olympics project restored the buildings and key cultural relics of the Prince Gong Mansion with the help of 360° HD technology. The Shanghai World Expo established a 5.28 km² virtual park online to provide panoramic roaming services for tourists. The Imperial Palace, Dunhuang, and other panoramic virtual roaming systems enable visitors to visit historic sites without leaving home (Tan & Yan, 2001). The Shanghai Museum, Nanjing Museum, and other museums with first-class facilities have also used panoramic technologies to build virtual museums (Zhang & Li, 2011). Using panoramic technologies can remove the constraints of time and space, making it possible to more vividly interpret cultural heritage, thus achieving the effective dissemination of cultural value (Gao & Lv, 2019; Wang, 2014).

2.5 Research Gaps in the Application of VR to Cultural Heritage

Applying panoramic technology to cultural heritage sites mostly rests on creating VR on a computer platform using static images (Zhang & Li, 2011). Yet, there is insufficient research on immersive multimedia experiences, interactive design, and utilization in the heritage context. The application of panoramic technology is still characterized by conflicts between digital technology and traditional culture, as well as the inability to reproduce the primordial nature of a culture. There is, moreover, a lack of discussion about the interrelationships between panoramic technology and the Charter. To address such problems and sustainably develop cultural heritage sites, the use of panoramic technology must respect the original culture in the process of interpreting and presenting it. This will expand the possible applications of panoramic technology and allow for greater complementarity with the physical presentation of cultural heritage sites (Chen, 2018; Kong, 2018).

Existing research has mainly focused on the development of emerging technologies, while specific scenario applications have been supplementary. Affleck and Kvan (2005) proposed an interpretation model for digital heritage by merging the concepts of popular interpretation and reconstruction; however, they were unsuccessful in presenting a reliable, workable framework. Primary application research tends to be user-focused. Rahaman (2018) proposed four objectives of digital heritage interpretation – namely, to satisfy, provoke, educate, and offer multiple perspectives. On that basis, specific functions were proposed for the assessment and development of digital heritage interpretation projects. However, that study mainly focused on end users and did not consider other stakeholders. In that regard, the preservation of cultural authenticity should be the guiding principle for interpretation, not simply user satisfaction. Furthermore, Rahaman (2018) used a web-based platform as the case study, which narrowed the research scope.

In summary, there is a limited research on the effectiveness of 360° VR for heritage site interpretation and presentation, and its effectiveness has not been specifically tested in the context of COVID-19. The present study, therefore, developed an evaluation framework for VR application based on the seven principles of the Charter, and relevant impact factors were developed on that basis.

3 Methods

This study consisted of three main parts. The first was to select a World Heritage Site as a case study and customize an OVRWCHT for it. The second part involved establishing an OVRWCHT evaluation framework. In the third part, the evaluation framework was applied to the case with the support of data from a questionnaire survey.

3.1 Developing an OVRWCHT for the Hailongtun Tusi Site

The Hailongtun Tusi World Heritage Site was selected as a case study for applying the OVRWCHT system. There were three main reasons for this selection. First, the authors participated in a UNESCO sustainable tourism project there from 2017 to 2019 and thus developed a deep understanding of the site. The authors also developed a 3-D point cloud of the site in 2019. Second, from a practical perspective, the Hailongtun Tusi site administration had aimed to build an online panoramic interpretation system, but it lacked a professional technology team. The Hailongtun Tusi site faces the problem of the inaccurate interpretation of its heritage. Moreover, the number of visitors decreased significantly during COVID-19, making it urgent to develop a system for publicity. The Hailongtun Tusi site administration was therefore very supportive of this study. Third, in terms of feasibility, the site covers an area of only 1.6 km²; thus, a system could be quickly established despite limited human resources.

The development process for OVRWCHT was as follows. To create a comprehensive presentation of the Hailongtun Tusi World Heritage Site, including cultural relics and its environment, panoramic spherical

mapping technology was used to shoot and produce 360° panoramic images. Panoramic roaming was established to support interaction between users and the application terminal. Virtual roaming combines two forms of interaction: direct mouse clicks and buttons for right and left rotation, looking upward, looking over, and pushing and pulling the scene. Smooth transition between scene points is achieved during the roaming process. The presentation of the overall layout was combined with the navigation plan so users could always grasp the actual position of the observation point but not lose a sense of the overall layout of the area. An interactive link between the navigation map and the 3-D panorama was achieved, and the combination of the navigation map guide, picture presentation, text introduction, and voice explanation enabled users to obtain information about the value of the site while browsing online. Users could conveniently switch between presentations through the navigation settings.

3.1.1 Collection and Stitching of Panoramic Images

Images of the Hailongtun Tusi site were captured using a DETU-F4FD121 camera, which has four fish-eye lenses and can take 360° photos around the center of the shot area (Figure 1). More than 200 key points were selected within the 160.42 ha area of the site over the course of seven days. More than 2,000 photos were taken for a collage covering all important relics and roads in the Hailongtun property zone (Figure 2).

A panoramic collage was created using the DETUF4FD121 camera's DetuStitch software (Figure 3). Image processing software (Photoshop) was used to repair and unify the exposure and color of some images.

3.1.2 World Heritage Site Series Release

Finally, 153 panoramic images reflecting the whole landscape of the Hailongtun area were selected to establish a one-way roaming path from the sightseeing bus stop at Hailongtun Village (the starting point) to Tou Dao Pass (the end point). At the pass, restoration models, an archaeological site survey map, and voice and text interpretations of the gateways were added. Important points and intersections were added to highlight the universal value of the site (Figures 4 and 5). Users could choose the content they were interested in by clicking on hot-spot icons in the panorama.

Navigation was created based on the property zone plan to create overall 3-D impressions of the site so users could understand the location of the current panoramic picture. In addition, various scene-switching modes (e.g., hot spots, small pictures, and navigation) made it convenient for users to jump to any tour location at will, allowing for an immersive tour experience. Finally, the system was imported into a cloud and was available free of charge. Users could access it using any mobile phone or computer with an Internet connection. The link for the system is <http://m.detu.com/zh/pano/show/691589?from=timeline>. Thus far, the system has received 9,590 visitors.

3.2 Evaluating the Effectiveness of the Hailongtun Tusi Site OVRWCHT

Effectiveness was evaluated based on the authenticity and accuracy of the information provided. First, the literature was reviewed to study methods used in related research. Second, a questionnaire was put online, and evaluation indicators were selected based on the responses. This questionnaire was in Chinese, and it examined public responses to the OVRWCHT during COVID-19. Third, a framework based on the actual situation in China was developed to evaluate the effectiveness of the developed OVRWCHT. The evaluation assumed qualitative and quantitative forms. Qualitative evaluation involved the authors' evaluation of the OVRWCHT based on the Charter. Quantitative evaluation focused on the results of the online questionnaire (Table 1).

Figure 1: Presentation selected for Feilong Pass.

3.3 The First Questionnaire Survey

Data collection was conducted from May 28 to June 2, 2020. A total of 1,283 online questionnaires were collected. After screening (e.g., removal of questionnaires with similar IP addresses, invalid email addresses, incorrect answers), 1,062 valid questionnaires were obtained. Based on IP addresses, the

Figure 2: Panoramic shooting at the heritage site.

Figure 3: Panorama of Feilong Pass after image collage.

respondents' geographical scope included all mainland China provinces, as well as Taiwan and Hong Kong. More people in densely populated coastal provinces filled out the questionnaire. Ninety-three of the valid questionnaires came from abroad, accounting for 8.76% (Figure 6).

All respondents were under 60 years of age and were distributed in several different age groups. The proportion of those aged 18–25 years was the highest, followed by 31–40 years, and 26–30 years (Figure 7). Given the high proportion of young Internet users in China, many respondents were relatively young. Thus, the age range of respondents was basically consistent with the profile of actual Internet users in China.

Figure 4: System interface based on panoramic images.

Three-dimensional digital restoration Picture of Tiezhu Pass

Archaeological Survey Map of Tiezhu Pass

Figure 5: Mapping and restoration sets used in the system for heritage interpretation.

The survey sample thus covered all of China and the main age groups. Thus, in terms of demographics, the 1,062 valid questionnaires can be considered representative for research and analysis.

A second questionnaire was designed and delivered October 25–30, 2020, to government officers at the Hailongtun Tusi site. Twenty-three responses were received. The questionnaire asked respondents who had used OVRWCHT to score the extent to which it helped promote recognition of the value of Hailongtun.

Table 1: Assessment framework based on the Charter for the Interpretation and Presentation of Cultural Heritage Sites

Principle	Indicators	Subindicators	Evaluation questions
Principle 1: Access and understanding	Interpretation and presentation program should facilitate physical and intellectual access by the public to cultural heritage sites	Accessibility to the value of cultural heritage	Assessment based on the questionnaire To what extent do users think the following ways of presenting the value of cultural heritage can bring a better sense of the experience when users visit the site?
		Understanding the value of cultural heritage	To what extent do users think the following ways of presenting the value of cultural heritage can help them better understand its outstanding universal value after visiting the OVRWCHT?
		Experience, public respect, understanding, and communication	Authors' assessment based on platform features Does OVRWCHT inspire further interest in learning, experience, and exploration?
		Audience demographics	Authors' assessment based on platform features Does OVRWCHT identify and assess the audiences demographically and culturally?
		Diversity of language	Authors' assessment based on platform features Does OVRWCHT encourage language diversity?
		Physically accessible to the public	Authors' assessment based on platform features Is OVRWCHT physically accessible to the public onsite and offsite?
Principle 2: Information sources	Interpretation and presentation should be based on evidence gathered through accepted research methods, as well as living cultural traditions	Sources of data and information	Authors' assessment based on platform features Are the sources of the heritage interpretation information documented, archived, and made accessible to the public?
		Quality of research on the site and its surroundings	Authors' assessment based on platform features Is the interpretation (including traditional storytelling or oral heritage interpretation) of OVRWCHT based on a well-researched multidisciplinary study of the site and its surroundings?
		Detailed and systematic analysis of visual reconstructions	Authors' assessment based on platform features Are the visual reconstructions (computer models) based on a detailed and systematic analysis of environmental, archaeological, architectural, and historical data?
Principle 3: Attention to setting and context	The interpretation and presentation of cultural	Significance of a site in its multifaceted historical,	Authors' assessment based on platform features

(Continued)

Table 1: *Continued*

Principle	Indicators	Subindicators	Evaluation questions
Principle 4: Preservation of authenticity	heritage sites should be related to their wider social, cultural, historical, and natural contexts and settings	political, spiritual, and artistic contexts	Does OVRWCHT explore the significance of the site in its multidimensional historical, political, spiritual, and artistic contexts?
		Clearly distinguish and date successive phases and influences in its evolution	Authors' assessment based on platform features Does OVRWCHT clearly distinguish and date the successive phases and impacts in its evolution?
		All groups that have contributed to its historical and cultural significance	Authors' assessment based on platform features Does OVRWCHT take into account all groups that have contributed to the historical and cultural significance of the site?
		Surrounding landscape, natural environment, and geographical setting	Authors' assessment based on platform features Does OVRWCHT consider the surrounding landscape, natural environment, and geographical setting?
		Intangible elements of a site's heritage	Authors' assessment based on platform features Does OVRWCHT consider intangible elements of the site's heritage and the cross-cultural significance of heritage sites?
	The interpretation and presentation of cultural heritage sites must respect the basic tenets of authenticity in the spirit of the Nara Document (1994)	Respect for the traditional social functions of the site	Authors' assessment based on platform features Does OVRWCHT respect the traditional social functions of the site and the cultural practices and dignity of local residents and associated communities?
		Conservation of authenticity	Authors' assessment based on platform features Does OVRWCHT contribute to conserving the authenticity of the cultural heritage site?
		Sensitivity	Authors' assessment based on platform features Is OVRWCHT sensitive to the character, setting, and cultural and natural significance of the site?
		Potential harm to authenticity	Authors' assessment based on platform features Does OVRWCHT harm the authenticity of the site in terms of on-site concerts, dramatic performances, and other interpretation programs?

(Continued)

Table 1: Continued

Principle	Indicators	Subindicators	Evaluation questions
Principle 5: Planning for sustainability	The interpretation plan for a cultural heritage site must be sensitive to its natural and cultural environment, with social, financial, and environmental sustainability among its central goals	Sustainability from the user's perspective	Assessment based on the questionnaire Do users agree that AI, 3-D visualization, light and shadow vision, and other technologies are important aspects of promoting sustainable heritage tourism?
		Overall planning and strategy	Authors' assessment based on platform features Is OVRWCHT an integral part of the overall planning, budgeting, and management process of the cultural heritage site?
		Potential heritage impact	Authors' assessment based on platform features Does OVRWCHT consider the potential effects of interpretive infrastructure and visitor volume on the cultural value, physical characteristics, integrity, and natural environment of the site in its impact assessments?
		Heritage education	Authors' assessment based on platform features Does OVRWCHT serve a wide range of conservation, educational, and cultural objectives?
		Heritage conservation	Authors' assessment based on platform features Is OVRWCHT an integral part of the conservation process?
		Stakeholders	Authors' assessment based on platform features Does OVRWCHT provide equitable and sustainable economic, social, and cultural benefits to all stakeholders?
Principle 6: Concern for inclusiveness	The interpretation and presentation of cultural heritage sites must be the result of meaningful collaboration between heritage professionals, host and associated communities, and other stakeholders	Integration of multidisciplinary professionals	Authors' assessment based on platform features Can OVRWCHT be integrated with the multidisciplinary expertise of researchers, community members, conservation experts, governmental authorities, site managers/interpreters, tourism operators, and other professionals?
		Respect traditional rights, responsibilities, and interests	Authors' assessment based on platform features Does OVRWCHT note and respect the traditional rights, responsibilities, and interests of property owners/hosts and associated communities?

(Continued)

Table 1: *Continued*

Principle	Indicators	Subindicators	Evaluation questions
Principle 7: Importance of research, training, and evaluation	Continuing research, training, and evaluation are essential components of the interpretation of a cultural heritage site	Open to the public	Authors' assessment based on platform features Is OVRWCHT open for public comment and involvement in expansion or revision?
		Legal ownership and rights are clarified	Authors' assessment based on platform features Does OVRWCHT clarify legal ownership and the right to use images, text, and other interpretive materials?
		Continuous monitoring and evaluation	Authors' assessment based on platform features Does OVRWCHT involve continuous monitoring and evaluation, ongoing research and consultation, and regular review?
		Possible uses in informal education	Authors' assessment based on platform features Does OVRWCHT take into account its possible uses in school curricula, informal/lifelong learning programs, communication/information media, special activities, events, and seasonal volunteer involvement?
		Training of qualified professionals	Authors' assessment based on platform features Can OVRWCHT assist in the training of qualified professionals in the specialized fields of heritage interpretation and presentation?

Moreover, interviews were conducted during field trips in August 2020. The authors visited the Hailongtun Tusi site to collect feedback on sustainable heritage tourism; they also asked for stakeholders' opinions of OVRWCHT. Stakeholders included two government officers, two Hailongtun tourism company managers, and two local researchers. Five of the six stakeholder respondents were local residents.

Both questionnaires were designed using Questionnaire Star. While the first survey was delivered online to users, the second was directly delivered to Hailongtun Tusi site administration staff.

4 Results and Discussion

The findings are summarized below in accordance with the research framework and the indicators from the Charter.

Figure 6: Geographical scope of survey respondents.

Figure 7: Age distribution of respondents.

4.1 Principle 1: Access and Understanding

The evaluation focused on whether general public access to OVRWCHT was convenient, easy to use, and easy to understand. Based on the questionnaire survey results (Tables 2 and 3), in terms of heritage interpretation and presentation, scores for the use of emerging technologies were higher than for traditional methods. Out of a total possible score of five points, OVRWCHT scored 3.65, while traditional site guides or audio guides scored 3.49. The traditional World Heritage Site publicity board and brochure scored 3.20. In terms of the effect of interpretation and presentation in highlighting the outstanding universal value of the site, users' scores for the use of new technologies were also higher than for traditional methods. OVRWCHT scored 3.61, while heritage site guides or audio guides scored 3.49. The World Heritage Site publicity board and brochure scored 3.31.

Table 2: Respondents' satisfaction with the interpretation and presentation of cultural heritage

Item/scores	1	2	3	4	5	Average score
Traditional exhibition boards and paper brochures of cultural heritage sites	98 (9.23%)	168 (15.82%)	361 (33.99%)	290 (27.31%)	145 (13.65%)	3.2
Traditional heritage guides or audio guides	25 (2.35%)	135 (12.71%)	377 (35.5%)	347 (32.67%)	178 (16.76%)	3.49
OVRWCHT	35 (3.3%)	96 (9.04%)	300 (28.25%)	407 (38.32%)	224 (21.09%)	3.65

Table 3: Respondents' evaluation of different means of highlighting the outstanding universal value

Item/scores	1	2	3	4	5	Average score
Traditional exhibition boards and paper brochures of cultural heritage sites	76 (7.16%)	171 (16.1%)	309 (29.1%)	360 (33.9%)	146 (13.75%)	3.31
Traditional heritage guides or audio guides	19 (1.79%)	131 (12.34%)	382 (35.97%)	373 (35.12%)	157 (14.78%)	3.49
OVRWCHT	26 (2.45%)	116 (10.92%)	301 (28.34%)	420 (39.55%)	199 (18.74%)	3.61

Thus, the data indicated that the general public believed OVRWCHT provided a better sense of the heritage experience, was easy to use and was easier to understand than traditional presentation methods. In addition, OVRWCHT could promote an understanding and appreciation of cultural heritage sites and cultivate public awareness of and participation in cultural heritage protection. Geographically speaking, OVRWCHT made it possible to conduct cultural heritage publicity in a broader geographical range. OVRWCHT can thus be considered an important method for off-site interpretation and presentation, though its application to broader contexts has not yet been demonstrated.

4.2 Principle 2: Information Sources

The second principle concerns evidence gathered through accepted scientific and research methods and traditions. The OVRWCHT platform presents the main content of cultural heritage as text, pictures, voice, and other forms so that users can get more information about the site's outstanding universal value. The Hailongtun Tusi site was recorded as digital panoramic photos, and an online platform was used to publicize the site's value during COVID-19. The cultural heritage information provided by the system came from accurate sources based on archaeological findings, such as those included in the Study of the Application for World Heritage and the Research Report on the Basic Information of the Hailongtun Site. Since these information sources are considered reliable and evidence-based, they can be regarded as gathered through accepted methods. However, there is no introduction to oral Tusi site history interpretation in OVRWCHT.

4.3 Principle 3: Attention to Setting and Context

This principle concerns how interpretation and presentation relate to broader social, cultural, historical, and natural contexts. Since OVRWCHT users did not fully understand the context and setting of the heritage site before using the platform, this principle was mainly assessed based on the authors' perspectives. It was determined that OVRWCHT attaches importance to the combination of natural and cultural environments and used panoramic technology to provide a digital recording of the surrounding environment. OVRWCHT describes the history of Hailongtun, the 725-year history of Yang rule over Bozhou, the architectural pattern of Hailongtun, and the military events, main landscapes, historical changes, and important events of Hailongtun as a military castle in the ancient era of the Bozhou Administration (876–1571 CE). This historical background is combined with digital information about historical relics. OVRWCHT also gives a brief introduction to the Han, Gelao, Miao, and other ethnic groups related to the Hailongtun Tusi site. However, OVRWCHT does not cover local folk customs, intangible cultural heritage, and local villagers' customs in depth.

4.4 Principle 4: Preservation of Authenticity

This concerns how to respect authenticity in the spirit of the Nara Document on Authenticity (1994). This principle was assessed using four subindicators: respect for the traditional social functions of the site, conservation of authenticity, sensitivity, and potential harm to authenticity. Since OVRWCHT users might not have fully understood heritage authenticity before using the platform, the assessment was mainly based on the authors' perspectives.

It was determined that OVRWCHT strictly abides by the principle of authenticity in accordance with the Nara Document (1994). As panoramic photos were taken of the site, the design of OVRWCHT aimed to fully

respect traditional social functions and the cultural practices and dignity of local residents and associated communities. The system also reduced the field pressure created by heritage tourism using an online digital guide. Thus, OVRWCHT contributes to conserving the authenticity of the site by reducing harm to the presentation facilities. In this way, OVRWCHT can be said to have achieved the purpose of protecting authenticity. However, it fails to fully demonstrate the link between the heritage site and local communities in terms of authenticity. Because of the need for heritage protection, former local Hailongtun residents moved away, which means this assessment item is less relevant. It is also difficult to evaluate its sensitivity to character, setting, and cultural and natural significance.

4.5 Principle 5: Planning for Sustainability

This principle concerns whether interpretation and presentation are sensitive to the environment, with social, financial, and environmental sustainability among the main goals. In the questionnaire, 93.79% of respondents agreed that AI, 3-D visualization, light and shadow vision, and other technologies are important means of promoting sustainable heritage tourism. Moreover, the older the respondents, the more supportive they were of applying technology to heritage interpretation and presentation (Figure 8). OVRWCHT can be said to be consistent with sustainable development objectives by promoting site protection, education, and cultural services. It also provides a way to reduce tourism pressure and share a World Heritage Site during an epidemic. Although OVRWCHT is currently free to use, there is no funding in place to ensure it will remain online. The research team promised to maintain OVRWCHT once the study was completed. However, OVRWCHT is not included in the current legal planning requirements of the Hailongtun site. That said, the interpretive purpose of OVRWCHT does not conflict with any of the legal planning goals.

Figure 8: Importance of emerging technologies for promoting sustainable tourism at cultural heritage sites.

OVRWCHT is not integrated with heritage assessment and does not involve any elements of permanent heritage facilities and maintenance. OVRWCHT is closely related to the network system and has little relationship with existing interpretation facilities and tourists.

4.6 Principle 6: Concern for Inclusiveness

This concerns meaningful collaboration between cultural heritage professionals, host and associated communities, and other stakeholders. This principle was assessed using four subindicators: integration with multidisciplinary professionals; respect for traditional rights, responsibilities, and interests; openness to the public; and clear legal ownership and rights.

Developing OVRWCHT involved large groups of stakeholders. For example, site administrators provided support, and managers of the local Chuanqi Tourism Company provided suggestions and detailed feedback. As a result of such combined efforts, OVRWCHT is accurate, convenient, and effective in explaining heritage value, and its costs are controllable. Local community members and tourists who had not visited the site were also pleased by OVRWCHT. Local heritage management departments praised it for facilitating site management and remote promotion for a large number of tourists. (Significantly, the system was launched on World Heritage Day, June 13, 2020.) Thus, stakeholders, site managers, local residents, and heritage tourism practitioners were all supportive of OVRWCHT and considered it effective for promoting the outstanding universal value of Hailongtun.

As described in Section 3.3, government officers at Hailongtun were also surveyed. The results indicated that 91.3% of respondents considered OVRWCHT effective for promoting the value of Hailongtun (Table 4).

The authors also interviewed the managers of a Hailongtun tourism company and local researchers who used the system. All considered OVRWCHT effective. Therefore, based on the interviews and questionnaires, OVRWCHT respects the interests of stakeholders and associated communities.

Table 4 : Question: Which methods do you think are most helpful for enhancing the outstanding universal value of Hailongtun?

Options	Count	Percentage
Training on highlighting universal value cognition of Hailongtun in Huichuan District in 2018	19	82.61
Report on the current situation of Hailongtun heritage written by the project team	18	78.26
Panoramic digital heritage interpretation and display system	21	91.3
Learning to highlight universal value organized in meetings of the authorities	19	82.61
Other	3	13.04

OVRWCHT was revised many times based on stakeholders' input. For example, directions to Hailongtun were adjusted, and more heritage signs were added. Yet, some suggestions could not be implemented. One user, for example, complained there were too many photos. The research team tried to reduce the number of photos but felt that doing so would fail to fully represent the Hailongtun Tusi site.

Heritage tourism has faced many problems during COVID-19, such as the reduction of income. Against this background, OVRWCHT can promote tourism development by allowing heritage managers to contact tourists directly so that middlemen in tourism operations can be eliminated.

In summary, the content production of OVRWCHT heritage interpretation was based on collaborative efforts among different stakeholders. It respected their opinions and made modifications based on their suggestions. Meanwhile, the online platform was produced by the authors, who work for Tongji University, with clear copyright and use rights.

4.7 Principle 7: Importance of Research, Training, and Evaluation

This principle concerns ongoing research, training, and evaluation, which are essential components of the interpretation of heritage sites. This principle was evaluated by the authors based on the research framework. Such assessment is part of an ongoing study of OVRWCHT, which is currently focused on the effectiveness of the platform. OVRWCHT will continue to be improved with ongoing research. This research

is still in the initial stages; however, there is currently no plan for professional training or international cooperation.

5 Conclusion

Although this study tried to ensure the validity of the information, most respondents were affected by COVID-19 and might therefore have different perceptions during a nonepidemic period. However, the impact on the overall authenticity of the research data was likely very small.

This study proposed an evaluation framework to assess the performance of an OVRWCHT system for the interpretation and presentation of a cultural heritage site during COVID-19. The research framework was based on the seven main principles of the Charter, and evaluation criteria were established for each. The framework was applied to an OVRWCHT system for the Hailongtun Tusi World Heritage Site developed by the authors. The data were mainly based on 1,062 online survey respondents as well as analyses of the online system created for this study.

The results indicated that, whether in terms of user experience or the interpretation of outstanding universal value, OVRWCHT was received relatively positively by users and stakeholders in the context of COVID-19. OVRWCHT was found to generally conform to the seven principles of the Charter. However, some elements of those principles are not specifically relevant to online interpretation; thus, OVRWCHT could not be evaluated on the basis of those items.

Panoramic 3-D imaging can be used for effective heritage presentation and interpretation during an epidemic. Emerging technologies such as AI and 3-D visualization have significant advantages over traditional methods in this field. More data support is needed to improve both technology and theory, especially the transferability of OVRWCHT to countries other than China. Based on this study's findings, it is suggested that ICOMOS should continue to issue charters on how emerging technologies can help activate cultural heritage site interpretation and presentation.

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Conflict of interest: The authors have no competing interests to declare.

Supplementary materials: Datasets may available from the corresponding author upon request, but share the datasets may need to grant approve by local heritage management authorities.

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Appendix 1 First Questionnaire Survey

1. Have you been to a Chinese cultural heritage site in the past ten years [single choice]?

Options	Subtotal	Proportion (%)
Yes	703	66.2
No	359	33.8
Valid number	1,062	

2. What problems do you think China faces in the field of cultural heritage exhibition and interpretation [multiple choice]?

Options	Subtotal	Proportion (%)
Not fully understanding the cultural history of a cultural heritage site after taking a tour	718	67.61
After visiting the heritage site, we did not fully understand its cultural heritage and universal value	712	67.04
The heritage exhibition content is too old-fashioned, unattractive, and lacking in technology	573	53.95
Other issues	32	3.01
Valid number	1,062	

3. Do you think the following methods of displaying the value of cultural heritage can give you a better experience when visiting a heritage site?

Link 1 for mobile panoramic guide: <http://m.detu.com/zh/pano/show/691589>

Link 2 shows the 3-D digital model: <https://demo.laozicloud.com/tjdx/>

Link 3 for the display of cultural heritage: <https://www.bilibili.com/video/bv14C4y1p7Cv>

Link 4 for cultural heritage VR display (VR equipment may be required): <https://www.bilibili.com/video/bv1GT4y1g7cf> [matrix scale questions]

Average score: 3.66

Title/options	1	2	3	4	5	Average score
Exhibition board and paper brochure of the cultural heritage site	98 (9.23%)	168 (15.82%)	361 (33.99%)	290 (27.31%)	145 (13.65%)	3.2
Cultural heritage guide or audio guide system	25 (2.35%)	135 (12.71%)	377 (35.5%)	347 (32.67%)	178 (16.76%)	3.49
Mobile panoramic heritage guide system (link 1)	35 (3.3%)	96 (9.04%)	300 (28.25%)	407 (38.32%)	224 (21.09%)	3.65
Cultural heritage 3-D digital model guide and display platform (link 2)	19 (1.79%)	96 (9.04%)	256 (24.11%)	423 (39.83%)	268 (25.24%)	3.78
						3.86

(Continued)

(Continued)

Technology of acoustic, photoelectric, and light and shadow displays of cultural heritage (link 3)	19 (1.79%)	80 (7.53%)	250 (23.54%)	390 (36.72%)	323 (30.41%)	
Virtual reality technology of cultural heritage (link 4)	22 (2.07%)	69 (6.5%)	203 (19.11%)	371 (34.93%)	397 (37.38%)	3.99
Valid number	218 (3.42%)	644 (10.11%)	1,747 (27.42%)	2,228 (34.97%)	1,535 (24.09%)	3.66

4. To what extent do you think the following ways to display the value of cultural heritage can make you more clearly understand its outstanding universal value after visiting the site?

Link 1 for mobile panoramic guide: <http://m.detu.com/zh/pano/show/691589>

Link 2 shows the 3-D digital model: <https://demo.laozicloud.com/tjdx/>

Link 3 for the display of cultural heritage: <https://www.bilibili.com/video/bv14C4y1p7Cv>

Link 4 for cultural heritage virtual reality display (VR equipment may be required): <https://www.bilibili.com/video/bv1GT4y1g7cf> [matrix scale questions]

Average score: 3.67

Topics/options	1	2	3	4	5	Average score
Exhibition boards and paper brochures of cultural heritage sites	76 (7.16%)	171 (16.1%)	309 (29.1%)	360 (33.9%)	146 (13.75%)	3.31
Cultural heritage tour guide or audio navigation system	19 (1.79%)	131 (12.34%)	382 (35.97%)	373 (35.12%)	157 (14.78%)	3.49
Mobile panoramic heritage guide system (link 1)	26 (2.45%)	116 (10.92%)	301 (28.34%)	420 (39.55%)	199 (18.74%)	3.61
Cultural heritage 3-D digital model exhibition platform (link 2)	20 (1.88%)	84 (7.91%)	263 (24.76%)	429 (40.4%)	266 (25.05%)	3.79
Cultural heritage display technology of sound, photoelectricity, and light and shadow (link 3)	21 (1.98%)	74 (6.97%)	264 (24.86%)	408 (38.42%)	295 (27.78%)	3.83
Cultural heritage virtual reality technology (link 4)	23 (2.17%)	74 (6.97%)	215 (20.24%)	344 (32.39%)	406 (38.23%)	3.98
Valid number	185 (2.9%)	650 (10.2%)	1,734 (27.21%)	2,334 (36.63%)	1,469 (23.05%)	3.67

5. After viewing the above links, do you agree that emerging technologies such as AI, 3-D visualization, and light and shadow vision are important methods for promoting sustainable heritage tourism [single choice]?

Option	Subtotal	Proportion (%)
Yes	996	93.79
No	66	6.21
Valid number	1,062	

6. What is your age range [single choice]?

Option	Subtotal	Proportion (%)
Under 18	28	2.64
18–25	451	42.47
26–30	182	17.14
31–40	254	23.92
41–50	108	10.17
51–60	33	3.11
60–	6	0.56
Valid number	1,062	

7. Please enter your email address for question 10 [fill in the blank].

These data may contain personal identity information and are therefore excluded.

Appendix 2 Second Questionnaire Survey

1. What is your current job [single choice]?

Options	Subtotal	Proportion (%)
Zunyi civil servant or employee of a public institution	20	86.96
Villager around Hailongtun (mainly farming)	0	0
Hailongtun-related enterprise (such as The legend Development Company)	0	0
Other	3	13.04
Valid number	23	

2. Are you aware of the outstanding universal value of the Hailongtun Tusi World Heritage Site [single choice]?

Options	Subtotal	Proportion (%)
Yes	21	91.3
I've heard about it, but I don't know what it is	2	8.7
Have not heard about it	0	0
Valid number	23	

3. What do you think is the most helpful way to enhance the universal value of the Hailongtun Tusi site [multiple choice]?

Options	Subtotal	Proportion (%)
The 2018 training on highlighting universal value recognition	19	82.61
The report on the current situation of Hailongtun heritage written by the project team	18	78.26
Panoramic digital heritage interpretation and display system	21	91.3
Learning to highlight universal value organized by meetings of the authorities	19	82.61
Others	3	13.04
Valid number	23	

4. May I have your name and mobile number [fill in the blank]?

Data excluded for privacy.

5. If you are a local resident, which village group do you belong to [fill in the blank]?

Data excluded for privacy.