



Digital Protection of Sanduo Village in Zigong Based on XR and Gamification

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Abstract. Located in Zigong City, Sichuan Province, Sanduo village is a traditional village with regional characteristics and historical details, bearing rich architectural culture, folk culture and local memory. This study takes the Sanduo village in Zigong as the core research object, focusing on the digital protection and activation utilization of the historical Castle buildings and their spatial features. The research comprehensively uses the cutting-edge methods such as AR smart glasses, XR interactive technology, high-precision 3D modeling and immersive interactive design to systematically complete the overall design of the digital restoration and gaming experience system of Sanduo village historical scenes, and actively explore the innovative path of digital display and dissemination of cultural heritage. In view of the practical problems of the existing physical buildings in Sanduo village, such as the difficulty of protection, the single traditional display form, and the limited coverage of cultural transmission, this study reconstructs the historical space and cultural scenes through digital technology to enhance the public's sense of participation and experience. It is expected to form a set of conceptual application scheme of XR historical scene restoration and game experience with complete structure and can be implemented, providing practical reference and technical support for the protection, inheritance, activation and utilization of traditional cultural heritage.

Keywords: Sanduo village; XR technology; Gaming experience; Digital protection

1 Introduction

As the representative of "city village type" in Zigong traditional villages, Sanduo village has the dual attributes of "city" and "village". Its architectural community is built along the mountains, with walls and defensive structures, reflecting the militarization characteristics of traditional villages in southern Sichuan. Its history is closely related to Zigong well salt culture. The architecture and culture contain the history of salt industry, salt merchant culture and local folk customs, which has important cultural value and protection significance [1]. However, under the multiple influences of long-term natural erosion, man-made destruction and urbanization process, Sanduo village is facing a serious survival crisis: the core building components are damaged, the walls are weathered and collapsed, and the historical features are missing; At present, the cultural and tourism display means of Sanduo village are limited, and only static repair and graphic display boards are used. The display means

are single and the narrative is weak, so it is difficult to fully display the historical scene and cultural connotation of the ancient village to the public.

In recent years, the research of cultural heritage protection has shown a trend of interdisciplinary. Virtual reality (VR), augmented reality (AR) and game design are widely used in the visualization and interactive experience of cultural heritage. For example, Anastasios Theodoropoulos and Angeliki Antoniou pointed out through systematic literature review that the application of VR games in cultural heritage is increasingly mature, especially in the field of historical, architectural and archaeological heritage, and game design is widely used to improve user participation and cultural understanding [2]. In addition, Bruno Rodriguez Garcia's systematic literature review further analyzes the application framework of immersive XR technology in cultural heritage, emphasizing its potential in education, immersive experience and cultural narrative [3].

In this context, this research aims at the digital protection and activation utilization of Sanduo village, integrates XR technology, high-precision 3D modeling and game design thinking, and carries out research on historical scene restoration, interactive system construction and cultural and tourism experience innovation, effectively solving the problems of low participation of tourists and outdated site display mode in Sanduo village. This study is not only an innovative breakthrough in the protection of traditional ancient villages and fortresses, but also an interdisciplinary practical exploration of architecture and XR technology. It is expected to provide replicable and scalable technical solutions and application paradigms for the digital protection, cultural tourism upgrading and public education of similar historical fortresses in Sichuan and even the whole country, so that the endangered local heritage can be reborn in the digital era.

2 Design Method

The purpose of this research is to build a digital protection and display platform for Sanduo village, which integrates historical authenticity, technology immersion and interactive interest. The design method is based on rigorous academic research, takes the advanced extended reality (XR) technology as the skeleton, and takes the game narrative as flesh and blood, and finally forms a complete prototype scheme for cultural tourism promotion. This chapter will systematically elaborate the complete design path from concept source to prototype landing.

2.1 Concept Source

The research is based on the systematic sorting and digital transformation of the material and non-material culture of Sanduo village, integrating historical documents, historical old photos, entity mapping and 3D data acquisition, and obtaining the high-precision point cloud and model of the site status through ground laser scanning (Fig. 1), UAV photogrammetry (Fig. 2) and other technologies, so as to provide an accurate spatial benchmark for digital reconstruction. This process follows the mature methodology from "cognitive stage" (data collection) to "three-dimensional digital reconstruction" [4].

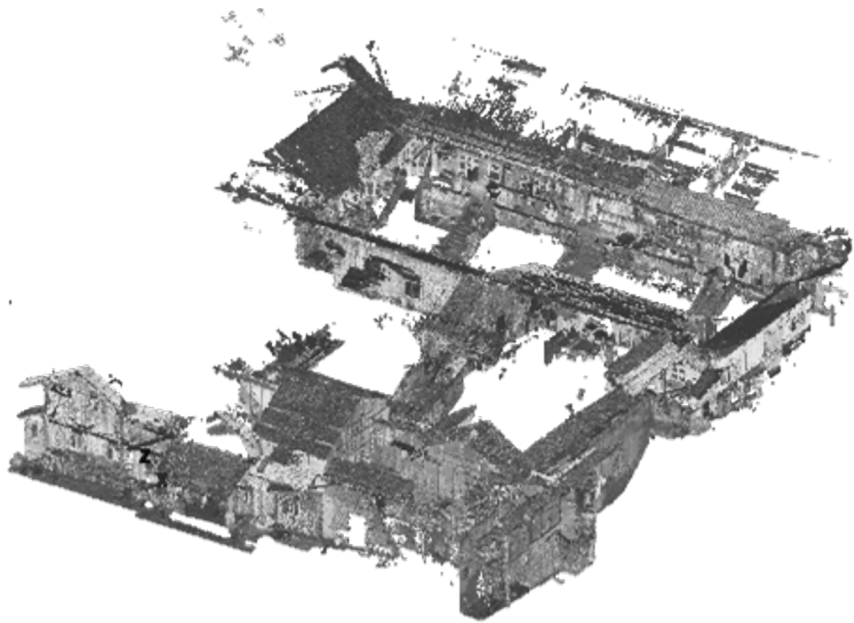


Fig. 1. Point Cloud Scan Photos of Siyong Hall (Picture credit: Original)



Fig. 2. Aerial Photos by Drone (Picture credit: Original)

In terms of cultural core excavation, this study takes the salt merchant culture as the cultural anchor point, refines the core symbols such as salt introduction, guild hall and stage, and draws lessons from the practice of "digital twin salt field" and Mr narration, aiming to break through the static display and realize the deep activation and dissemination of cultural value [5]. Finally, with XR (extended reality) technology as the core media, integrating VR, AR, MR and other forms, the paper will build an

immersive experience scene of virtual and real integration, and provide innovative solutions that break through the physical limitations for the digital display and educational inheritance of Sanduo village cultural heritage [6].

2.2 Design Strategy: The Trinity of Authenticity, Narrative and Gamification

At the design strategy level, this study focuses on the balance between "historical accuracy" and "user experience", and constructs an immersive experience system with the unity of "reality immersion interaction".

First of all, in terms of historical accuracy and cultural authenticity, this study follows the principles of the London charter in all digital restoration, distinguishes between "evidence-based restoration" and "hypothesis-based restoration", and clearly marks them in the model. Ensure the accuracy and completeness of historical information as the basis for the academic rigor of the project [7].

Secondly, in terms of the coherent emotional narrative strategy, the design of this study runs through the narrative line, weaving the scattered historical information, architectural space and cultural symbols into a coherent story. Guide tourists from "shallow sightseeing" to "deep cultural experience", and deepen their understanding of culture through the interweaving and transformation of three interactive modes: text and reading, history and contemporary, virtual and real scene [8].

In terms of immersive experience design, this study flexibly selects XR technology according to the application scenarios: for the disappeared or damaged buildings, VR is used to build a fully immersive virtual history scene; For the existing sites, the AR/MR technology is used to superimpose the virtual restoration model on the field environment to achieve the visual effect of "ancient and modern same frame".

Finally, this study systematically integrates the Gamification interaction mechanism into Gamification design. This not only means adding points, badges and other elements, but also the core is to meet the users' internal psychological needs - a sense of ability, autonomy and belonging, stimulate the motivation of continuous exploration and learning, and improve the viscosity and interest of the tour experience [9].

2.3 Prototype Design and Case Reference: Adaptive Innovation Based on Liangzhu Project

This study takes "AR guide project of 'Mojiao mountain pilgrimage road' in Liangzhu ancient city site" as an example, and adapts it in combination with the characteristics of Sanduo village. At the technical level, this study uses its mature technologies such as point cloud scanning, 3D modeling, AR overlay and AI digital human [10] for reference to verify the possibility from accurate data collection to immersive experience design. At the design level, the idea of "narrative leading the tourist route" in Liangzhu ancient city was continued, and the theme was changed to "the rise and fall of Sanduo village and the defense of traditional fortresses", and the narrative chapter of "resident village - thriving village - guarding village" was constructed. At the same time, upgrade the digital human navigation system, integrate the large language model and multimodal interaction, support personalized question and answer outside the basic explanation, and improve the problem of insufficient traditional navigation interaction [6]. Finally, with AR smart glasses as the core, it integrates the functions of AR overlay,

Gamification task and intelligent digital human dialogue to form a complete immersive cultural tourism display scheme.

3 Expected Results

3.1 Final Presentation

This study plans to use portable intelligent augmented reality (AR) glasses as the core hardware platform to build an immersive digital experience for cultural heritage tourism. The scheme aims to make use of the portability and ease of operation of wearable AR devices to break through the inherent limitations of traditional heritage sites in physical space, number of exhibits and display forms [11]. Compared with the large fixed virtual reality (VR) head display, lightweight AR glasses can significantly reduce the user's equipment burden and use threshold, so that visitors can access and interact with the enhanced environment superimposed with virtual cultural information at any time and anywhere in the field or remote context [12]. On the one hand, this technical route broadens the narrative angle and presentation mode of Sanduo village, and on the other hand, it also opens up a new possibility for creating a more personalized and scene fitting cultural travel experience.



Fig. 3. Game map (Picture credit: Original)

Game Map. Based on the real mapping map of Sanduo village, this study finally constructed a 1:1 matching XR gamified Panoramic Map (Figure 3). As the core guide tool for tourists to enter the Sanduo village scenic spot, the map clearly marks the complete tour route and task trigger points of the three stages of "Settle the Village - Vitalize the Village - Guard the Village", so that tourists can intuitively understand the overall tour process when arriving at the scenic spot.

Settling-in Phase: Initial Understanding of the Stockade and Identity Integration.

As the initial link for tourists to deeply experience the historical and cultural connotation of Sanduo village, the core of the Settling-in Phase is to guide tourists to complete the identity transformation from modern visitors to participants in historical situations through cutting-edge digital technology (Figure 4). Here, AI digital man guide "Yan Xiaoyan" completes the scene guidance and basic information popularization. His identity was set as the legitimate daughter of Yan's salt merchant, which was not invented out of thin air, but rooted in the historical fact that Yan, Wang and Li jointly built the village in Sanduo village. Among them, the three core playing methods at this stage include: through the scanning and identification of the stronghold gate, Stockade Tower and other defensive buildings, solving the mechanism puzzles under the guidance of digital people, and intuitively feeling the defensive wisdom of the ancient stronghold; Stand beside the city wall and follow the gesture instructions to complete the actions of ramming earth, building stones, erecting wood, etc., participate in the construction of the city wall in real time, and support multi person team cooperation to deepen the understanding of the construction process of the fort; And follow the digital man "Yan Xiaoyan" Village Building Guide to walk around the ancient village wall, follow the prompts to find the village building keepsakes hidden everywhere, and unlock the past of the construction of Sanduo village. In addition, when tourists encounter difficulties in decryption or exploration, "Yan Xiaoyan" will automatically provide corresponding prompts to assist tourists to smoothly promote the travel experience



Fig. 4. Concept Map of Gameplay in the Settling-in Phase (Picture credit: Original)

Development Phase: Restoration of Salt Merchants' Life and Functional Scenes.

The design of Development Phase aims to simulate and restore the production and life, business system and cultural ecology of Sanduo village in its heyday through the game task mechanism. The core of this stage is to transform specific historical knowledge and cultural experience into interactive tasks with clear goals, rules and incentive

systems, so as to enhance tourists' participation and cognitive depth [13]. Specifically, this stage includes the following Gamification modules (Figure 5): tourists can summon virtual theatre characters in front of the stage of Siyong hall and interact with Sichuan opera characters, switch tracks by one key gesture, and immersively experience the ancient opera culture and folk life; People can also cooperate with the virtual cashier in front of Guixin hall to complete the bookkeeping and reconciliation tasks, so as to understand the business model and wealth exchanges of ancient village salt merchants; People can also trigger a virtual ancient bazaar at the old street of Sanduo village to collect salt merchants' props and clues, so as to unlock the salt merchants' historical stories and trade details.



Fig. 5. Concept Map of Gameplay in the Development Phase (Picture credit: Original)

Guardian Phase: Heritage Protection and Contemporary Inheritance Practice.

The Guardian Phase aims to build a practical framework centered on the living inheritance of cultural heritage and the deep participation of the public (Figure 6). By designing a series of multi person collaborative tasks, this stage aims to guide participants from passive "bystanders" to active "collaborative protectors", so as to achieve the contemporary interpretation, dissemination and education goals of the cultural value of Sanduo village in the interactive experience [14]. Specifically, tourists can participate in the collaborative interaction of multiple people at the gate of the North Village to solve puzzles and light the Kongming lamp, so as to jointly create a visual landscape of "Star River lamp sea" and convey the blessing culture and collective memory of the ancient village; In addition, tourists can complete the defense game of the ancient stronghold in the form of teams at the wall of the North stronghold gate to experience the ancient stronghold defense, so as to deepen their understanding of the

traditional stronghold defense system; Finally, tourists can gradually restore the complete history of Sanduo village by collecting virtual "keepsakes" at various stages (such as architectural component patterns, historical character marks, etc.), and establish an overall understanding of the cultural context of Sanduo village.

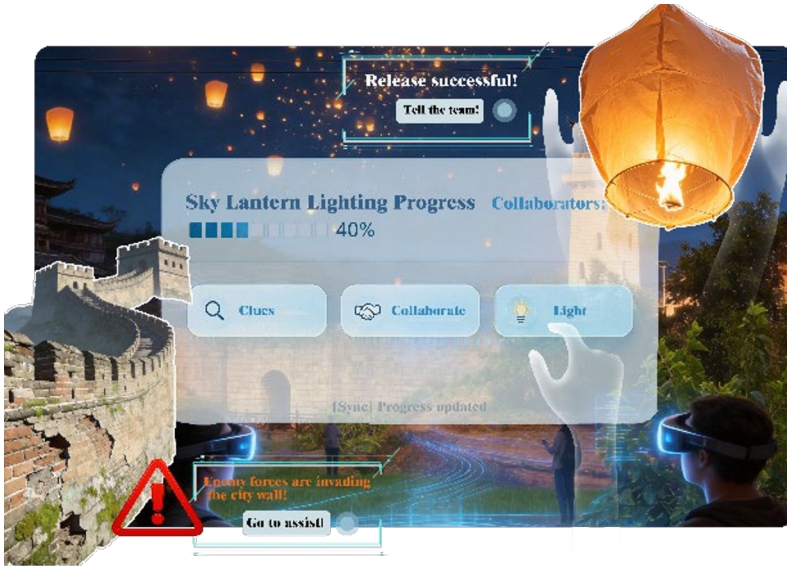


Fig. 6. Concept Map of Gameplay in the Guardian Phase (Picture credit: Original)

3.2 Summary of Multimodal Interaction Methods

This study built a multimodal XR interaction system with gesture, vision and voice as the core for the immersion experience of Sanduo village cultural heritage. This system establishes an intuitive connection between the real physical space and digital content through the real scene level virtual and real fusion control of gesture and space interaction; A variety of interaction modes cooperate with each other, which significantly improves the immersion experience of users in the whole process of settlement, promotion and guarding, and also provides a more innovative technical path and interaction paradigm for the digital display and live inheritance of traditional stronghold cultural heritage.

4 Application Scenarios

This study aims to build a comprehensive digital solution, and its results will be mainly applied to the following three core scenarios, in order to form synergy in the field of activation, protection and inheritance of cultural heritage.

First, in terms of cultural tourism experience innovation, this study will integrate augmented reality (AR) smart glasses and lightweight mobile applications (applets) to

develop an immersive interactive navigation system for historical and cultural scenic spots (Figure 7). The system can accurately overlay the historical original appearance, character activities or cultural information layers of ancient buildings on the real scene in the view of tourists, so as to create a deep experience connecting history and reality, and enhance tourists' perception and understanding of Sanduo village.

Secondly, in terms of heritage protection and restoration research, this study is committed to building a high-precision digital twin model of Sanduo village and rendering the scene according to historical data (Figure 8), providing a visual data base for academic research and the repair and protection of local cultural tourism groups, while realizing the digital archiving of Sanduo village and preventing irreversible losses caused by natural or human factors.

Finally, in terms of public education and research promotion, based on the above-mentioned digital assets, this study will design and develop a series of interactive digital teaching courses (Figure 9), design immersive learning content of ancient architecture knowledge for students, combine virtual and real interaction and task driven mechanism, improve academic learning motivation and cognitive depth, inject digital vitality into the traditional classroom, and help the popularization and systematization of cultural heritage education.



Fig. 7. Concept map of cultural tourism application (Picture credit: Original)



Fig. 8. Restored Rendering of Sanduo Village (Picture credit: Original)



Fig. 9. Concept map of public education application (Picture credit: Original)

5 Conclusion

This research takes Sanduo village in Zigong City as the research object, focusing on the digital protection and cultural tourism utilization of salt merchants' defensive strongholds in southern Sichuan, and realizing the high-precision digital restoration of Sanduo village by comprehensively using the methods of literature research, field mapping and three-dimensional modeling; Taking ar glasses as the carrier, the three-stage immersive tour route of Settle the Village - Vitalize the Village - Guard the Village " is designed, which integrates multimodal interaction modes such as gestures, vision and voice, and promotes the transformation of tourists' visiting mode from passive viewing to active exploration, so as to effectively enhance the attraction of cultural heritage display and public participation. The results of this study show that the integration of XR and Gamification can significantly alleviate the current problems such as the difficulty of entity protection, single display form and insufficient communication efficiency, and provide a reusable technical path for the digital protection of fortified villages cultural heritage. There are two core challenges in the research process: one is the lack of historical documents related to Sanduo village, which leads to the limited restoration accuracy of some architectural details and historical scenes; Second, the high cost of AR interactive equipment procurement and operation and maintenance form a certain threshold for the implementation and promotion of local cultural and tourism bureaus. In the future, the accuracy of the model will be improved through the textual research of multi-source historical data, and the lightweight mobile terminal AR scheme will be developed to reduce the landing cost and help the digital activation of the fortified villages cultural heritage in southern Sichuan.

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