USER-CENTERED DESIGN (UCD) BASED WEB VR FOR THE VALUE OF CULTURAL HERITAGE

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Abstract. This study explores the use of Web-based Virtual Reality (Web VR) in effectively communicating the value of cultural heritage. At the heart of this research is the integration of User-Centered Design (UCD) principles to enhance User Experience (UX) within Web VR environments. The research underscores the accessibility and cost-effectiveness of Web VR in overcoming the limitations of traditional museum visits and in broadening public engagement with cultural heritage. Additionally, it highlights how UCD contributes to creating immersive and interactive experiences, with a focus on user needs and expectations. Furthermore, the study points out the critical importance of storytelling, advanced 3D modeling, and intuitive interfaces in delivering the complex narratives and values of cultural heritage. These approaches aid in facilitating a deeper understanding and emotional connection with the heritage, beyond just visual experiences. The findings of this study suggest that Web VR, enriched with UCD principles, storytelling, 3D modeling, and intuitive interfaces, offers a comprehensive and appealing approach to making cultural heritage accessible and meaningful to a diverse audience. This research provides foundational insights for future studies and practical applications in the field of digital cultural heritage exhibition.

Keywords. Cultural Heritage, Virtual Reality (VR), Web VR, User-Centered Design (UCD), User experience, Storytelling.

1. Introduction

The advancement of digital technologies has brought about significant changes in the way we experience culture and history. At the forefront of this transformation is Virtual Reality (VR), a technology continually evolving to offer users an enhanced immersive experience (Okanovic et al., 2022).

Currently, VR technology is primarily divided into web-based Web VR and Head-Mounted Display (HMD) VR. Each type has its strengths and weaknesses based on their distinct characteristics. In particular, the high cost and usage restrictions of HMD

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VR make it difficult for everyday use, which highlights the accessibility and cost-effectiveness of Web VR in exhibition formats. Despite this, Web VR primarily focuses on visual information delivery, still limiting deeper interactions of users with cultural heritage or exhibits (Jensen and Konradsen, 2018). Recognizing this issue, it is crucial to explore new interactive methods that can effectively convey the cultural and historical value of cultural heritage within a Web VR environment.

This study aims to redefine Web VR by applying a User-Centered Design (UCD) approach to effectively communicate the value of cultural heritage, and to establish a specific process for this purpose.

1.1. METHOD AND SCOPE OF RESEARCH

This study was conducted through a process that applied three key methodologies: digital reconstruction, UCD, and storytelling. The first stage, digital reconstruction, is the restoration and delivery of heritage rich in historical and cultural value as digital models, focusing on providing users with broad accessibility and enhanced educational value through Web VR (Jung & Lee, 2021). The second methodology, UCD, is a systematic design approach that prioritizes user experience to improve usability and plays a crucial role in compensating for the lack of user-centered experiences in Web VR (De Clerk et al., 2019). Lastly, storytelling is utilized as a technique for structuring and delivering stories to deepen understanding of cultural heritage and enhance user immersion through scenario construction (Gershon and Page, 2001).

The spatial scope of this research focused on the digital reconstruction of Onsuri Anglican Church in Korea, a significant cultural heritage symbolizing the transformation of Korean Christian culture through the combination of traditional and contemporary architectural styles, offering high value for the study (Choi and Hahn, 2003). While emphasizing the importance of a repetitive design process based on user feedback within the scope of UCD application, this study specifically concentrated on reflecting user requirements in the initial stages of design. In the storytelling aspect, focus was placed on conveying stories based on user location and architectural space, applying Chatman's (1978) narrative theory in scenario construction.

These methodologies establish the structure of this study, providing users with rich and immersive experiences through the digital reconstruction and dissemination of cultural heritage.

2. Web VR Construction Methodology

Web VR technology can provide users with an immersive experience similar to an on-site visit, significantly enhancing educational value and accessibility. However, there are limitations to experience-focused interactions in Web VR, for which the use of immersive VR devices like Head-Mounted Displays (HMD) has been proposed as an alternative. Yet, this too comes with several practical constraints (Alamäki et al., 2021).

The first constraint is cost-related. The penetration rate of VR devices in Korea is very low, and the introduction of expensive HMD equipment is challenging even for educational institutions due to budget constraints (Information and Communication Policy Research Institute, 2022). Secondly, cyber sickness arising from HMD use acts as a major factor degrading user experience (Jang and Kim, 2018). Lastly, the need for

installing dedicated software for high-quality content processing or content downloading imposes additional burdens on users, and the complex operation and battery life of VR devices also present obstacles to use (Jensen and Konradsen, 2018).

Considering these issues, Web VR can be seen as having the potential to overcome the technical limitations of HMD VR and offer higher accessibility and a more comfortable experience. Therefore, this study presents a methodology that integrates storytelling, various modeling techniques, and intuitive interfaces based on UCD principles to deliver the value of cultural heritage in a richer and more immersive manner through enhanced Web VR construction (Figure 1).

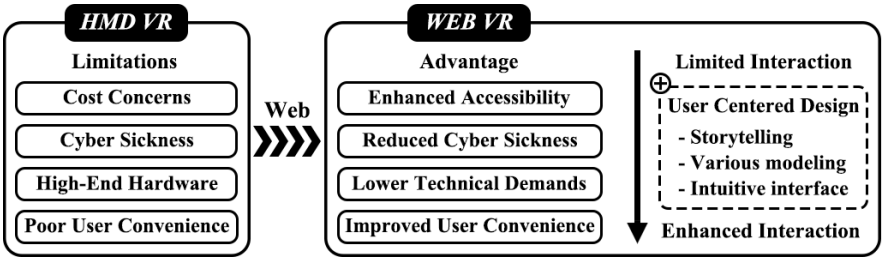

Figure 1. Method of Advancing from HMD VR to Interaction-Enhanced Web VR

2.1. DIGITAL RECONSTRUCTION FOR WEB VR

This study employs a range of technologies for the digital reconstruction of cultural heritage within Web VR, aiming to transform heritage of significant historical and cultural value into digital format. Utilizing digital photography, 3D scanning, and virtual reality technologies, the process aims to provide users with a realistic experience within a web-based VR environment (Jung & Lee, 2021).

Techniques such as panoramic photography using 360-degree cameras, extensive 3D modeling via photogrammetry, and precise modeling with laser scanning and LiDAR technology are primarily used. Each technique, chosen for its unique ability to suit specific cultural heritage reproduction needs, contributes to creating digital models that offer an experience mirroring reality. This approach enhances the educational value of cultural heritage and significantly improves accessibility through Web VR, offering users an immersive experience that closely resembles visiting the actual site.

2.2. UCD FOR WEB VR

While traditional Human-Computer Interaction (HCI) approaches focus on the practical functionality of products and systems, UCD is a systematic design approach that prioritizes user experience to maximize usability. It aims to enhance product usage the effectiveness, efficiency, and satisfaction of product use in specific usage contexts (De Clerk et al., 2019). This approach plays a crucial role in optimizing user interactions and experiences in the design and development of Web VR. This study particularly focuses on the initial stages of UCD, which involve understanding user requirements and using these insights to establish design and development strategies. This approach emphasizes the importance of accurately understanding and

concretizing the early stages, recognizing that UCD is a repetitive process, to ensure a successful start to the project.

This study redefines UCD based Web VR by integrating the three core perspectives of User Experience (UX) as proposed by Hassenzahl and Tractinsky (2006): the state of the user, the characteristics of the system, and the interaction between the user and the system. This reestablished Web VR includes three main components, as shown in Figure 2. Firstly, a content strategy that provides a variety of contents and VR environments catering to individual users' interests and needs, enabling personalized experiences. This allows users to have richer interactions with cultural heritage. Secondly, the construction of intuitive interfaces that facilitate easy access to and efficient utilization of information within the VR environment. These interfaces enhance usability and make interactions within the virtual space more natural and effective. Thirdly, the application of 3D VR staging techniques to create an environment where users can freely explore and interact, offering experiences that transcend the limitations of existing VR environments. These components play a crucial role in enriching the Web VR experience and enhancing interactions with cultural heritage.

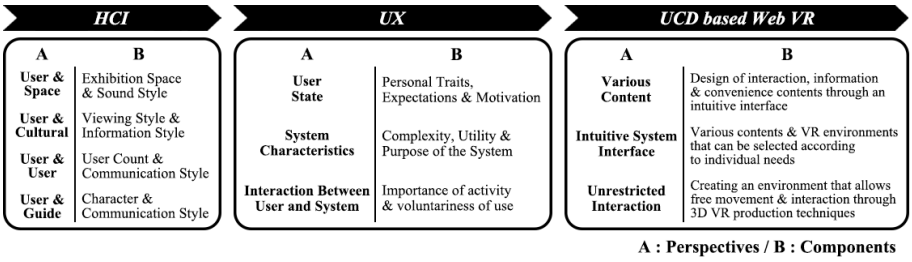

Figure 2. Development Process from HCI to UCD based Web VR

2.3. STORYTELLING TECHNIQUES

Storytelling transcends mere transmission of information to effectively convey and enable the experience of the deep values of cultural heritage. It is an integrative form of art and technology that combines text, images, and sound to deliver educational messages, provide entertainment, and vividly preserve cultural values (Gershon and Page, 2001).

This study enhances the Web VR experience by applying Chatman's (1978) narrative theory, which distinguishes between two structural elements: 'story' and 'discourse.' 'Story' refers to the structural elements of a scenario, such as events, actions, goals, and motives, forming the basic skeleton of the narrative. On the other hand, 'discourse' signifies the manner in which the story is conveyed, delivering the narrative to the audience through a specific perspective, style, and tone. The application of storytelling enables users to form deep cognitive and emotional connections with cultural assets, going beyond merely receiving information. This process provides users with an immersive experience, deepening their understanding of cultural heritage and enhancing value recognition.

3. Constructing UCD-Based Web VR

The construction process of UCD based Web VR is subdivided into four stages: planning, collection, processing, and implementation, as illustrated in Figure 3. This process includes important tasks at each stage, and this study specifically emphasizes content planning with UCD considerations, the development of scenarios applied with storytelling, various 3D modeling techniques, and the design of intuitive interfaces.

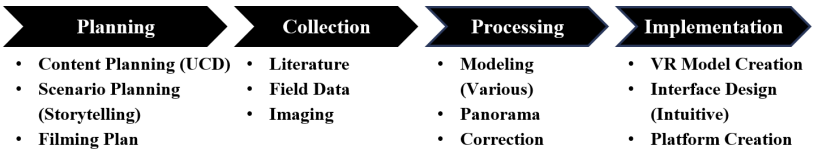

Figure 3. UCD based Web VR Construction Process

3.1. CONTENT PLANNING FROM A UX PERSPECTIVE

The content planning stage is based on the three components of UCD as shown in Figure 3. Firstly, a variety of VR environments are constructed to expand the range of choices for users. Advanced 3D VR environments are provided for users who prefer visual immersion, while 2D VR environments are provided for those who focus on emotional elements and interactions, thus meeting the expectations of different users. Secondly, intuitive interfaces are designed for efficient system use. These interfaces include ease-of-use functions such as restarting exhibits or adjusting the sound, and optimize the smooth delivery of high-quality 3D assets, point cloud data (PCD), and content information. Thirdly, 3D VR staging techniques are used to allow users to move freely in VR space, interact with various content, and experience rich information. This enables users to perceive their activities as meaningful and self-motivated experiences.

3.2. CONSTRUCT SCENARIOS THROUGH STORYTELLING

Scenario development begins with the application of storytelling techniques to effectively convey the rich narratives of cultural heritage. As shown in Figures 4 and 5, panorama image and 3D modeling are critical to establishing the narrative structure within the VR space. Each scene is enhanced with various elements of discourse, including sound, interactive actions, and changes in perspective, to maximize the user's immersion in the cultural heritage.

The 3D part of the scenario is designed to allow users to focus on visually rich scenes. The third-person perspective in the background allows for free exploration and personal experience. As users enter the interior of the church, the perspective shifts to first person, providing a realistic sense of being in the actual church (Figure 4). In contrast, elements of emotional intensity and interactive fun are integrated into the 2D configuration. Natural bird sounds are set as the basic background sound, and in the chapel, chanting sounds, and in the cathedral, bell sounds are introduced, enabling users to become emotionally immersed through sound. Interactive 3D assets, applied to gravestones or stone altars, allow users to explore various information and stories upon

Figure 4. Storytelling-Integrated 3D Scenario for Onsuri Anglican Church

interaction. The piano sound playing when entering an interior space, along with detailed action features, further enhances the VR experience (Figure 5).

Thus, the richly constructed Web VR scenario of Onsuri Anglican Church offers users a powerful experience that goes beyond mere visual perception. The delicate integration of story and discourse aids in the intuitive and emotional understanding of the history and value of cultural heritage, drawing users deeply into the cultural context of Onsuri Anglican Church.

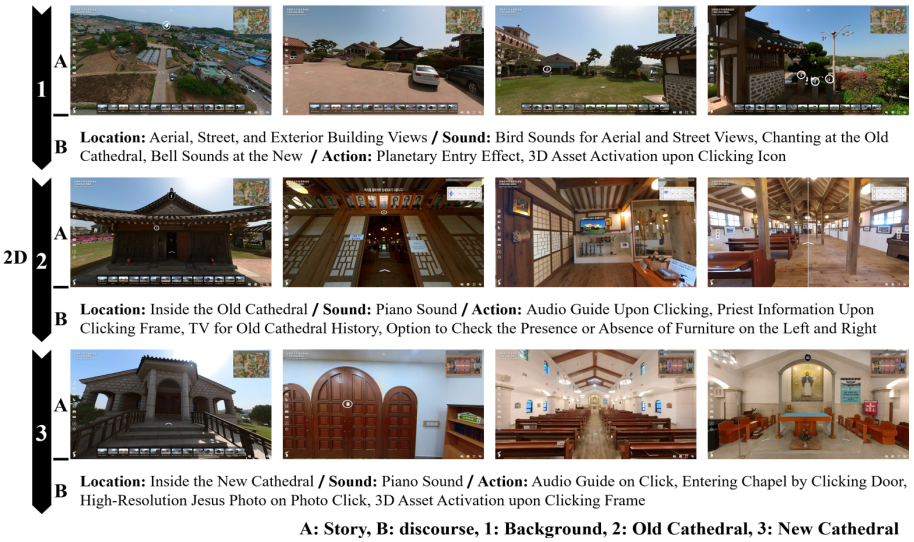

Figure 5. Storytelling-Integrated 2D Scenario for Onsuri Anglican Church

3.3. VARIOUS 3D MODELING TECHNIQUES FOR REALISM

The 3D modeling process utilizes three techniques to maximize realism and immersion, as illustrated in Figure 6. Firstly, the exterior of Onsuri Anglican Church is reproduced using the photogrammetry technique. Images captured with drones are processed using the Structure from Motion (SfM) technique to detect feature points, and triangulation is employed to create Point Cloud Data (PCD). Subsequently, mesh and texture work are conducted using the WebODM program to construct realistic broadband models (Lim et al., 2015). Secondly, laser scanning is utilized for building modeling of the church interior. Each point inside is precisely measured with laser scanners, minimizing non-visible areas. Professional software such as Realworks and Recap PRO are used for alignment, meshing, and texturing, meticulously replicating the actual structure of the church interior (Kim et al., 2014). Lastly, LiDAR technology is applied for object modeling of detailed structures. Data collected with LiDAR is integrated with the Sketchfab platform, allowing users to intricately experience various aspects of the church, such as plaques, altars, and gravestones, from different angles.

The application of these three 3D modeling techniques plays a pivotal role in delivering the historical and cultural value of cultural heritage accurately and vividly within the Web VR environment of Onsuri Anglican Church. The choice of each technique is based on the characteristics of the object to be modeled and the suitability of the measuring equipment.

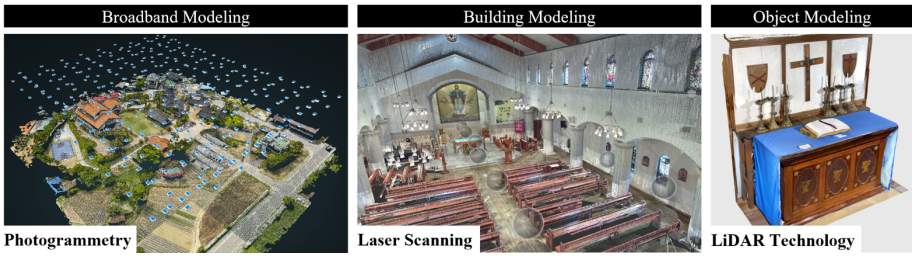

Figure 6. 3D Modeling techniques through the use of photogrammetry, laser scanning, and LiDAR

3.4. INTUITIVE INTERFACE DESIGN

The Web VR interface is designed with the user as the top priority and is intuitively divided according to three main content types: interaction, information provision, and convenience, as depicted in Figure 7.

Interactive content focuses on user activities and interactions, enabling users to directly explore Onsuri Anglican Church and experience its details through 3D VR, 3D Assets, and PCD. This allows users to have direct and in-depth experiences of the church's history and structure, thereby enhancing user-led participation and immersion. Information provision content, including Panorama VR, photo albums, and detailed information, enables users to easily access necessary information at specific points they select, facilitating in-depth learning and understanding. Convenience content includes features that support efficient navigation within the Web VR, such as thumbnail previews, control guides, and current location indicators, making it easier and more efficient for users to navigate the Web VR environment and acquire information.

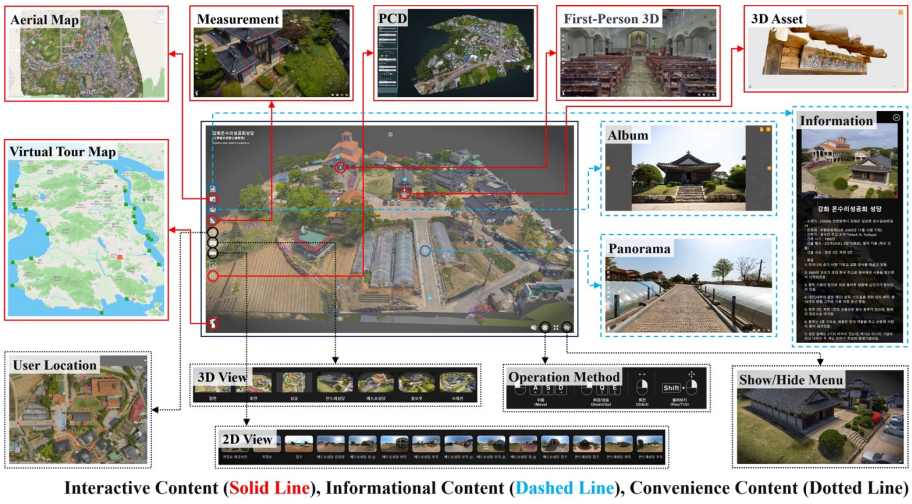

Figure 7. User-Centered Intuitive Interface Design

Such meticulously designed interfaces enable users to experience cultural heritage in Web VR more deeply and richly, playing an essential role in enhancing understanding of cultural heritage.

4. Conclusion

This study aimed to apply a UCD approach in the Web VR environment to effectively convey and experience the value of cultural heritage and develop a specific process based on this approach. The conclusions drawn from this study are as follows.

By analyzing the differences between Web VR and HMD VR, it was confirmed that Web VR is more beneficial to a wider audience in understanding and experiencing cultural heritage due to its cost effectiveness and accessibility. Despite the market entry of low-cost VR devices lowering barriers, considerations regarding functional aspects remain. This suggests the need for ongoing research into HMD VR technology to provide immersive VR experiences prioritizing user experience.

By focusing on HCI and UX, we established UCD based Web VR, considering the emotional and cognitive aspects of users, and developed content strategies tailored to the interests and needs of individual users.

Storytelling techniques played a crucial role in effectively conveying the value and meaning of cultural heritage. They were used to construct narratives that would immerse and engage users, allowing them to develop a deep understanding and emotional connection with cultural heritage.

Advanced 3D modeling techniques and intuitive interface design were key elements in enabling natural interactions and experiences of cultural heritage within the Web VR environment. The application of these technologies allowed users to feel the realism of the VR space and have a more immersive experience.

Based on these findings, this study successfully developed and implemented a

UCD based Web VR process for effectively conveying the value of cultural heritage. Future research will focus on collecting and analyzing user feedback to continuously improve the Web VR configuration, further enhancing the efficiency and accessibility of cultural heritage dissemination.

Acknowledgements

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