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Meet the Virtual Jeju Dol Harubang—The Mixed VR/AR Application for Cultural Immersion in Korea's Main Heritage

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Abstract: Jeju Island comes second to only Seoul as Korea's most visited destination, yet most visitors do not have the chance to go beyond brief visits and immerse themselves in the island's history and cultural heritage. This project introduces the cultural heritage of Jeju Island to visitors through virtual reality/augmented reality (VR/AR) model visualization technology, namely *JejuView*, which provides an intuitive way to experience cultural heritage sites on the island. The proposed VR/AR application is designed to introduce a series of heritage spots on Jeju Island through (i) a printed Jeju map with embedded QR code markers that enable viewers to experience the locations without being present at the site, (ii) a mobile device with WebGL supported browser which allows 3D content to be rendered, and (iii) an AR library (A-Frame.io) that enables enthusiasts to recreate similar work. To test the effectiveness of the proposed VR/AR application, the authors conducted an experiment with 251 participants to test the research model based on the technology acceptance model (TAM) and employed generalized structured component analysis (GSCA) for the analysis. Results show that when using sensory new media such as VR/AR, consumers are more focused on the hedonic value than on the utilitarian value of the information. In conclusion, the proposed VR/AR application is complementary to existing studies and provides significant support to researchers, engineers, and designers developing VR/AR technologies for use in cultural education and tourism marketing.

Keywords: virtual reality; augmented reality; a-frame; cultural education and preservation; Jeju island; heritage tour; tourism marketing; technology acceptance model; generalized structured component analysis

1. Introduction

The tourism industry plays an important role in promoting local economic development as well as in disseminating the national cultural values of one country to others around the world. Many efforts have been made in this line to provide information to tourists using both traditional media, such as flyers, magazines, newspapers, videos, and podcasts, and new means of communication (e.g., social media). Recently, with the help of new media technologies, advertising in tourism has gone beyond giving information; it now serves educational as well as entertainment purposes to attract more tourists. For example, by using a head-mounted display (HMD), customers are now able to immerse themselves in a virtual world (or virtual reality [VR]) to experience a place that they have never been to, or to explore forgotten artifacts. By using a device with an attached camera (e.g., binoculars, tablet,

smartphone) tourists can recreate lost buildings, see 3D animals running around, travel into the past, or visualize the sculptural heritage [1]. These combinations of multi-modal platforms pave the way for new methods to provide a richer experience to customers.

In recent years, the world has witnessed a series of unexpected catastrophic events such as earthquakes, tsunamis (in Japan, Thailand), bushfires (in Australia), and snowstorms (in the US), as well as the spread of disease (e.g., the Ebola virus, Covid-19), making it difficult or even impossible for tourists to travel [2]. Existing approaches may not be optimal since they require customers to be at the site in order to use technological devices (e.g., programmed HMDs, binoculars, markers). The need to disseminate information combined with a desire to discover have pushed us to think of a new way to alleviate this problem. Furthermore, the new idea should be robust, meaning that it is applicable even when there is no catastrophe.

Korea is known as one of the leading countries in telecommunication, entertainment, and tourism. Jeju Island comes second to only Seoul as Korea's most visited destination. Due to its isolated location just off the southern tip of Korea, most visitors do not have the chance to go beyond brief visits and immerse themselves in the island's history and cultural heritage. Therefore, taking into account the changing global context, there is a clear need to have a new means of communication that enable remote tourists to experience and enjoy the cultural values of Jeju without necessarily being present at the actual location.

In response to this need, our research introduces a comprehensive approach that combines multiple existing methods as well as our newly developed procedure to construct a multimodal VR/AR application, called *JejuView*. In our application, visitors are able to navigate to different places with the help of a virtual avatar assistant, or they can immerse themselves in a virtual world using only a smartphone and a low-cost VR headset (i.e., Google Cardboard). On the other hand, the augmented reality (AR) application enables remote tourists to experience Jeju artifacts in the comfort of their own homes, by watching the virtual Dol Harubang, Jeju's iconic stone guardian, introduce various places. The use of VR/AR has shown numerous advantages in many different domains, from production design, manufacturing [3], infrastructure [4] to fostering decision making processes [5]. Berg and Vance [3] suggested that VR has reached a level of mature, stable, usable performance and this suggestion was confirmed in the study of Nguyen et al.[6]

2. Research Aim

To the best of our knowledge, there is no other study that exploits the use of multi-modal VR/AR web applications to promote national cultural values, which makes this research a unique contribution. Our study addresses this gap by introducing a comprehensive web-based VR/AR application that helps promote cultural identity by enabling remote tourists to experience some typical places on Jeju Island. Consequently, this paper contributes to current research as it:

- provides a unique multimodal approach to introduce places and artifacts on Jeju Island;
- illustrates its approach through an open-source, web-based VR/AR application called *JejuView*; and
- evaluates the proposed VR/AR application using the technology acceptance model with the following hypothesises:

  – H1: Perceived visual design will have a positive effect on perceived Task-Technology Fit.
  – H2: Perceived visual design will have a positive effect on Perceived Usefulness.
  – H3: Perceived Task-Technology Fit will have a positive effect on Perceived Ease-of-Use.
  – H4: Perceived Ease-of-Use will have a positive effect on Perceived Usefulness.
  – H5: Perceived Usefulness will have a positive effect on Intention to Use.
  – H6: Perceived Ease-of-Use will have a positive effect on Intention to Use.
  – H7: Perceived Usefulness will have a positive effect on Intention to Visit.
  – H8: Perceived Ease-of-Use will have a positive effect on Intention to Visit.

The paper content is structured as follows: Section 3 outlines existing work that is similar to our study. Section 4 presents the methods for designing our proposed application, and also describes the

VR/AR system architecture in detail. Section 5 evaluates the *JejuView* application using the technology acceptance model. Some challenging problems and research implications are discussed in Section 6. We conclude our work in Section 7.

3. Related Work

The convenience of using VR/AR technology for heritage locations has been the focus of several studies. The feasibility of AR adoption was conducted in a study by Chung et al. [7], where visitor intention was measured in terms of technology readiness (TR), visual appeal, facilitating conditions, perceived usefulness, perceived ease-of-use, AR attitude, AR usage intention, and intention to visit the destination. Among these variables, only technology readiness, visual factors of AR, and situational factors influence visitors to actively utilize AR. The findings showed that perceived usefulness and ease of use had an impact on the participants' intention to use AR and to visit the site. An expensive approach that relies on dedicated AR devices was conducted in References [8,9], where an ancient civilization's cultural values were brought to life through a mixed virtual reality recreation of Pompeii. Heritage artifacts (i.e., clothes, body, skin, face) were simulated and animated on the virtual human actors superimposed on the physical world. Visitors' experience was enhanced through a series of indoor and outdoor activities. Specifically, participants in Reference [10] were equipped with a head-mounted display designed to impose 3D content, images, and audio onto the physical world. Users walked around a given area and the corresponding content was triggered through Global Positioning System (GPS) information. A practical work on the usage of AR technology was presented in the application of ARCHEOGUIDE [11,12], which facilitated visitors' exploration and experience of the artifacts based on their interests. ARCHEOGUIDE was installed in a customized electronic device and functioned as a tour guide. Upon the visitor's selection of the place of interest, an introduction for navigation was generated through the website. The AR technology used a position–orientation tracking component to superimpose on the ancient buildings.

Han et al. [13] proposed a 3D model visualization system built on AR technology, which allowed smartphone users to see 3D models of heritage locations by using video footage of real heritage locations for both indoor and outdoor use. The research used 3D models of actual stone tombs and dolmens with the aim to render a 3D visualization system of cultural sites based on outdoor AR technology. The results of the study showed that outdoor augmented reality technology relying on outdoor GPS, compass, and gyroscope sensor goes beyond the space limitations of existing methodology for indoor 3D model visualization and enables users to utilize information without difficulty for both outdoor and indoor cultural sites.

Jung et al. [14,15] recently analyzed the application of AR technology for heritage conservation through the software PalmitoAR, which reenacts a crucial battlefield in the American Civil War, in Palmito Ranch, Cameron County, Texas. The data collected from 26 users and an algorithm for AR markers recognition that enabled specific contextual and temporal positioning of 3D models, enabled PalmitoAR to render a series of historical battles with the help of embedded markers on a printed map, a mobile device with a WebGL supported browser, and an AR library for future developments of the application. The results pointed out the positive influence of visual design on the task technology, which in turn had a positive impact on perceived ease of use, and the latter positively affected the intention of use and perceived usefulness of the application.

In terms of VR experience, Jung et al. [16] showed that participants had a positive attitude towards a tourist visit based on virtual reality technology. The study was conducted with 35 participants who took a VR tour in the Lake District of England. A more comprehensive study through the lens of VR on the tourism sector was conducted by Guttentag [17]. The study showed that VR could successfully be used as a substitution for a real visit due to its benefits such as reduced cost, no language barriers, bureaucracy, or the need to wait for or change transportation, and a safer ride, regardless of the weather conditions. Although the advantages overcame the issues encountered, the acceptance of substitutes was determined by the visitors' attitude toward authenticity, motivations, and constraints.

Yung and Catheryn [18] synthesized 46 literature studies on the use of VR/AR in tourism. Their study showed that if the proposed technology could not be used by potential customers, positive results could be inappreciable. Furthermore, the lack of theory-based research in VR/AR posed a limitation to existing work.

Overall, the review of previous studies showed a positive attitude of visitors toward the adoption of VR/AR technology. Many applications were made specifically for VR, AR, or a combination of both. However, the most feasible approaches were dependent on the presence of visitors. Our work differs from existing studies in that we primarily target remote tourists.

4. Methods

4.1. System Design

In this section, we describe the methodology and process of developing the VR/AR application in detail and we encourage readers to refer to the video demo of the VR/AR application available on YouTube [19].

JejuView was developed using JavaScript libraries, particularly ThreeJS [20]—a library for generating and displaying animated 3D contents in a web browser, Mapbox GL JS [21]—a WebGL JavaScript library used to render interactive maps, A-Frame [22]—a web framework for building VR experiences through a component, and AR.js [23]-an open-source library built on top of the ARToolkit and integrated with A-Frame. Unlike other studies that created VR/AR applications for dedicated devices (e.g., Microsoft Hololens, Oculus Rift, HTC Vive, Google Glasses), we intended to make the VR/AR experience available to a more diversified public by only using a smart device (e.g., smartphone, tablet with built-in WebGL support). Our approach not only accommodates a variety of devices but is also affordable. The use of web-based technology to design VR/AR experiences has been researched extensively in References [24–27].

The main objective of *JejuView* is to design a VR/AR application that introduces visitors to an advanced exploration of heritage locations on Jeju Island. Several considerations were taken into account when designing *JejuView*-(1) retrieving information from a heritage location; (2) displaying a variety of heritage contents such as text, images, video, virtual artifacts; 3) encouraging immersion in a virtual reality environment; and 4) experiencing a heritage site integrated in the physical world. To meet these goals, we followed the visual design suggestion by Munzner [28], in which the requirements of the application were categorized into tasks, and the visual design was carried out to fulfill these tasks. The proposed VR/AR application addresses the following high-level tasks:

- **Task 1 (T1)**. Enable visitors to retrieve information about a given heritage site.
- **Task 2 (T2)**. Support multiple content formats including text, images, virtual artifacts.
- **Task 3 (T3)**. Support users to access information in various ways such as lip reading, audio listening, or text skimming.
- **Task 4 (T4)**. Enable visitors to be immersed in a given heritage location.
- **Task 5 (T5)**. Allow visitors to experience heritage places in a mixed reality environment.

Building on these tasks, we developed *JejuView* with two main components—(1) a virtual reality component and (2) an augmented reality component.

4.1.1. The Virtual Reality Component

The first step of the *JejuView* VR application was an overview design as illustrated in Figure 1, where the four main heritage sites are superimposed as thumbnails onto the 3D interactive map. Each thumbnail is the representation of the most typical artifact at the site. Mapbox GL JS was used to render the interactive 3D map. Section A allows users to show/hide 2D or 3D content to prevent occlusion, Section B introduces a virtual assistant that features animated lip syncing onto the spoken text, and Section C enables the creator to update heritage site information.
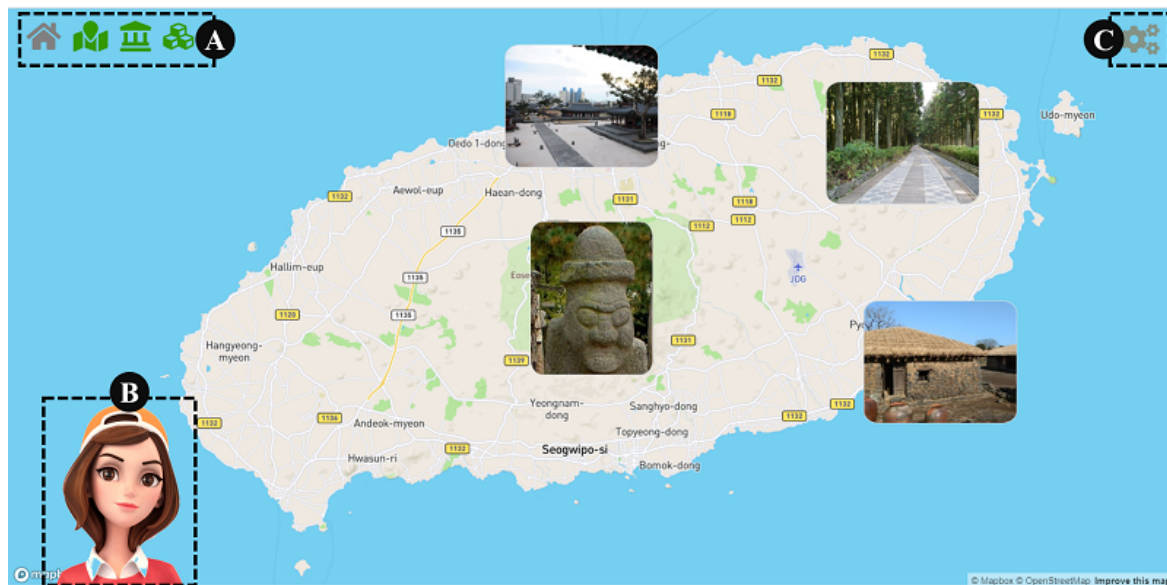
Figure 1. The virtual reality (VR) component—(**A**) utility section where users can toggle information on or off, (**B**) virtual assistant to support users, (**C**) configuration section to update heritage information.

Figure 1 introduces visitors to four destinations: (1) Dol Harubang—Jeju's stone guardian deity and cultural symbol; (2) Gwandeokjeong Pavilion—a training ground built during King Sejong's reign (1448) as a model of excellence in strengthening the minds and souls of soldiers; (3) Bijarim Forest—nicknamed the "Forest of a Thousand Years", a haven for hundreds of bija (nutmeg yew) trees and the largest forest in the world to be made up of one plant species, also sheltering a 800-year-old, conjoined nutmeg yew; and (4) Jeju Folk Village—the highlight of the island's heritage, featuring a mountain village, a fishing village, a botanical garden, a market place, an old government building, in addition to a genuine shamanic rite shrine, reflecting the particularities of traditional culture on Jeju Island in the 19th century.

Upon selection of the site of interest, information about the heritage shows up on the screen (**Task T1**). A short description is provided along with other available content (e.g., video, "See 3D artifact in VR", "View 3D artifact in AR" for **Task T2**), as depicted in Figure 2 when users click on Gwandeokjeong's thumbnail.

In Figure 2, off-site visitors can access information by either reading the description by themselves or getting the virtual assistant to read the text out loud (by clicking on the sound icon in Figure 2a). A virtual assistant has been used extensively in many digital advertising campaigns, games, and news channels to engage user interaction or support people with impairment (i.e., by listening to the voice or reading lip movement—for **Task T3**). The virtual assistant (in Figure 1B), named "Rose", was retrieved from an open-source repository [29] as an image in graphics interchange format (GIF). It was customized to align with *JejuView*, such as removing the white background and scaling. The audio for reading out text was automatically generated from Web Speech API (text-to-speech). The duration of the speech, estimated according to the length of the heritage site's information, was adjusted to match Rose's lip movements.

Figure 3 illustrates a scenario where users can get more information about a given heritage site by clicking on the zoom icon (Figure 2b). The interactive map takes visitors to the corresponding location. Available assets (3D model of artifacts, videos, images) will be superimposed on the locations identified by the creator. In Figure 3, the 3D model of the temple was positioned on its actual place. Users can rotate, zoom, and pan the interactive map to view the artifact from multiple angles. The model was created in 3D software (Blender [30] 3D software), then exported as a JSON file, and finally manipulated in ThreeJS to read and render it.
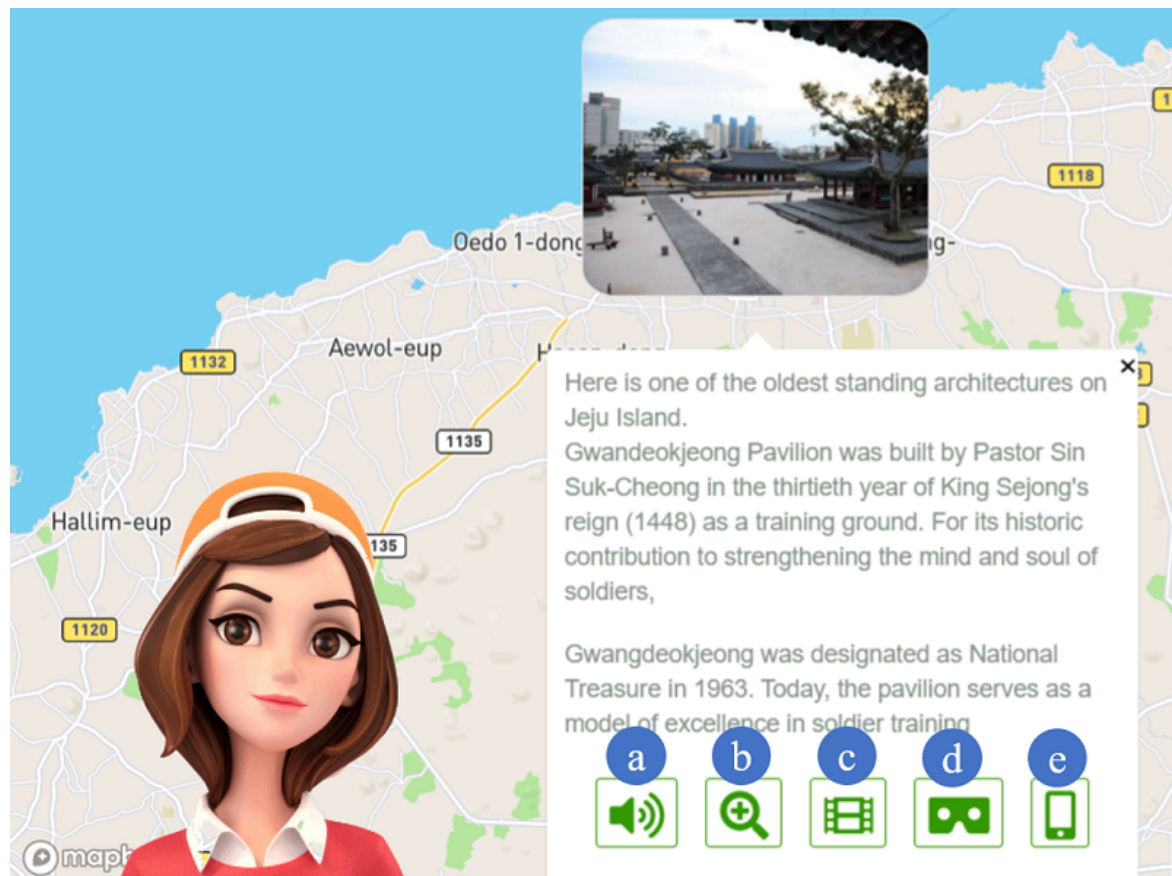
Figure 2. Available information for a given heritage location: (**a**) read out loud, (**b**) go to site, (**c**) watch the video, (**d**) see the artifact in VR, (**e**) view the artifact in augmented reality (AR).
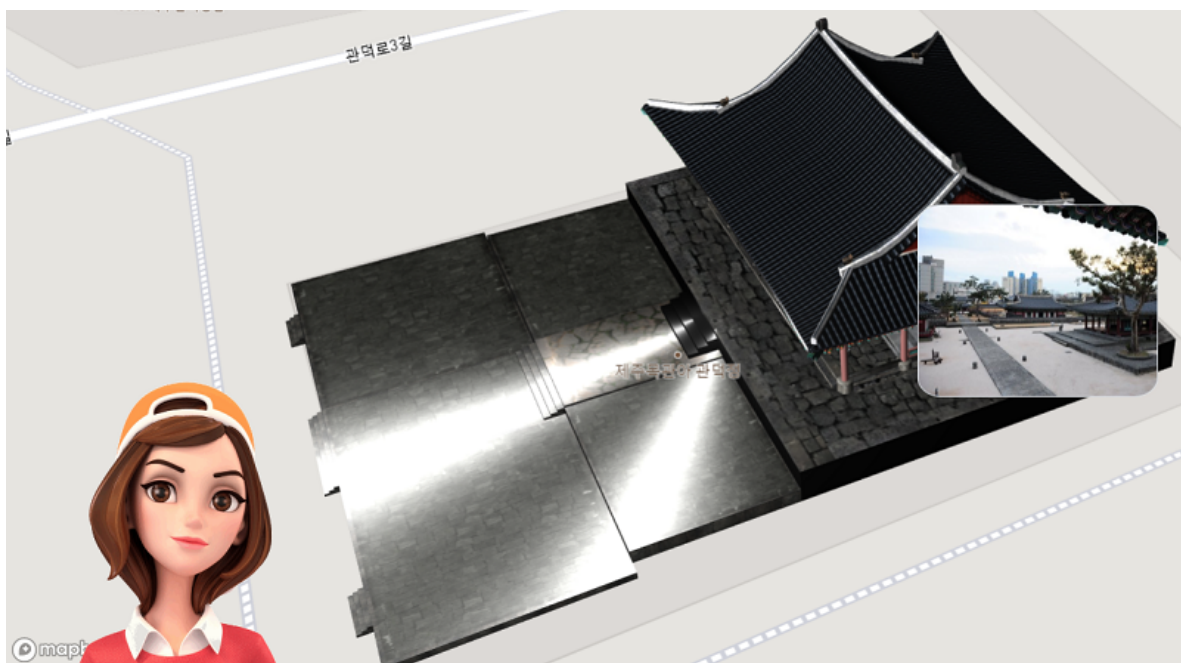

Figure 3. The 3D model of the heritage artifact is accurately positioned on the interactive map.

While the overview design interface facilitates a holistic approach to the application and its navigation, the detailed view offers information to users, in addition to allowing them to experience the location. The actual VR begins when visitors want to look inside the artifact. *JejuView* supports this

feature by rendering a new scene with the desired artifact. For example, when users click on the VR icon as in Figure 2d, a new VR environment is generated (as depicted in Figure 4) and visitors are able to look and move around using a Google Cardboard headset (**Task T4)**.
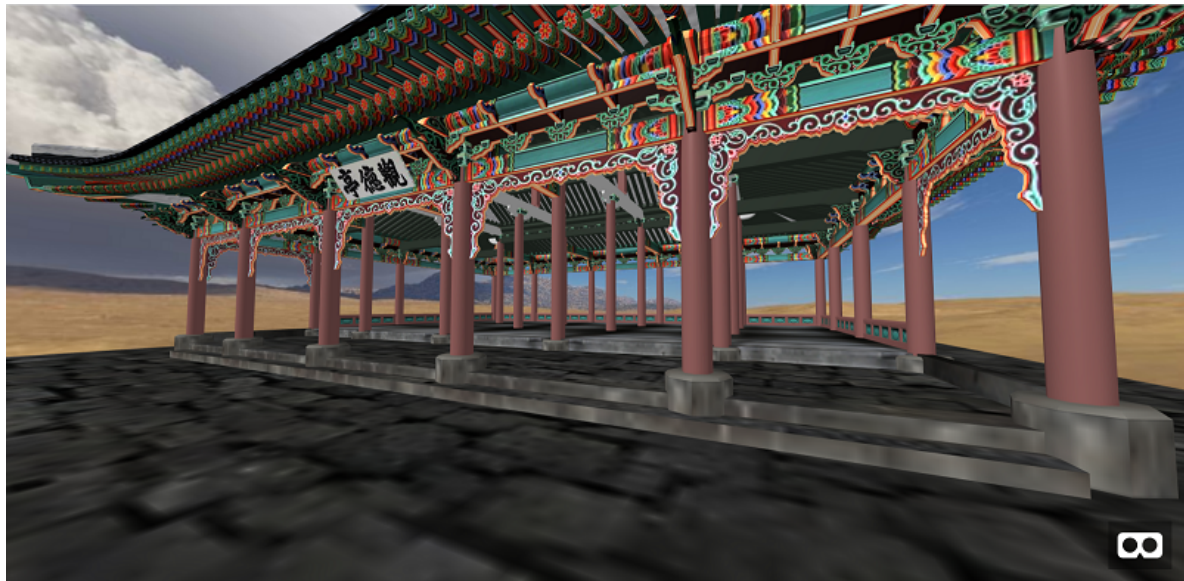

Figure 4. The VR component allows users to fully engage with the virtual environment and experience the artifact.

4.1.2. The Augmented Reality Component

Along with the VR feature, the *JejuView* application is equipped with an AR component that acts as storytelling platform about Jeju Island (**Task T4**). The AR component is triggered by following the AR button in Figure 2e.

Figure 5 shows the main interface of the AR component, which includes six buttons positioned at the top of the screen (note that the "QR" code located at bottom right is not part of the visual design). The QR code indicates that users can use their smartphone camera to directly open the link, which is convenient because users do not have to enter a long URL manually.
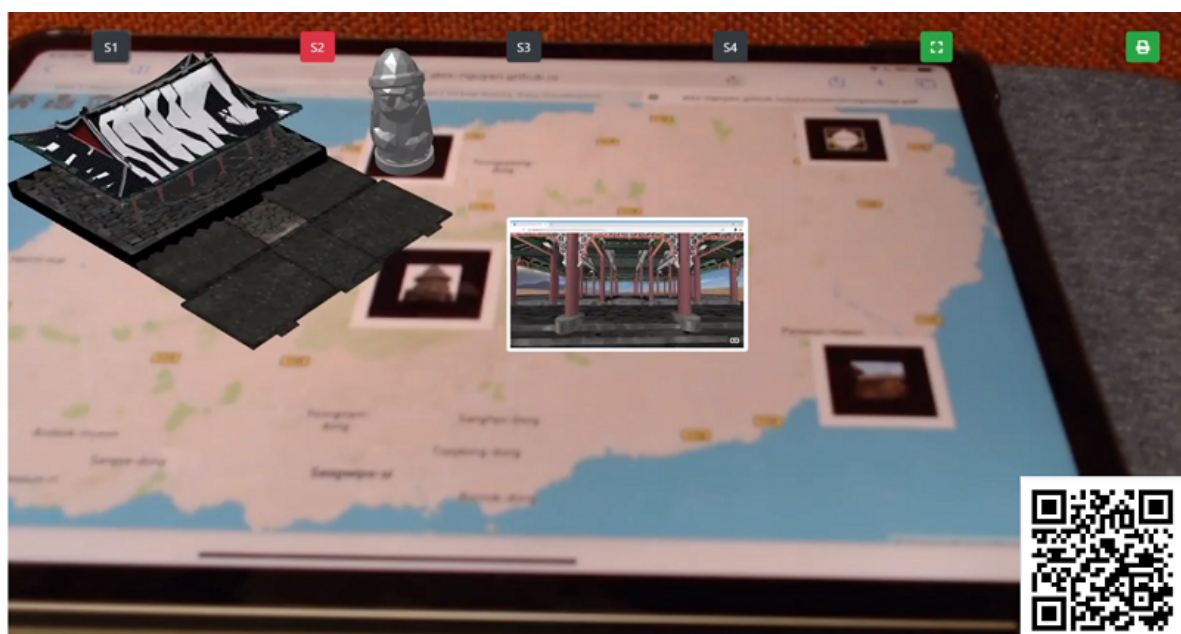

Figure 5. The main interface of the AR component.

The "Full Screen" button enables users to display the AR scene in full screen mode. The map used for triggering 3D content can be downloaded through the "Print Map" button. The "Location Stage" (denoted as *S*) 1–4 indicates each heritage location (Tasks T1, T2) which users can play/trigger individually. For each heritage point, a short description is provided in the caption space at the bottom of the device's view port. Normally, once a visualization finishes the next location is automatically introduced, with a delay time of 3 seconds. By triggering the event of a button, visitors can experience the corresponding location (Task T1). Available assets or content formats, including images and a 3D model of the artifact, are shown according to the chosen stage. A particular heritage site (stage button) is activated when the marker associated with that location is found. The button will be highlighted to indicate the activation and simulation of the current heritage site. Next, we describe each heritage section:

- *Dol Hareubang* (S1): "Hello! My name is Dol Hareubang. I am also called Tol Harubang, or Harubang. I am a large rock statue found on Jeju Island, off the southern tip of South Korea. I am usually considered to be a god granting both protection and fertility, and placed outside of gates for protection against demons travelling between worlds. I have become the symbol of Jeju Island, and replicas of various sizes are sold as tourist souvenirs. Now let me take you to the great tourist spots of Jeju Island!"
- *Gwandeokjeong Pavilion* (S2): "Here is one of the oldest standing architectural structures on Jeju Island. Gwandeokjeong Pavilion was built by Pastor Sin Suk-Cheong as a training ground in the 30th year of King Sejong's reign (1448). Gwangdeokjeong was designated as a National Treasure in 1963, for its historic contribution to strengthening the minds and souls of the island's soldiers. Today, the pavilion serves as a model of excellence in soldier training."
- *Bijarim Forest* (S3): "Bijarim Forest is the ideal spot for a relaxing forest retreat! The dense forest is home to hundreds of bija (nutmeg yew) trees, and is the largest one-plant-species forest in the world. Most of the trees in the forest have lived for 500 to 700 years, earning the forest the nickname "Forest of a Thousand Years". While taking a stroll through Bijarim Forest, make sure you visit the 800-year-old conjoined nutmeg yews."
- *Folk Village* (S4): "Stretching across 4,500 hectares in Pyoseon-ri, Jeju Folk Village is the island's main tourist attraction, where you can explore customs from the old days. At the folk village, the unique lifestyle and traditional culture of Jeju Island come to life just as they unfolded over two centuries ago. Take a walk through the mountain village, the fishing village, the botanical garden, and the marketplace, and further discover the old government quarters and even an authentic shamanic shrine!"

Each heritage site description was transcribed into audio by a Text-To-Speech (TTS) application to enhance the user experience. Various methods have been tested to obtain the most natural speech including Google TTS, iOS, Windows, and IBM TTS. We found that IBM TTS gave the best output in terms of human-like voice. The audio segments are played inline for each heritage location.

Our application used a marker-based approach to position the Harubang on the printed map. This method adds an easily detectable image to the system. Once the image was identified, we extracted its location and superimposed the 3D artifact on it. Figure 6 illustrates the steps required to construct the pattern and generate a marker. First, a representative image of a certain heritage site was chosen and fed into the marker training/generator [31]. The generator component provides two outputs: the marker (Figure 6(2)) and the pattern associated with it (Figure 6(3)). The marker was embedded from the directory into the printed map (Figure 6(5)), whereas the pattern was used as an input for the AR pattern/marker detector (Figure 6(4)). Once the marker (Figure 6(7)) was matched with its pattern (Figure 6(6)), the location was extracted and used to display the 3D artifacts.

Figure 6. The printed map-making process: (1) representative image of a heritage site, (2) generated marker with augmented region, (3) marker pattern extraction, (4) AR pattern detector, (5) marker inserted into the map, (6) detector marker position, and (7) superimposed artifact on the printed map.

4.2. Evaluation

The technology acceptance model (TAM) introduced by Davis [32] for assessing an individual's acceptance of information technology provided the theoretical instrument to test the *JejuView* application, as it has proven useful in both explaining certain aspects of information technologies and offering insight into the customer attitude toward using these technologies. Previous research has empirically validated the use of TAM in different fields from mobile technology [33], virtual communities [34] and the virtual world [35] to healthcare [36] and the consumer decision-making process [37]. Davis identified the initial two main measures used in TAM as "perceived usefulness", which refers to "the degree to which a person believes that using a particular system would enhance his or her job performance", and "perceived ease-of-use", which explains the degree to which an individual believes that "using a particular system would be free from effort" [38]. Research on the TAM model has steadily expanded over the years, with special attention given to evaluating the durability and effectiveness of survey questionnaires.

In addition, we considered the task-technology fit model (TTFM) [39], which matches the TAM framework in that task-technology will impact the performance outcome. Specifically, task requirements are matched with information technology features and support. This approach is reinforced by Dishaw and Strong [40], who broadened the TAM paradigm with TTFM constructs and suggested that the task-technology fit framework influences the perceived ease-of-use. The resulting composite model has since been applied in various research [41–43]. Visual design (or visual appeal) is a crucial factor in designing an application because it increases consumer trust and loyalty [44]. For example, Hartmann et al. [45] argued that "beauty matters and it influences decisions that should be independent of aesthetics." Consequently, consideration for visual design has been embraced in many domains, as in the case of Verhagen et al.'s [46] study, which supports the premise that visual attractiveness has a positive impact on perceived usefulness.

4.3. Data Collection and Analysis

The research model in Figure 7 integrates the hypotheses into a schema of causal relationships and provides the onset for our study. We measured the constructs (latent variables) specified in the oval boxes with a set of items, and the arrows represent the eight hypotheses.

We conducted an online survey using Amazon Mechanical Turk (MTurk) panel with 251 participants in order to test the hypotheses. Respondents received a questionnaire consisting of a YouTube video link and 25 question items, of which 22 questions about user behavior and three questions about demographic information. The survey first covered questions about personal attitude and behavioral intention of using *JejuView*, which were assessed with a 5-point Likert scale ([1] strongly disagree, [2] disagree, [3] neutral, [4] agree, [5] strongly agree). The second part required participants to provide general demographic information such as gender, ethnicity, and English as a first language.

The six constructs used to develop the questionnaires were perceived visual design (VD) (adapted from Reference [46]), perceived task-technology fit (TTF) [43], perceived usefulness (PU) [38], perceived ease-of-use (PEU) [38], intention to use (ITU) [38], and intention to visit (ITV) [38]. Table 1 presents a list of the items used to measure each construct.
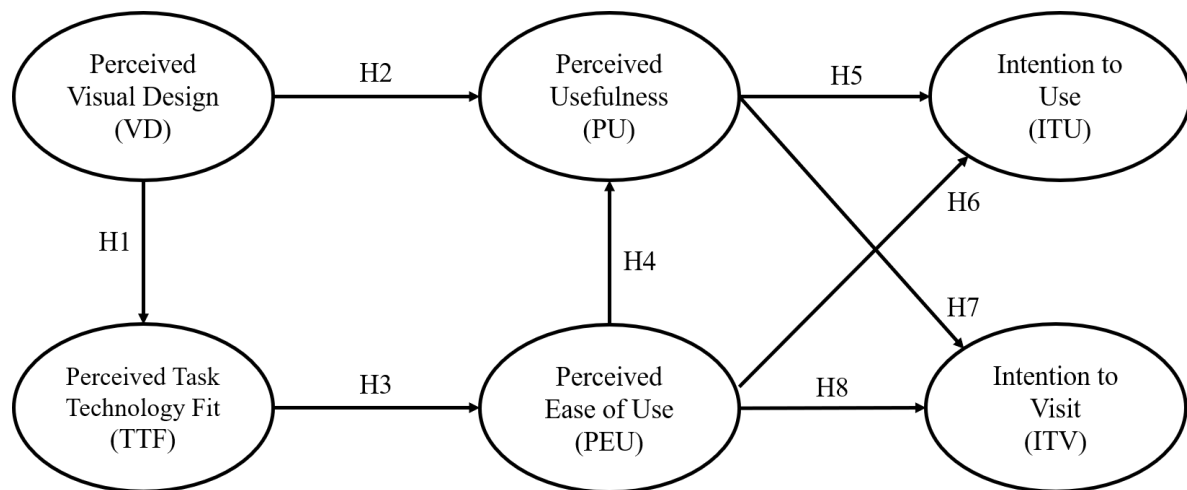

Figure 7. Conceptual research model [32]. Oval boxes indicate the constructs and the arrows show the hypotheses [1–8].

Table 1. Construct and items.

Construct	Source
Perceived Visual Design	[46]
(VD1) The visual design of the application is appealing.	
(VD2) The size of the 3D virtual objects is adequate.	
(VD3) The layout structure is appropriate.	
Perceived Task Technology Fit	[43]
(TTF1) The application is adequate for the described scenario of "Jeju Cultural Tour."	
(TTF2) The application is compatible with the task of controlling virtual objects.	
(TTF3) The application fits the task (i.e., experiencing and learning the culture of Jeju) well.	
Perceived Usefulness	[38]
(PU1) Using this application would improve my understanding of Jeju Island.	
(PU2) Using this application, I would accomplish tasks (e.g., learning cultural knowledge) more quickly.	
(PU3) Using this application would increase my interest in cultural events.	
(PU4) Using this application would enhance my effectiveness on the task (i.e., learning cultural knowledge).	
Perceived Ease-Of-Use	[38]
(PEU1) Learning to use the VR/AR application would be easy for me.	
(PEU2) I would find it easy to get the VR/AR application to do what I want it to do.	
(PEU3) My interaction with the VR/AR application would be clear and coherent.	
(PEU4) I would find the VR/AR application to be flexible to interact with.	
(PEU5) It would be easy for me to become skillful at using the VR/AR application.	
(PEU6) I would find the VR/AR application easy to use.	
Intention to Use	[38]
(ITU1) I intend to use the VR/AR application in the near future.	
(ITU2) I intend to check the availability of the VR/AR application in the near future.	
Intention to Visit	[38]
(ITV1) I will visit Jeju Island after experiencing the VR/AR application.	
(ITV2) I intend to visit Jeju Island frequently after experiencing the VR/AR application.	
(ITV3) I will continue to visit Jeju Island in the future after experiencing the VR/AR application.	
(ITV4) I want to recommend Jeju Island to others after experiencing the VR/AR application.	

Out of the 255 subjects who received the questionnaires, 251 participants yielded data usable responses. The classification and proportion of participants in each category are rendered in Table 2. 57.2% of the participants were male and 42.4% were female. A majority of the participants reported

English as a first language (81.3%) and 18.3% were not. A majority of the participants was Caucasian (45.8%), 36.3% were Asian, 10.4% were African-American, 2.4% were Hispanic, 2.4% were American Indian/Alaska Native, and 2.8% reported "other" ethnicity.

In order to test the hypotheses, we used a web-based software for generalized structured component analysis (GSCA) [47]. Generalized structured component analysis [48,49] is an approach to component-based structure equation modeling (SEM) that works well with a small sample size and avoids rigid distributional assumptions (e.g., multivariate normality assumption) [50,51].

Table 2. Demographic information.

Variable		Frequency	Percentage
Gender	Male	143	57.2
	Female	106	42.4
	Did not say	1	0.4
English as first language	Yes	204	81.3
	No	46	18.3
	Did not say	1	0.4
Ethnic heritage	Caucasian/White	115	45.8
	Asian	91	36.3
	African American/Black	26	10.4
	Hispanic/Latino	6	2.4
	American Indian or Alaska Native	6	2.4
	Other	7	2.8
Total		251	100

5. Results

The individual items and descriptive statistics for the six constructs are shown in Table 3. All means are above the midpoint of 3, and the standard deviations range from 0.91 to 1.33. Cronbach's alpha coefficients [52] in Table 4 demonstrated reasonable internal consistency of the measures, ranging from 0.776 to 0.927, thereby exceeding the reliability estimates ($\alpha = 0.70$) recommended by Nunnally [53].

Table 3. Means and standard deviations of technology acceptance model measures (N = 251).

Construct	Item	Mean	SD
Perceived Task Technology Fit	TTF1	4.10	0.91
	TTF2	3.74	1.10
	TTF3	4.15	0.94
Perceived Visual Design	VD1	3.70	1.16
	VD2	3.82	1.05
	VD3	3.96	1.02
Perceived Usefulness	PU1	4.15	0.99
	PU2	4.01	0.94
	PU3	3.96	1.00
	PU4	4.03	0.98
Perceived Ease-of-Use	PEU1	3.92	0.96
	PEU2	3.83	1.02
	PEU3	3.79	0.97
	PEU4	3.80	0.94
	PEU5	3.90	0.96
	PEU6	3.89	0.99
Intention to Use	ITU1	3.63	1.08
	ITU2	3.62	1.07

Table 3. *Cont*.

Construct	Item	Mean	SD
Intention to Visit	ITV1	3.29	1.24
	ITV2	3.24	1.33
	ITV3	3.26	1.25
	ITV4	3.58	1.22

Table 4. Coefficient alpha.

Construct	Item	Alpha
Perceived Task Technology Fit (TTF)	3	0.776
Perceived Visual Design (VD)	3	0.821
Perceived Usefulness (PU)	5	0.890
Perceived Ease-Of-Use (PEU)	5	0.921
Intention To Use (ITU)	2	0.860
Intention To Visit (ITV)	4	0.927

The hypothesized model provided FIT (overall goodness of fit index in GSCA) value of .669, indicating that the model accounted for 66.9% of the total variance of the six constructs and their items. Table 5 presents the loading estimates for the items along with their standard errors (SEs) and 95% bootstrap percentile confidence intervals (CIs) with the lower bounds (LB) and the upper bounds (UB), calculated from 100 bootstrap samples. Here, a parameter estimate is assumed to be statistically significant at .05 alpha level if the CI does not include the value of zero. All the loading estimates were statistically significant, indicating that all those items were good indicators of the constructs.

Table 5. Estimates of loadings.

	Estimate	SE	95% CI_LB	95% CI_UB
TTF1	0.872	0.021	0.820	0.906
TTF2	0.754	0.047	0.664	0.830
TTF3	0.864	0.023	0.815	0.908
VD1	0.863	0.018	0.825	0.897
VD2	0.845	0.025	0.783	0.888
VD3	0.861	0.028	0.794	0.905
PU1	0.824	0.028	0.761	0.883
PU2	0.890	0.018	0.849	0.919
PU3	0.880	0.021	0.835	0.917
PU4	0.873	0.025	0.817	0.913
PEU1	0.831	0.030	0.768	0.890
PEU2	0.853	0.022	0.813	0.892
PEU3	0.860	0.021	0.819	0.901
PEU4	0.802	0.027	0.746	0.850
PEU5	0.869	0.018	0.831	0.903
PEU6	0.867	0.016	0.828	0.894
ITU1	0.942	0.010	0.917	0.958
ITU2	0.934	0.011	0.913	0.956
ITV1	0.931	0.009	0.911	0.946
ITV2	0.913	0.012	0.884	0.931
ITV3	0.923	0.009	0.905	0.940
ITV4	0.857	0.022	0.801	0.891

The structural model with path coefficients is depicted in Figure 8. Table 6 provides the estimates of path coefficients along with their standard errors and 95% confidence intervals. Results showed that Visual Design had statistically significant and positive influences on Task Technology Fit (H1 = 0.663,

SE = 0.040, 95% CI = 0.591–0.741) and Perceived Usefulness (H2 = 0.485, SE = 0.051, 95% CI = 0.422–0.619). Task Technology Fit had a statistically significant and positive influence on Perceived Ease-of-Use (H3 = 0.592, SE = 0.059, 95% CI = 0.457–0.687). In turn, Perceived Ease-of-Use had statistically significant and positive effects on Perceived Usefulness (H4 = 0.422, SE = 0.062, 95% CI = 0.275–0.520), Intention to Use (H6 = 0.461, SE = 0.098, 95% CI = 0.310–0.675), and Intention to Visit (H8 = 0.339, SE = 0.096, 95% CI = 0.178–0.552). However, hypotheses H5 (Perceived Usefulness → Intention to Use) and H7 (Perceived Usefulness → Intention to Visit) were not supported.
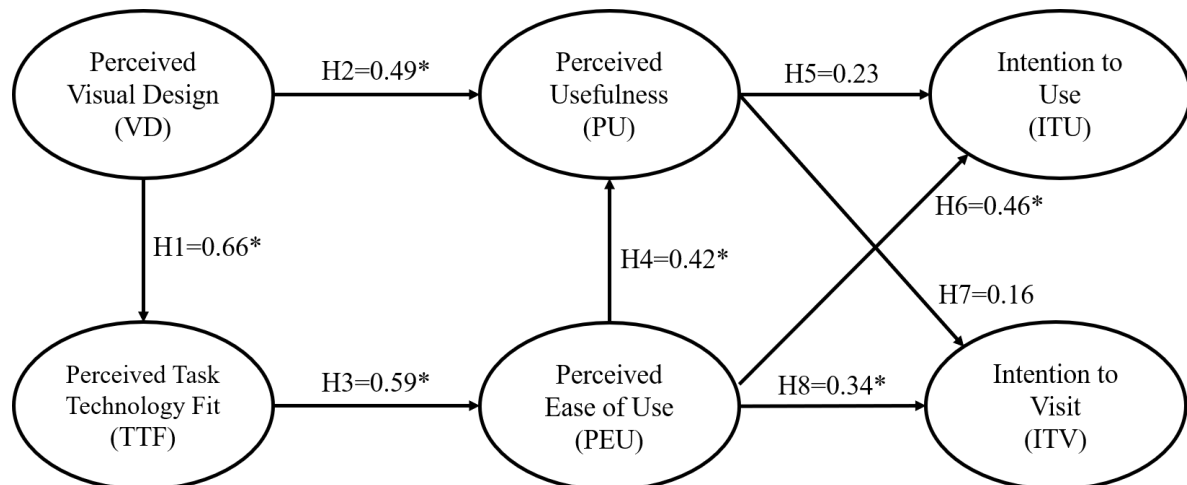
Figure 8. Research model with path coefficients.

Table 6. Estimates of path coefficients.

	Estimates	SE	95% CI_LB	95% CI_UB
VD → TTF	0.663 *	0.040	0.591	0.741
VD → PU	0.485 *	0.051	0.422	0.619
TTF → PEU	0.592 *	0.059	0.457	0.687
PEU → PU	0.422 *	0.062	0.275	0.520
PU → ITU	0.229	0.110	−0.003	0.405
PEU → ITU	0.461 *	0.098	0.310	0.675
PU → ITV	0.158	0.113	−0.088	0.368
PEU → ITV	0.339 *	0.096	0.178	0.552

6. Discussion

Our findings are in line with prior research by van der Heijden, who argued that "perceived usefulness loses its dominant predictive value in favor of ease-of-use and enjoyment" [54]. Our findings are also in line with the previous studies in various domains such as VR gaming production [55], VR museum design [56], AR educational method development [57], and VR tourism design [58]. Specifically, utilitarian information systems are focused on task performance and efficiency and are intended for productive use, while hedonic information systems offer enjoyment to the user through animated, multi-media-enabled content that delivers an aesthetically appealing visual experience. Therefore, the main design objective of hedonic information systems is to encourage long-term use of the system. However, the decisive impact of ease-of-use rather than perceived usefulness on system usage is particularly valid for hedonic information systems.

The perceived convenience of using a VR/AR system lowers a user's access barrier in using the VR/AR and encourages a user to use the system repeatedly. Recently, Kim and Hall [58] extended the Hedonic Motivation System Adoption Model (HMSAM) to emphasize the importance of perceived ease-of-use in a VR system design in the repeated use of a VR tourism app for travelers. Specifically, in their study, the continued use was greatly influenced by the user's flow state and subjective well-being.

During the development of the Jeju VR/AR application, we encountered several technical issues that should be tackled in future research. First, it is a challenging task to create 3D models for different artifacts since it requires expertise in graphic design. We tried to look for free models on the Internet to alleviate this technical issue. Unfortunately, our search was not successful. Thus, we had to design and generate 3D content manually. Future collaboration with computer graphics specialists would be warranted to address this issue in creating 3D artifacts dedicated to Jeju Island.

Second, our 3D models had the same level of detail used in both the AR and VR environments. For the AR application, users may need to see only an overview of the 3D models without exploring them in detail. On the other hand, a more thorough investigation of the 3D artifacts would be required for user immersion in the virtual world. Thus the level of detail should be taken into account, balancing trade-offs in 3D model design (e.g., fidelity and performance).

Third, selecting a representative image to be used as a marker requires time-consuming, trial-and-error effort. The markers might be easy to detect if they contained distinct features. In some other AR applications, default marker images such as hiro, kanji, or Arabic letters are often used. However, putting these markers on the Jeju map would lose the context for each location, where the marker itself is the representation of that location. Thus, the selected image had to undergo manipulation such as removing noise, contrast, or even adding a feature. To mitigate this issue, future work could be carried out by incorporating machine learning techniques to exploit more features on the existing images, thus enhancing the detection mechanism of our application. Furthermore, the machine learning techniques would also allow us to create transparency for the markers, meaning that the markers would not be visually presented on the map. Rather, they would be parts of the map.

7. Conclusions

In this study we developed the VR/AR application *JejuView* and used the Technology Acceptance Model to evaluate its effectiveness to advertise the cultural heritage of Jeju Island to potential overseas visitors. Following the assessment of 251 online participants, Visual Design had a statistically significant positive effects on Task Technology Fit and Perceived Usefulness. Besides, Task Technology Fit prompted a positive effect on Perceived Ease-of-Use. Furthermore, Perceived Ease-of-Use showed a positive effect on Intention to Use and Intention to Visit. However, there was no significant impact of Perceived Usefulness on either Intention to Use or Intention to Visit. Therefore, it can be said that when using immersive media such as VR/AR, consumers are more focused on the hedonic value than the utilitarian value (i.e., usefulness) of the medium.

The primary purpose of this study was to test a new type of tourism promotion VR/AR application using the TAM. We look forward to conducting usability focused research on future developments of the VR/AR application proposed in this paper in a more elaborated and commercialized form. For example, if studies are conducted on the effectiveness for tourists and the cost-effectiveness of VR/AR applications compared to traditional media forms (e.g., TV or mobile advertising), we can make the results of this study more practical.

We believe that our VR/AR application's user demographic information and previous experience with immersive new media might have had a complex influence on the user's psychological/behavioral responses. In future studies, it would make sense to complement research not just on the users' demographic information, but also on their psychological motivation. For example, if additional variables such as users' involvement in tourist attractions, cultural interest in the country they plan to visit and tourist innovativeness will be further researched, we believe this study could provide more meaningful results. Specifically, many visitors to Korea are looking for tourist attractions such as Jeju Island due to their interest in Korean Culture (K-Culture or Hallyu) represented through K-pop, K-drama, film, and traditional culture. We believe it will be an excellent future research task to explore how the interest of potential overseas tourists in Hallyu affects their use of tourism VR/AR applications.

We expect that future VR/AR applications will be more technologically advanced and actively deployed for cultural education and tourism marketing. Moreover, going beyond technological development, if deep understanding of the users' psychological acceptance of technology is added, VR/AR could grow into a more effective communication tool.

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