Preserving the Past: Digital Strategies for World Heritage Protection

Lv,Weihan* Yue,Shaolei

Zhengzhou Automobile Engineering Vocational College, Zhengzhou, Henan, 450000, China

Abstract: This paper explores the application of Virtual Reality (VR) and Augmented Reality (AR) technologies in the preservation of world heritage, focusing on key technologies such as 3D modeling, panoramic photography, display technology, audio technology, motion sensing interaction, transmission technology, registration positioning technology, and GIS (Geographic Information System). By introducing the principles of these technologies and their specific applications in the digitization of cultural heritage, the paper demonstrates how VR enhances heritage preservation and interactive experiences. The research shows that VR not only enables the restoration of damaged heritage but also improves the display and public engagement of cultural heritage through the integration of virtual and real elements, real-time interaction, and multi-sensory enhancement. Additionally, the combination of GIS and AR technologies provides innovative methods for navigation and protection of large-scale heritage spaces. This paper aims to highlight the potential and significance of VR technology in cultural heritage preservation and offers a reference for future research and practice in related fields.

Keywords: Sustainable heritage management; Digital media in heritage protection; Immersive technology

DOI: 10.62639/sspjinss04.20240103

Human history is vast and rich, leaving behind countless treasures, both material and intangible, such as songs, music, drama, crafts, and festivals[1]. However, these cultural heritages have been threatened and damaged by the passage of time. Internationally, there have long been strategies and regulations in place for the protection of cultural heritage, while China has lagged behind countries like India and Brazil in this regard. Although the earliest regulations concerning intangible cultural heritage in China can be traced back to the Copyright Law enacted in 1990, it wasn't until 2011 that the Law on Intangible Cultural Heritage was promulgated. Consequently, there remains a significant journey ahead for China in terms of cultural heritage protection.

With the continuous advancement of modern technology and the widespread digitization of society, methods of cultural transmission have shifted from oral, written, and material forms to digital technologies. In this new era, awareness of heritage preservation has permeated daily life, prompting the exploration of how digital technologies can be employed to protect ancient heritage. The advent of the 5G era, characterized by faster information transmission, has made VR (Virtual Reality) and AR (Augmented Reality) technologies more accessible, offering an array of applications. Both VR and AR technologies provide a profound sense of presence, integrating virtual entities with the real world and creating an unprecedented form of interaction termed "immersive communication." As this mode of communication gains acceptance among the public, it evolves into a super-medium that surpasses traditional media, enabling multi-dimensional interaction with users and enhancing their emotional experiences. This presents a new avenue and technical means for the protection of world heritage.

This article examines the current status and existing challenges in the preservation of both material and intangible heritage, further elucidating the importance and advantages of digitalization in the cultural heritage

(Manuscript NO.: JINSS-24-3-19001)

Corresponding Author

Lv,Weihan (1996-07), Male, Han nationality, Origin: Zhengzhou City, Henan Province, China, School of Digital Art and Design, Title: No Master's degree, Research Direction: Design.

About the Author

Yue,Shaolei (1984-10), Male, Han nationality, Origin: Zhengzhou City, Henan Province, China, College of Electronic Commerce and Logistics, Title: Lecturer Master's Degree, Research Direction: Economics.

protection process. The application of augmented reality and virtual reality technologies can address the deficiencies in physical heritage preservation and allow for the retention and dissemination of cultural heritage in innovative ways that transcend temporal boundaries. By introducing the concepts of augmented reality and virtual reality, along with case studies in cultural heritage protection, this study ultimately affirms the superior advantages and potential of VR and AR technologies in this field.

1. Current Status and Contradictions in World Heritage Protection

The world's cultures have a long history, and the legacies left behind by each culture are innumerable. These legacies have gradually disappeared due to the ravages of time and human destruction. As society evolves and progresses, awareness of the need to protect world heritage is increasing. In 2003, during its 32nd session, UNESCO adopted the Convention for the Safeguarding of the Intangible Cultural Heritage, which sparked an international movement towards cultural heritage protection, with digitalization at its core. In France, the National Library has initiated the digitalization project "Gallica," encompassing a wide range of collections from books to static images, the website of the National Museum of France is shown in Figure 1. Japan enacted the Cultural Properties Protection Law as early as 1950 to safeguard cultural heritage, categorizing cultural properties into tangible and intangible assets. The National Diet Library of Japan similarly prioritized the digitalization of cultural heritage and developed a database,The website of the National Library of Japan is shown in Figure 2. Countries such as Italy, Germany, and Canada have also made significant strides in digitalizing cultural heritage. In China, notable progress has been made in heritage protection, with successful applications for intangible cultural heritage recognition for Kunqu Opera, Guqin, Mukam, Shaolin Kung Fu, Regong Art, New Year Paintings, Tibetan Opera, and Nanyin. Consequently, many scholars have shifted their research focus towards digitalization.

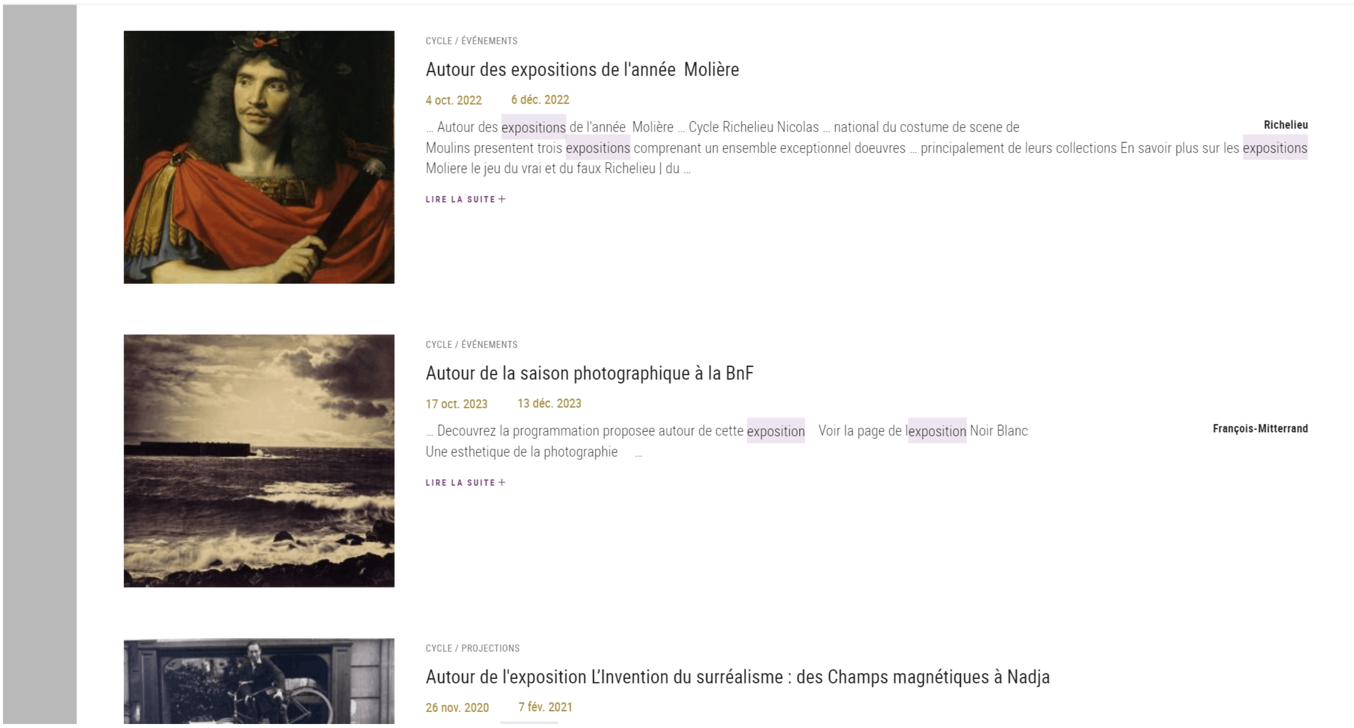

Figure 1: Performance History Museum (National Library of France)

Figure 2: Internet Archiving Project (National Diet Library of Japan)

As awareness of cultural heritage protection deepens, several real-world issues and contradictions have emerged: (1) Conflicts between heritage preservation and urban-rural planning; (2) Discrepancies between traditional museum exhibitions and the rapidly evolving aesthetic standards of the public; (3) Budget constraints versus large-scale heritage preservation efforts; (4) The paradox of local residents' poverty preventing them from benefiting from heritage protection; (5) The vulnerability of cultural artifacts versus large-scale tourism development; (6) The specificity of preservation techniques versus advancements in technology. These contradictions require resolution, and digitalization represents a viable pathway to address them.

2. Digital Preservation

(1) Virtual reality technology

Virtual reality technology originated in the United States in the 1980s. It primarily relies on computer technology, supplemented by various scientific technologies, to simulate environments. When users wear specialized display devices, they can interact with the virtual environment, resulting in a strong sense of presence and immersion.

For virtual interactions to occur in virtual reality technology, a comprehensive hardware and software system, along with various sensing and positioning systems, is required. The hardware system includes the main computer base station, which serves as the core computer, and a series of auxiliary computers. The software system encompasses various sensing systems, which can be divided into control systems, feedback systems, and so on. The control system primarily transmits information to the computer to achieve human-computer interaction. The feedback system processes the information received from the computer, transforming it into graphical symbols for participants. A detailed technical composition is shown in Figure 3.

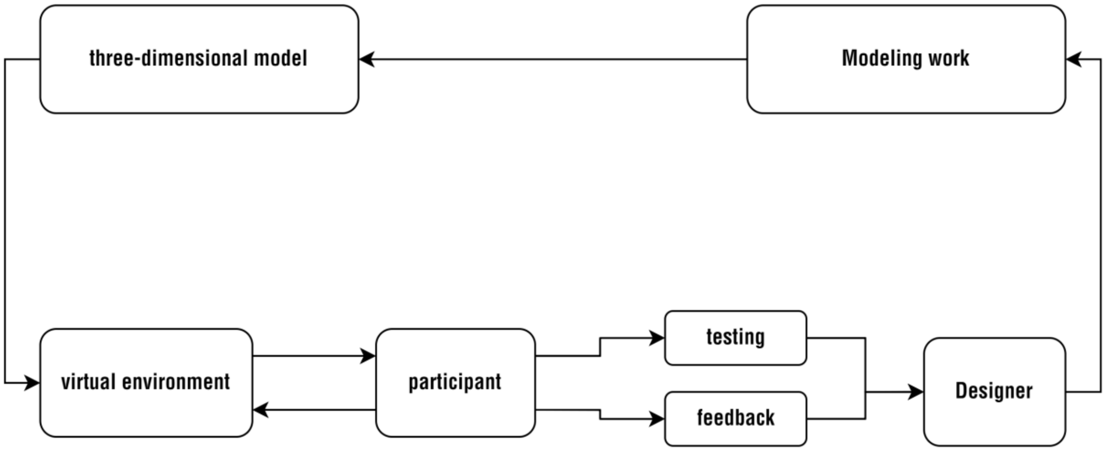

Figure 3 Schematic diagram of the structural elements of virtual reality technology

Non-Immersive VR System: Users can interact with designed scenes through mobile terminals, mice, keyboards, and other devices. Non-immersive virtual reality technology has become widely popular and applied in modern times. Luo Qian and Xiang Minggang conducted digital construction in archives and completed the derivation and theoretical preparation for non-immersive virtual reality on mobile clients.

Semi-Immersive VR System: Also known as Augmented Reality (AR) technology, this involves overlaying virtual scenes onto real-world scenarios after creating models, providing users with an enhanced aesthetic experience that transcends display. There are three types of augmented reality devices: head-mounted, handheld, and projection-based, with head-mounted displays (HMDs) being the most widely used. They can be categorized into two types: optical see-through and video see-through. The AR system comprises three fundamental elements: overlaying virtual scenes onto real ones, real-time rendering of virtual scenes in accordance with changes in the real environment, and tracking and locating the real scene. In the 1990s, Professor Paul Milgram from the University of Toronto proposed the “Reality-Virtuality Continuum Theory Model,” which effectively describes the state of augmented reality as the merging of real and virtual environments[2][3].

Immersive VR System: Full name “Immersive Virtual Reality Technology,” also referred to as VR technology or presence technology, enables participants to interact with a virtual environment and achieve an immersive experience. This is realized through two methods: one being Cave Automatic Virtual Environments (CAVE), and the other being head-mounted displays. CAVE technology has been around for over 20 years but is complex to set up and costly, making it unaffordable for most people. Its costs are generally higher compared to head-mounted displays. Afonso Gonçalves and Sergi Bermúdez[4] developed a low-cost CAVE based on the Unity 3D engine and Kinect V2 sensors.

Here's the translation with the content in brackets retained:

(2) Key technologies in world heritage protection

In the digitization of cultural heritage protection using virtual reality, there are some key challenges and key technologies that need to be developed and researched to provide participants with a better sense of presence and immersive experience.

1) Modeling technology

3D modeling technology is at the core of virtual reality (VR) technology, requiring precision and realism to enhance the sense of presence and interactivity for participants. Three-dimensional digital models are essential in many applications, such as inspection, navigation, object recognition, visualization, and animation. While creating a simple 3D model may seem easy, generating an accurate and photorealistic computer model of a complex object remains quite challenging. Different modeling methods are employed across various fields; for instance, in architecture and archaeology, models can be created manually or formed through scanning with 3D scanners[5].

There are two common methods for object scanning. The first method is based on digital photo data, which further utilizes single-row scanning technology and multi-row scanning technology. Single-row technology involves horizontally circling the object for scanning, while multi-row scanning technology entails scanning the object from an oblique angle or above in a horizontal circle, with the resulting data being processed into a 3D image using software. Alternatively, multiple camera positions can be used to take digital photographs, which can also be processed in software.

The second method involves using lasers to scan objects, obtaining data from various nodes to generate object models in software. This method has the advantage of capturing details without omission, leading to more precise modeling. The challenge lies in the need for software to denoise and smooth the data before modeling, and the difficulty of scanning large objects, which often requires manual texturing to ensure quality after scanning.

2) 3D panoramic photography

The construction of virtual reality scenes based on digital photography involves using a digital camera to capture the surrounding environment and integrating the photos through panoramic software. There are three output formats: cylindrical, spherical, and cubical. The cylindrical model allows for a 360° horizontal rotation and less than 120° vertical rotation, while spherical and cubical models are not limited by viewing angles.

In the process of capturing panoramic images, to ensure a 360° horizontal rotation of the overall environment, lenses of different focal lengths are required to take 12-16 photos, ensuring that each photo has a 30% overlapping area to facilitate the combination in modeling software. For creating spherical models, additional photos must be taken at 45° upward and downward angles during the horizontal captures, and finally, vertical photos must be taken pointing directly upward or downward. Care should be taken to ensure horizontal shooting; using leveling instruments can help maintain horizontality, as failure to do so may lead to ghosting and distortion during the stitching of panoramic images.

Due to algorithm differences, various software packages yield different results when combining photos. In earlier attempts to achieve higher image quality, manual input methods were predominantly used. Inadequate algorithm optimization often led to ghosting. Matthew Brown and David G. Lowe[6] optimized algorithms to identify multiple panoramas within disordered image data while providing more details. Matthew Uyttendaele and Ashley Eden[7] studied methods to eliminate ghosting and exposure artifacts in image stitching. Currently, there are many software options available domestically and internationally for 3D panoramic photography, such as Stitcher software and Landscape Designer software, which effectively combine panoramic images.3. Display Technology

3) Display technology

Our world is three-dimensional, yet traditional display technologies have been limited to two dimensions. With the advancement of technology, 3D display technology has matured and found its way into our lives. Current 3D display technologies include 3D movies, stage holograms, holographic projections, and volumetric 3D displays. In the realm of VR display technology, volumetric display is a type of 3D display that produces images with volumetric filling. According to Barry Blundell and Adam Schwarz's definition[8], "Volumetric display devices allow the generation, absorption, or scattering of visible radiation from a physically localized and specific set of regions." The 3D image is generated by projecting a series of 2D bitmaps ("image slices") onto a diffuse screen spinning at 600 revolutions per second. High-resolution projectors are required for operation. Koo Jae Phil, Kim Dae Sik, and Kim Su Gun[9] proposed a volumetric 3D display system using multilayer organic light-emitting devices, which reduces overall size and cost by eliminating the need for expensive high-resolution projectors. By distributing multiple 2D images across several transparent planar display panels, a 3D image is formed. Gregg Favalora, Rick K. Dorval, et al.[10] introduced an 8-color, multi-plane volumetric display that uses an image volume of over 90 million voxels, achieving excellent projection effects.

4) Audio technology

In virtual reality, more realistic sound effects can enhance the sense of presence or immersion in the virtual environment. J. Broderick and others emphasize the importance of audio technology in virtual reality[11]. Adding audio cues in virtual environments can aid user navigation, such as using auditory waypoints at targets or locations to help users navigate and orient[12]. Optimizing auditory elements significantly improves the user experience. Users are not distracted but simply listen for changes in the auditory background, signaling where their attention should be directed[13].

5) Motion-sensing interaction technology

Motion-sensing interaction technology enables users to interact with virtual environments through gestures, sounds, and other actions, making it an essential part of virtual reality technology. As early as the 1990s, the Fraunhofer Institute for Industrial Engineering in Freiburg, Germany, pioneered the development of its own virtual assembly system, which won the Best System Design Award in Munich in 1996[14]. Early motion-sensing interaction required external devices such as gloves and helmets. However, with the development of machine vision technology, it has gradually become possible to capture motion without external peripherals. A prime example is Microsoft's Kinect sensor, which uses infrared to scan the participant's body along the x, y, and z axes, and through its built-in algorithms, it builds models that allow interaction with the virtual environment.

Good motion-sensing interaction technology can provide participants with a better sense of presence. In contrast, immature interaction technologies, such as those where action input and feedback are not synchronized, can diminish user immersion. In more severe cases, this desynchronization can cause dizziness, blurred vision, and other issues[15], severely impacting the user experience.

6) Transmission technology

Fully immersive virtual reality requires the real-time transmission of vast amounts of data. Although the arrival of 5G has improved its feasibility, model optimization is still necessary; otherwise, issues like latency and stuttering may arise. Yaping Sun, Zhiyong Chen, and others[16] proposed a mobile VR delivery framework based on MEC (Multi-access Edge Computing), which not only meets low-latency requirements but also significantly reduces communication bandwidth.

7) Registration and positioning technology

Registration, or positioning technology, is a key aspect of augmented reality (AR). Before displaying AR images, it is necessary to register and locate the target, determining the participant's head direction and position to establish a coordinate system, allowing the virtual images to overlap with the real-world environment. There are two types of registration methods: marker-based and markerless[17]. Marker-based registration relies on either image-matching recognition[18] or recognition based on encoded features. Markerless registration can be categorized into recognition based on natural features, model features, hardware sensing, and hybrid technologies.

8) GIS technology

GIS (Geographic Information System) is a specialized spatial information system that, with the aid of computers, can calculate, store, and analyze the geographic conditions of specific spaces. In the process of digitizing cultural heritage, it is important not only to focus on the cultural assets themselves but also to digitally protect the surrounding environment to enhance interactivity and presence. By integrating AR with GIS, architectural and road data can be superimposed onto corresponding buildings and streets, providing AR navigation and location services over large outdoor areas. Deng Chen, You Xiong, and Zhi Meixia explained the basic concepts and technical principles of AR geo-registration and proposed a method for quantifying geographic registration accuracy, allowing for better alignment between AR and the real world.

(3) Advantages of virtual reality technology in world heritage protection

Using virtual reality technology in the protection and dissemination of cultural heritage can digitize cultural heritage through digital modeling or panoramic photography, with the following advantages:

1) Integration of reality and virtuality

With the support of VR and AR technologies, damaged cultural heritage can be digitally reconstructed, allowing users to experience and interact in a virtual environment. This enables exploration of the scene, promoting the display and study of cultural heritage as individuals or groups.

2) Real-time interaction

With the continuous development of 5G networks and ongoing optimizations in virtual reality technology, existing virtual reality technologies can now achieve real-time rendering and interaction. This development space allows participants to appreciate cultural heritage from various angles, significantly narrowing the gap between viewers and cultural heritage.

3) On-site protection

Both VR and AR technologies operate as on-site protection models for heritage. The contradiction between limited funding and the vast amount of cultural heritage can be alleviated through virtual reality technology. In impoverished areas rich in cultural heritage, using virtual reality technology can not only enhance appreciation and research but also boost tourism, thereby promoting local economic development and indirectly increasing local residents' motivation to protect cultural artifacts.

4) Positive and negative enhancement

The enhancement of the real world through AR or VR technology can be categorized into positive and negative enhancement modes. Positive enhancement refers to the enhancement, supplementation, and explanation of objects. The negative enhancement mode involves using materials that harmonize with the environment to obscure existing objects, leading participants to be unaware of the original materials [19].

5) Diverse enhancement

Virtual reality technology simulates not only visual and auditory aspects of the virtual environment but also incorporates gustatory, olfactory, and tactile elements for diverse enhancement, creating interactions that provide participants with a better sense of presence. The diverse enhancement of virtual reality holds significant importance for the protection of both tangible and intangible cultural heritage.

3. Conclusion

As the concept of cultural heritage protection gradually deepens in public awareness and digital devices continue to evolve, the digitalization of world heritage has become a trend. Recent domestic and international applications of virtual reality technology for the digital protection and utilization of cultural heritage have shown significant results. Currently, the use of this technology for digital protection in the country is just beginning. We should seize this opportunity to accelerate the development of new technologies and promote work progress, making positive contributions to the protection of world heritage and the continuation of human civilization.

References

[1] Zhao, Zhonghua. "Digital Protection Method of Intangible Cultural Heritage Based on Augmented Reality Technology." 2017 International Conference on Robots & Intelligent System (ICRIS), 2017, pp. 135–138.

[2] Milgram P, Kishino F. A taxonomy of mixed reality visual displays[J]. IEICE TRANSACTIONS on Information and Systems, 1994, 77(12): 1321-1329.

[3] Yu Riji. Research on Digital Development of Intangible Cultural Heritage Based on AR Technology [D]. Wuhan University: Yu Ri Ji, 2014.

[4] KAVE: Building Kinect Based CAVE Automatic Virtual Environments, Methods for Surround-Screen Projection Management, Motion Parallax and Full-Body Interaction Support

[5] Remondino, F., & El-Hakim, S. (2006). IMAGE-BASED 3D MODELLING: A REVIEW. Photogrammetric Record, 21(115), 269–291.

[6] Brown, M., & Lowe, D. G. (2007). Automatic Panoramic Image Stitching using Invariant Features. International Journal of Computer Vision, 74(1), 59–73.

[7] Uyttendaele, M., Eden, A., & Skeliski, R. (2001). Eliminating ghosting and exposure artifacts in image mosaics. In Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition. CVPR 2001 (Vol. 2, pp. 509–516).

[8] Blundell, B. G., Schwarz, A. J., & Horrell, D. K. (1994). Cathode ray sphere: a prototype system to display volumetric three-dimensional images. Optical Engineering, 33(1), 180–186.

[9] Phil, K. J., Sik, K. D., & Gun, K. S. (2006). Volumetric 3d display system using multi-layer organic light emitting device.

[10]Favalora, G. E., Dorval, R. K., Hall, D. M., Giovinco, M., & Napoli, J. (2001). Volumetric three-dimensional display system with rasterization hardware. In Stereoscopic Displays and Virtual Reality Systems VIII (Vol. 4297, pp. 227–235).

[11] Ohn, M. G. R., Lokki, T., & Takala, T. (2005). Comparison of Auditory , Visual , and Audiovisual Navigation in a 3D Space, 2(4), 564–570.

[12]Walker, B. N., & Lindsay, J. (2006). Navigation performance with a virtual auditory display: effects of beacon sound, capture radius, and practice. Human Factors, 48(2), 265–278.

[13]Broderick, J., Duggan, J., & Redfern, S. (2018). The Importance of Spatial Audio in Modern Games and Virtual Environments. In 2018 IEEE Games, Entertainment, Media Conference (GEM) (pp. 1–9).

[14]Bullinger H J, Richter M, Seidel K A. Virtual assembly planning[J]. Human Factors and Ergonomics in Manufacturing & Service Industries, 2000, 10(3): 331-341.

[15]KATSIGIANNIS S, WILLIS R, RAMZAN N. A QoE and simulator sickness evaluation of a smartexercise-bike virtual reality system via user feedback and physiological signals[J]. IEEE Transactions on Consumer Electronics, 2019, 65(1): 119-127.

[16]Sun, Y., Chen, Z., Tao, M., & Liu, H. (2019). Communications, Caching, and Computing for Mobile Virtual Reality: Modeling and Tradeoff. IEEE Transactions on Communications, 67(11), 7573–7586.

[17]Gandy, M., & MacIntyre, B. (2014). Designer's augmented reality toolkit, ten years later: implications for new media authoring tools. In Proceedings of the 27th annual ACM symposium on User interface software and technology (pp. 627–636).

[18]Khan, D., Ullah, S., Yan, D.-M., Rabbi, I., Richard, P., Hoang, T., … Zhang, X. (2018). Robust Tracking Through the Design of High Quality Fiducial Markers: An Optimization Tool for ARToolKit. IEEE Access, 6(1), 22421–22433.

[19]Zhang, Z., Weng, D., Jiang, H., Liu, Y., & Wang, Y. (2018). Inverse Augmented Reality: A Virtual Agent's Perspective. In 2018 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct) (pp. 154–157).