REMEMBERING URBAN VILLAGE

Using CloudXR Technology as an Enhanced Alternative to Better Disseminate Heritage

XINYI ZHOU[1], YAO CHEN[2] , FUKAI CHEN[3], KAN LI[4],
TIANTIAN LO[5], RUFENG XIANG[6] and LIQUAN LIU[7]
[2,3,5]*Harbin Institute of Technology (Shenzhen)*
[1]*xinyiz.uk@gmail.com, 0000-0002-8781-209X*
[2]*chenyaoyaoyao0809@gmail.com*
[3]*stevenchen1703@gmail.com*
[4]*kan.li@aaschool.ac.uk*
[5]*skyduo@gmail.com*
[6]*xrf7000@163.com*
[7]*leo@configreality.com*

Abstract. Urban villages are strictly related to urban growth. It reflects the era characteristics and memory in urban growth, which has significant value in heritage and sustainable cities (SDG 11). Due to the continuous development of urbanization and the shortage of urban land, many urban villages will be replaced by more valuable functions. Therefore, better preserving the digitalization of urban villages and making more people understand the value of urban villages is particularly important. However, the existing technology still has shortcomings in disseminating digital heritage. For urban villages, usually a large-scale and complex environment, the hardware requirements will be very high for high-precision visualization. Most existing solutions use large hardware devices, such as the virtual sand table. Unlike hand-held devices, such devices are expensive and not portable, limiting better dissemination of such heritage. Due to the hardware limitation of hand-held devices, neither the display resolution nor the interaction effect is satisfying. Therefore, this paper proposes a new workflow by NVIDIA CloudXR streaming technology to achieve high-precision visualization and a rich interactive experience on hand-held devices. Such heritage can be promoted and cities can be more sustainable.

Keywords. CloudXR Technology; Urban Village; Digital Heritage; Preservation; Dissemination; Portable Devices; SDG 11.

1. Introduction

Urban villages appear in the central parts of major Chinese cities, including Shenzhen

POST-CARBON, Proceedings of the 27th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2022, Volume 1, 757-766.

and Guangzhou. They are surrounded by skyscrapers and the infrastructure of modern cities, a unique phenomenon in China's urbanization process. Urban villages have become a powerful booster for the urbanization process, providing low-income immigrants with affordable housing and daily needs in the past few decades. It reflects the characteristics and memories of the current era in the city's development, and it is of great value to be recorded and widely disseminated as a historical heritage.

However, many urban villages in China are endangered. Due to the continuous urbanization process and the shortage of urban land, many urban villages will be replaced by new spaces with more valuable functions. Therefore, utilizing digital technologies to preserve urban villages and let more people realize the value of urban villages is particularly essential.

Since the emergence of digital technology, digital heritage has become an essential part of the whole world's cultural heritage. With the digital evolution, the data accumulation and the application of information processing systems are becoming universal, enabling updates of heritages such as urban villages. Nowadays, data sources are highly accurate, have timeliness, and ample space span. It enables cultural heritage (such as the spatial appearance of a village in a city) to be stored in digital formats (such as CDs and disks) to achieve persistent data Storage (Tobiasz et al., 2019). At the same time, digital storage data provides valuable resources for cultural heritage preservation and research in this field (Hoon et al., 2019).

However, the explosive growth of data poses specific challenges to data analysis and processing capabilities. There are still bottlenecks in transforming data into more general information or knowledge to serve management departments, research institutions, museum industry, education, and the public related to cultural heritage (Hou et al., 2018). The application of digital technology in urban villages still has problems such as low information integration and weak information. In addition, the limitations of the current equipment's communication capabilities and user sharing capabilities have severely restricted the promotion and integration of the cultural heritage of urban villages and society. The village in the city is usually a large-scale and complex environment, and the requirements for high-precision visualization of hardware will be very high. Most existing solutions use large hardware devices, such as virtual sandboxes. Unlike hand-held devices, such devices are expensive and not easy to carry, which dramatically limits the spread of large-scale urban village heritage. Moreover, due to the hardware limitation of the hand-held device, its display resolution and interactive effect are not ideal.

Therefore, it is urgent to organize and correlate multi-source data both accurately and efficiently. Potential solutions include extracting essential information based on the characteristics of different data types, such as drone scanning, and visualizing it in various data formats. In this way, various scalable and customizable solutions can be further proposed to meet the requirements of different applications. With the evolution of computer technology, cloud computing platform, as the core technology of digital urban villages to promote resource sharing and iteration, is an inevitable choice to respond to the current situation.

This article proposes a new workflow based on NVIDIA CloudXR streaming media technology to achieve a high-precision visualization effect and a rich interactive experience on hand-held devices. Thus, digital heritages can be popularized more

effectively.

2. Related Technologies

For the digitization of large-scale and complex heritage types such as urban villages, the main applications can be divided into two types: focusing on specific applications and application systems and workflows.

2.1. THE APPLICATION OF DIGITAL HERITAGES IN URBAN VILLAGES

The purpose of protecting the digital cultural heritage of urban villages is conducive to the persistence of historical archives and to use these digital resources to provide more beneficial help for the sustainable development of cultural heritage. Researchers in this field have made great efforts. Digital technology has attempted to visualize three-dimensional urban villages, but it is challenging for most researchers to understand and interact with portable devices. For example, the "4D-GIS" model in Longwu Village, Shenzhen, synthesizes material flow and stock analysis (MFSA) with geographic information system (GIS) to illustrate time and spatial attributes of buildings and the evolution of materiality metabolism (Wang et al., 2019).

Despite the continuous iterations in technological development and dissemination efficiency, the preservation and dissemination of digital heritages in urban villages is non-user-oriented, designed, and developed in a non-descriptive way. They only focus on the "process" (data authentication, on-site investigation, and display) or "product" (re-interpretation and the representation of technical art which are more similar to reality), but seldom consider the "end-user" (how end-users are disseminated) (Rahaman and Tan, 2011).

2.2. APPLICATION SYSTEM AND WORKFLOW

With the advancement of computing skills, mobile devices, display technology, wide-ranging high-speed networks, and the increasing research and development of immersive digital media and artificial intelligence (AI), more and more attention is paid to the dissemination and preservation of urban villages by end-users. In terms of equipment of extended reality (XR), including augmented reality (AR), virtual reality (VR), and mixed reality (MR), including having provided consumers with convenient and affordable experiences (such as mobile phones or iPads). It offers more opportunities for immersive interaction. XR on mobile devices provides a new experience for us to interact and interpret the world, mobile games such as Pokemon Go, Ingress Prime, and Knightfall: AR, educational experiences such as BBC Civilisations AR, and practical everyday tools such as Google Lens, Translate and Maps AR. Regarding data processing for hand-held devices, improving 5G communications has shown great potential in real-time rendering and rapid delivery of the high-quality immersive experience. There are many technologies, including cloud-based services and machine learning, create location-based personalized experiences, such as NVIDIA's CloudXR, streaming dense graphics for XR and GridRaster, support artificial intelligence-based immersive MR platforms, and assist in creating a more meaningful and more engaging experience, such as PopStic VR and Epic's Apollo 11: Mission AR on Microsoft HoloLens. Microsoft Mesh also interrupts our interaction

with the real and virtual worlds, introducing digital intelligence into the real world to disrupt the way we share experiences, collaborate, communicate and recognize existence.

To promote sustainable development of the digital cultural heritage of urban villages and disseminate it effectively, researchers should cooperate to achieve a higher level of information visualization sharing skills and data interaction with certain restrictions on copyright. Therefore, it is urgent to design a more flexible systematic structure to satisfy end-users various demands and device restrictions to create a general CloudXR workflow for the digital cultural heritage in urban villages.

3. Method

3.1. METHODOLOGY

There are many methodologies for architectural heritage preservation, such as the eCAADe 2016 paper on 3D Digital Reconstruction of Lost Buildings that has inspired a further workflow in this paper (Mascio et al., 2016). This paper proposes a methodology with documentation-computation-dissemination (DCD) workflow, mainly utilizing NVIDIA CloudXR technology to promote high accessibility, fidelity, and interactivity in disseminating digital heritage. This methodology proposes a new perspective of the preservation of digital architectural heritage. In figure 1, The application of the method is shown in the three sections of "What," "Why," and "How." The workflow content such as Documentation, Digital Reconstruction, Computational Process, and Dissemination is listed in "How."

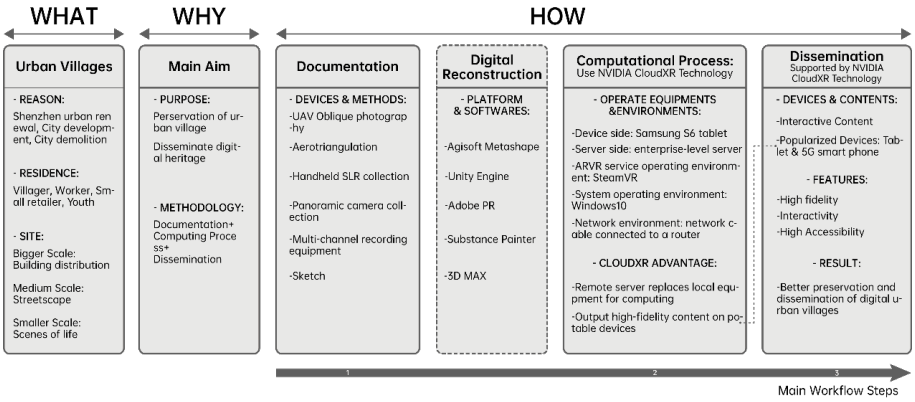

Figure 1. DCD Workflow that highlights technology to promote the spread of digital heritage

3.2. DOCUMENTATION

In this documentation part, various technical methods are being used to collect data on Baishizhou from three different scales to collect and preserve the appearance of urban villages more comprehensively. In terms of large-scale: The general form, overall layout, and regional distribution of urban villages are preserved. The specific method is to use a drone to carry a 20-megapixel lens to perform oblique photography and then operate aerial triangulation. In terms of medium-scale: Preserve the daily street scenes

and the spatial experience in human perspectives, which use four different ways to synthesize. Small-scale: Through field measurement and digital modeling to document interior living spaces.

3.3. COMPUTATIONAL METHOD

3.3.1. Introduction to NVIDIA CloudXR Technology

Compared with using traditional localized high computing power equipment, NVIDIA CloudXR technology can remotely control server equipment for data processing. It is innovative digital heritage preservation and can replace localized high computing power equipment.

CloudXR breaks the traditional limitations of VR and AR, streaming XR content to untethered devices, and its fidelity is indistinguishable from the native bondage configuration. Figure 2 visualizes the equipment and operating environment of NVIDIA CloudXR Technology from three parts: Server, Network, and Client.

3.3.2. Operate Equipment Used in NVIDIA CloudXR Technology

When using NVIDIA CloudXR technology, it needs to use devices at both sides: the device and the server, respectively. Device: In the AR (augmented reality) environment, the Samsung S6 tablet is used. If in the VR environment, the Meta Quest 2 is used. Server: The server is configured with two Intel Zhiqiang E5 processors, 96GB ECC memory, SDD disk matrix with a total capacity of 2T, NVIDIA RTX 2060S four graphics cards are connected in a pass-through mode. ARVR service operating environment: The SteamVR environment. System operating environment: Windows10.

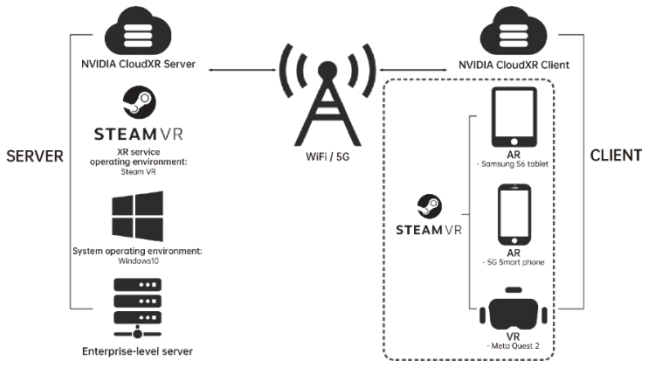

Figure 2. NVIDIA CloudXR Architecture

3.3.3. Practical results of using NVIDIA CloudXR technology workflow

To practice the workflow using NVIDIA CloudXR technology, we use the tablet as the output terminal of AR and Meta Quest 2 as the VR output terminal to visualize. As shown in figure 3, this table highlights the advantages of CloudXR technology and the results of CloudXR technology testing using different devices such as AR and VR.

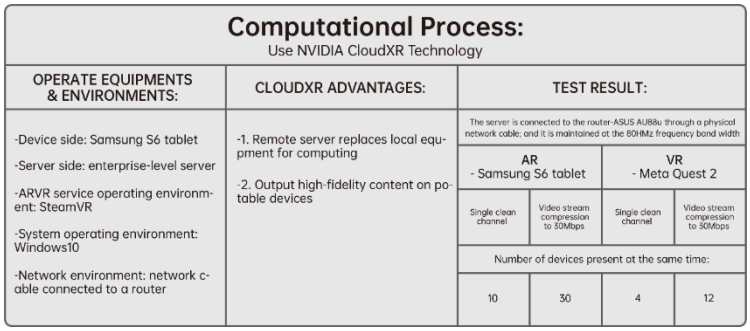

Figure 3. Computational process

3.4. DISSEMINATION

3.4.1. Interactive design in the dissemination

When disseminating digital heritage, NVIDIA ClouxXR technology significantly promotes the accessibility and fidelity of the content. Meanwhile, the Unity engine enables visualized information, amusing animation, sound effects, and UIUX design to be linked to the digital heritage to enhance the fun and interactivity of the content. Therefore, it enhances the experiencer's curiosity and acceptance of digital heritage.

3.4.2. Hand-held devices in the dissemination

In figure 4, this picture shows the three advantages of CloudXR technology in disseminating digital heritage. The following are the three aspects that why CloudXR technology is disseminated efficiently: a. Based on the application of CloudXR technology, complex data is transferred by the network to the edge and remote high computing power devices for calculation, maintaining the high fidelity of content b. Combined with the popularization of 5G communication networks, CloudXR technology is better used in hand-held devices with higher popularity. c. Better interactive experience.

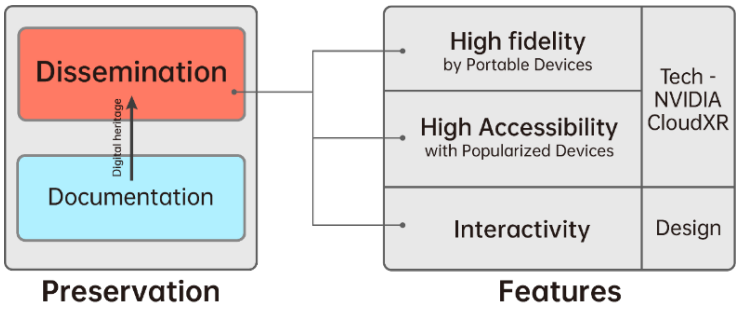

Figure 4. Portable Devices in Dissemination

4. Experimental System and Case Study

This study takes Baishizhou, Shenzhen, Guangdong Province, China as an example to test the feasibility of a new workflow based on NVIDIA CloudXR streaming media technology in digital heritage preservation. As a newly emerged city, Shenzhen has a limited history that can be traced back, and the urban villages in the city are witness to this collective memory. Baishizhou is a place for the fringe people to integrate into city life as much as possible. Low-income labour and rural migrations live temporarily in an urban village like Baishizhou, different from most developed urban spaces. However, it still could be possible to identify their urbanites identities. The preservation of the memory space of Baishizhou is not only related to the materiality and construction history of its architectural space but also to how its spatial characteristics affect our experience, thus emerging the place property of Baishizhou. (Junyi, 2017, p.24) The protection of heritage in Baishizhou also means the protection of collective memory of people related to the space.

Figure 5. The Location and Street View of Baishizhou

Based on the current situation of Baishizhou, we tried to make the Baishizhou AR interactive sandbox open to the public for the experience. The purpose is to allow the people of Baishizhou to experience and communicate in the IDG industry incubation centre space. Figure 6 shows the experimental process.

First, we extract the data collection of Baishizhou; use Agisoft Metashape and other software to generate 3D architectural models from 3D scanning data. After that, use 3DMax to model and make animations. Then, import digital assets such as the generated models and animations into the Unity game engine; carry out model reduction and resource integration. Finally, use NVIDIA CloudXR workflow to transfer the content that needs to be presented to the remote tablet for display. The interactive user experience is as follows: a.Activates the device camera's Ray casting algorithm. When the user aligns the device camera at a specific area of the digital model (Baishizhou consists of six regions), the area will be highlighted, and the device screen will pop out of it. b.After the highlighted area is displayed, slide the screen upwards: the specified animation and sound effects emerge, and then the detailed information interface of the village pops up. c.Swipe the screen up again: the designated animation and sound effects appear, the iconic digital building in the corresponding area with animation is shown. d.Based on the technical support of bi-directional audio in CloudXR, users who experience the product remotely can simultaneously have real-time communication and discussion.

Figure 6. AR representation and Multiplayer experience in experiment

We invited 27 people to participate in this experiment: Currently living in Baishizhou: 11 people and previously living in Baishizhou: 16 people. In the experiment, 27 volunteers were divided into two groups to conduct experiments respectively: The first group consists of 11 people currently living in Baishizhou; two to three people experience at the same time as a group; hold Samsung tablet devices; the experience time is controlled within 5-10 minutes. The second group consists of 16 people who have lived in Baishizhou; the settings of factors such as the number of experienced persons, experience equipment, and experience duration are the same as those of the first group of experiments. Figure 8 shows the experimental process of the multiplayer experience.

We evaluate the experience process into three parts: model presentation content, interactive experience, and overall experience. Meanwhile, we refined the specific content of each part based on the Baishizhou AR sandbox experience, made these nine items into a table (experience level is divided into ten Levels), and invited a simple questionnaire survey after the people have experienced it. In the end, the questionnaire data filled out by the 27 people we interviewed in the future was calculated into the following table:

5. Results & Discussion

This section begins with a summary of the seminar. We choose to use the main subject categories that appear in the data to present the results (Figure 9):

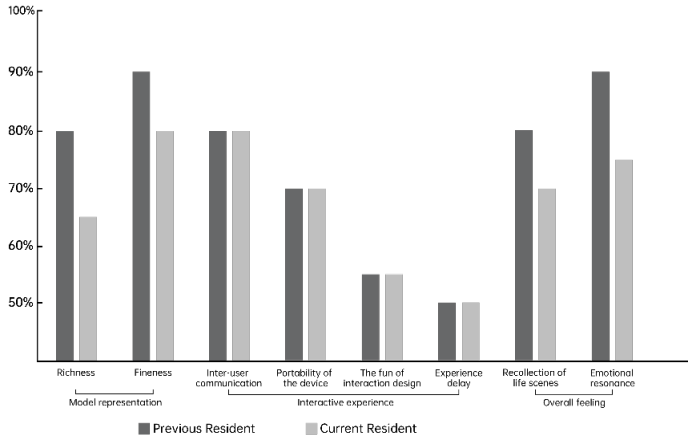

Figure 7. Data of 3 aspects (model representation, interactive experience, and overall feeling)

According to the comprehensive table, based on the high-precision Baishizhou data collection and NVIDIA CloudXR technology for the transmission of high-precision content, the Baishizhou AR Sandbox shows excellent performance in the presentation model content, regardless of the richness or the accuracy of the model content. It exceeds the imagination of the viewer significantly. From the high-precision data collection of Baishizhou and the presentation of high-precision content, NVIDIA CloudXR technology has played a vital role in the workflow. From the perspective of interactive experience, the portable tablet archives the multiplayer AR experience. It creates real-time communication opportunities for the viewers while watching the sandbox content. It is noticeable that the amuse and interactivity of UI design, animation, and sound effects in the display process need to be improved. The content delay caused by NVIDIA CloudXR technology needs to be continuously improved technically. Finally, from the viewer's overall experience, the high-precision AR sandbox brings a fantastic visualization experience to the experiencer, breaking through the limitation of time and space, creating a "space-time journey" and a natural, localized experience.

Essential aspects of Cloud XR optimization are finding the right balance between the calculations performed and the calculations performed by the cloud and optimizing the cloud's computation efficiency (R. Yadav et al., 2020). Many similar pieces of research have proposed different strategies to optimize the XR scene rendering, such as caching the actively generated video frames and their transmission by reserving network resources (Y.Sun et al., 2019; M. S. Elbamby et al., 2018; T.Xu et al., 2019). However, the application of CloudXR technology in architectural heritage and sustainable cities is still very limited. Based on this attempt, it is believed that new ideas will make urban villages such communities preserved and documented better.

6. Conclusion

The research uses this workflow based on CloudXR technology to present the large-scale and complex architectural heritage of urban villages on mobile-device. For the large-scale and complex architectural heritage of urban villages, limited by the computing power of hardware devices, the existing presentation methods have certain limitations. That is, relatively large-scale hardware devices are required. Therefore, we hope to explore a mobile-device method to disseminate urban villages better. CloudXR provides technical support for this demand.

To summarize, in the era when the wave of urbanization in China is still raging, one after another. Urban villages are about to disappear, and cities' sustainability gradually becomes an essential thesis. Using scientific technology and innovative design to retain and preserve them has become an urgent research content.

Acknowledgments

We very much appreciate the technical production of "Baishizhou Renewal" provided by Configuration Studio. The specific thanks are as follows: Derek Peng provides information on technical details; Rufeng Xiang's technical contribution to Baishizhou documentation and implementation of NVIDIA CloudXR Technology; Zhiwei Deng and Haida Sun's contribution to the realization of NVIDIA CloudXR Technology;

Mengqi Tu's contribution to interactive animation content production; Leo Liu provides technical and innovative advice; Derek Peng and Shenmeizi Cao's contribution to commercial publicity and promotion of the project.

References

Elbamby, M. S. , Perfecto, C. , Bennis, M. , & Doppler, K. . (2018). Edge Computing Meets Millimeter-wave Enabled VR: Paving the Way to Cutting the Cord. *IEEE WCNC'2018*. IEEE.

Hafizur, Rahaman, Beng-Kiang, & Tan. (2011). Interpreting digital heritage:a conceptual model with end-users' perspective. *International Journal of Architectural Computing Ijac*.

Hao, P., Sliuzas, R & Geertman, S. (2011). The development and redevelopment of urban villages in Shenzhen. *Habitat International*, 35.

Hou, M., Yang, S., Hu, Y., Wu, Y., Jiang, L., Zhao, S., & Wei, P. (2018). Novel method for virtual restoration of cultural relics with complex geometric structure based on multiscale spatial geometry. *ISPRS International Journal of Geo-Information*, 7(9), 353.

Jo, Y. , & Hong, S. . (2019). Three-dimensional digital documentation of cultural heritage site based on the convergence of terrestrial laser scanning and unmanned aerial vehicle photogrammetry. *International Journal of Geo-Information*, 8(2).

Leng, J. (2017). The Value and Utilization of the Memory Space of Urban Villages in Urban Renewal from the Perspective of Symbiosis Thought: A Case Study of the North District of Baishizhou, Shenzhen. *China Academic Journal Electronic Publishing House*. TU-10590-31.

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(99), 7573-7586.

Tobiasz, A. , Markiewicz, J. S. , Sawomir apiński, Nikel, J. , & Muradov, M. . (2019). Review of methods for documentation, management, and sustainability of cultural heritage. C*ase study: museum of king jan iii's palace at wilanów. Sustainability*, 11(24), 7046.

Wang, H., Chen, D., Duan, H., Yin, F., & Niu, Y. (2019). Characterizing urban building metabolism with a 4D-GIS model: A case study in China. *Journal of Cleaner Production*, 228, 1446-1454.

Xu, T. , Sun, Y. , Xia, S. , Li, H. , & Chen, Z. . (2019). Optimal Bandwidth Allocation with Edge Computing for Wireless VR Delivery. *2019 IEEE/CIC International Conference on Communications in China (ICCC)*. IEEE.

Yadav, R. , Zhang, W. , Huang, C. , & Tao, G. . (2017). MuMs: Energy-Aware VM Selection Scheme for Cloud Data Center. *International Workshop on Database & Expert Systems Applications*. IEEE.