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Heritage Revitalization Design Based on Gamification and AR Technology: A Case Study of the Old Library of Wuhan University

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Abstract. In the context of the digital technology-enabled revitalization of cultural heritage, this study takes the Old Library of Wuhan University as the research subject. Drawing on existing research results such as the structural characteristics of its roof, and using AR technology as the core, it integrates gamification concepts and human-computer interaction design to explore innovative approaches to the revitalization and protection of individual historical buildings. The research will employ literature review, case analysis, and prototype design methods to construct a gamified interactive system based on AR technology. It is expected to enhance public awareness and protection consciousness of the Old Library of Wuhan University, improve the immersion and engagement of heritage experiences, and provide a practical model for the revitalization and protection of similar individual historical building heritage sites. Furthermore, by combining storytelling with interactive elements, the system aims to create an emotional connection between users and the building, fostering a deeper understanding of its historical significance and architectural value, thereby promoting sustainable cultural heritage preservation in the digital age.

Keywords: Gamification, Augmented reality, Heritage preservation.

1. Introduction

In the context of the rapid advancement of urbanization, many historical architectural heritages face the dilemma of protection versus utilization. The Old Library of Wuhan University, as a landmark building within the historic campus, embodies profound historical, cultural, and artistic values. Its unique roof structure is a concentrated representation of architectural craftsmanship. However, in the process of inheritance and revitalization, it faces prominent issues such as insufficient public awareness of its distinctive structure, limited forms of participation, and fragmented presentation of historical information. AR technology, with its unique advantage of 'virtual-real overlay,' can seamlessly integrate virtual information into real-world scenes, offering new possibilities for dynamic heritage display and public interaction. The concept of gamification, through mechanisms such as goal orientation and reward incentives, can effectively stimulate public engagement. The combination of these two approaches provides a breakthrough opportunity for the revitalization of the building. Many scholars have conducted related research. Chen Nan, taking the Old Shanhai Han Tomb as an example, designed a VR large-space digital cultural tourism plan. By using high-precision 3D reconstruction and real-time interaction, visitors can explore archaeological sites immersively, enhancing cultural heritage protection and exhibition. This emphasizes the practical deployment and economic value of VR large-space technology in cultural tourism projects, including software and hardware advantages and market promotion strategies [1]. Bozzelli et al. proposed the ArkaeVision project, which integrates VR and AR frameworks for cultural heritage experiences. By gamified exploration and digital storytelling, it enhances user engagement and achieves multi-sensory interaction and personalized cultural journeys [2]. Yu et al. evaluated the user experience of VR headset systems, focusing on interaction operation and motion sickness factors, finding that device comfort and interaction design significantly affect user performance and comfort [3]. Alhazzaa and Yan developed the BIMThermoVR and BIMThermoAR prototypes for building energy simulation education, demonstrating that AR outperforms VR in reducing cognitive load and providing contextual learning [4]. Li explored smart city VR landscape planning, combining V2X vehicular networks and AI technology to optimize urban traffic management and entertainment experiences,

highlighting the potential of multi-technology integration [5]. Tang studied the impact of virtual keyboard distance and angle on bare-hand interaction user experience, finding that medium distance and vertical angle perform best in text input efficiency and comfort [6]. This study integrates AR technology and gamification concepts into the revitalization and protection of the Old Library of Wuhan University. By combining existing research on its roof structure and other features, it innovates the means of communication and experience of the building, allowing the public to perceive the historical context and unique structural value through interaction, enhancing emotional attachment and protection awareness for heritage. It provides theoretically valuable and practically significant research outcomes for the field of revitalization and protection of individual historic architectural heritage, promoting the development of heritage conservation toward a more dynamic direction.

2. Design Method

The Old Library of Wuhan University, a Sino-Western landmark on Luojia Mountain, now serves as a university history museum and rare book repository, but its rich details remain under accessed (figure 1). AR technology is thus integrated to overlay its hidden historical scenes and structural specifics onto reality, making its cultural value more vivid and accessible.

Figure 1. Geographical location of the old library of Wuhan University.

2.1. Source of Concept

Based on the core elements of gamification design [7], integrating all the technical features of AR technology in enhancing real-world scenes and overlaying virtual information, as well as the principles of 'natural interaction and immersive experience' in human-computer interaction design, and relying on the research results of the rooftop structure of the old library of Wuhan University, the core design concept for the revitalization and protection of this building is distilled—to construct an experience framework using AR technology where the 'real building serves as the body, virtual information serves as the soul, and gamified interaction serves as the bridge.'

2.2. Design Strategy

2.2.1. Content transformation level

This study takes the architectural archives of the old library of Wuhan University as the core basis, systematically reviewing the historical events of the building and stories related to famous individuals

[8]. It particularly focuses on its uniquely featured roof structure and construction techniques. By employing fragmented analysis and scenario-based reconstruction, it builds interactive gamified content modules. For example, a roof structure code-breaking module is designed based on the mortise and tenon structure of the roof; a roof construction scene reconstruction module is developed according to construction records from the 1930s; and a virtual dialogue module with architects discussing roof design is created based on architects' design sketches. Each content module corresponds to specific AR trigger points within the physical spaces of the old library, thereby ensuring precise alignment between the virtual content and the real building [9].

2.2.2. In terms of AR technology applications

To achieve a deep integration of virtual information and real-world architecture, the study employs high-precision image recognition algorithms to conduct sample training on features such as the overall outline of the old library building, roof surface shapes, relief textures, and door and window designs, maintaining an identification accuracy of over 98% for the building as a whole and its key components. Additionally, spatial positioning technology is introduced, using physical markers such as building walls and roof ridgelines as anchors to achieve millimeter-level accurate anchoring between virtual information and real scenes. AR overlay content is centered on the roof structure and includes layered deconstruction of the 3D roof model, showing successive levels from roof tiles to the beam framework, as well as dynamic construction process animations, such as glazed tile laying and the installation of roof ornaments. Interactive knowledge cards of roof structural features are also provided, labeling the names, functions, and cultural meanings of different ridge decorations. Users can manipulate the view using pinch-to-zoom and drag-to-rotate gestures to observe from multiple perspectives, helping the public intuitively understand the complexity of the roof structure [10].

2.2.3. Aspects of Human-Computer Interaction Design

Building a multimodal interaction system around the core goal of a seamless experience, users can perform gesture-based swipe operations, like horizontally sliding on the screen, to switch between upward, side, and downward views of the roof, thereby adjusting the observation perspective. They can also use voice commands, such as asking to display the roof's beam structure or zoom in on the details of the gargoyle, to quickly access target information. Additionally, users can interact through real-scene clicks, for example, by clicking on AR-marked roof components on the screen to trigger in-depth analysis content. Considering that users of different age groups have varying operational abilities, the system offers a simplified mode and an advanced mode. The simplified mode automatically plays core information and animated demonstrations of the roof structure to lower the usage threshold for elderly and young users, while the advanced mode unlocks all interactive features, catering to architecture enthusiasts and professional learners seeking autonomous exploration.

2.2.4. Gamification Mechanisms

This study aims to build a complete closed loop covering exploration, achievement, and social interaction. During the exploration phase, users tour historic libraries in reality and use AR scanning to discover hidden tasks related to the roof structure, such as finding specific decorative patterns on the ridge of the roof or answering questions about the principles of roof slope calculation. In the achievement phase, when users’ complete tasks, they can unlock corresponding virtual badges with titles like 'Roof Structure Expert' or 'Architecture Exploration Enthusiast.' Exclusive AR effects are also triggered, such as generating virtual historical construction scenes above the roof to simulate the bustling scenes of craftsmen at work. In the social phase, the system allows users to generate UGC content, such as creating AR videos analyzing the roof frame alongside it or interactive clips of conversations with virtual craftsmen and share them within the app's built-in social module. Users can view their friends' task completion progress and compete for the number of badges earned, creating a social interaction atmosphere centered around knowledge of roof structures.

2.3. Prototype Plan

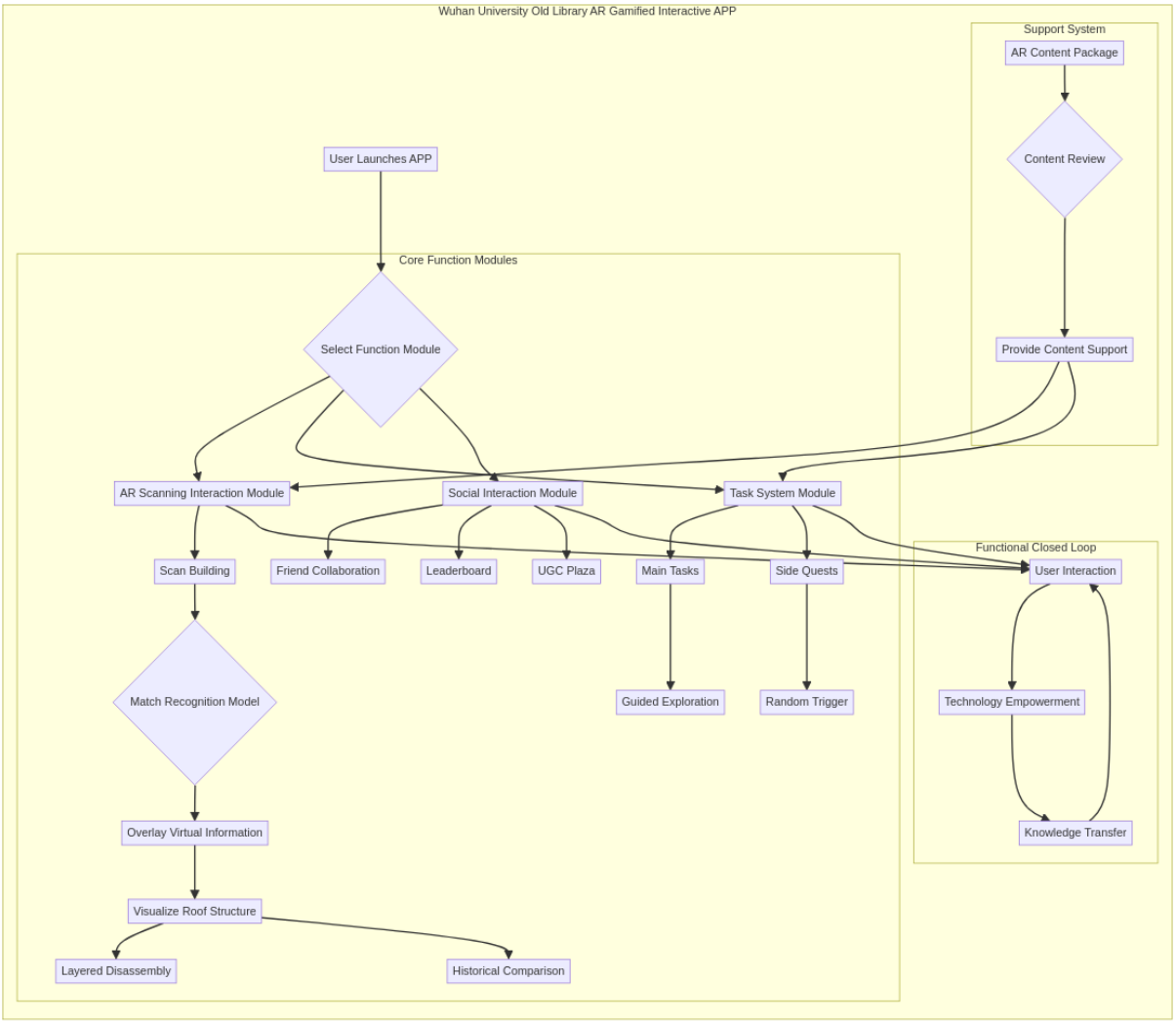


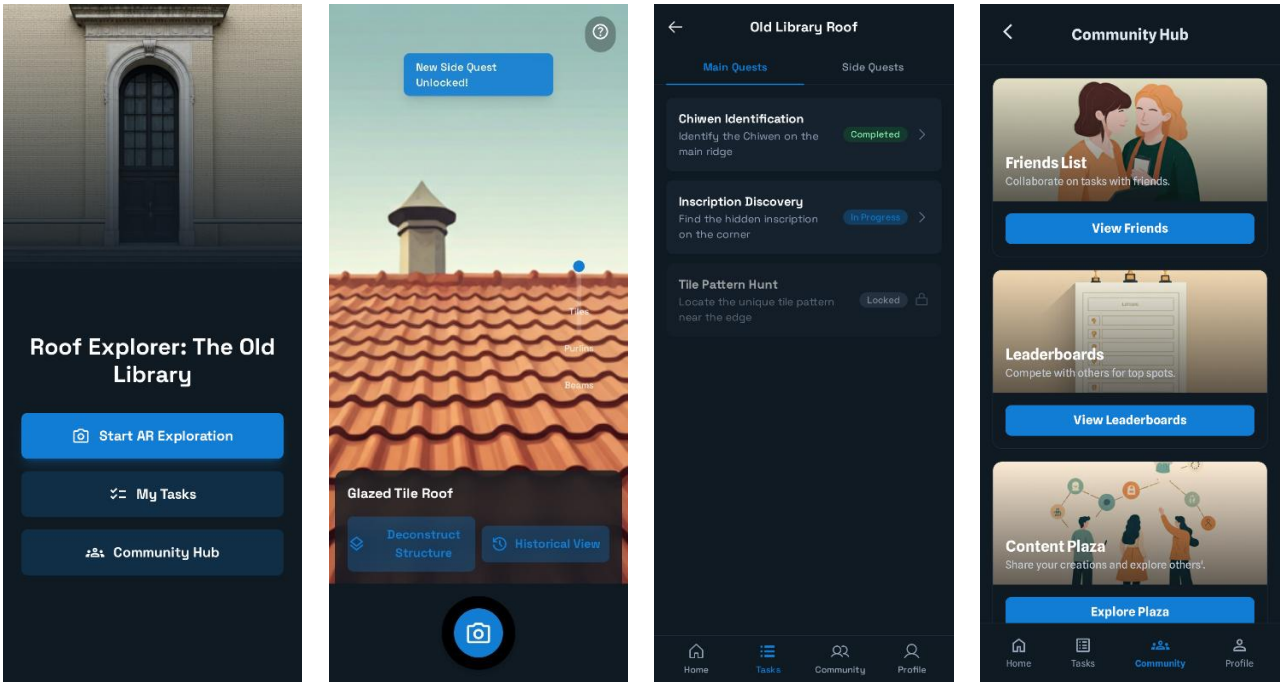
Figure 2. Prototype Flowchart.

Based on the revitalization needs of the old library of Wuhan University and the rooftop structure, this study developed a dedicated AR gamified interactive APP prototype. By leveraging three core modules (figure 2), it achieves a functional loop of 'technology empowerment - knowledge dissemination - user interaction.' The AR scanning interaction module uses the physical building as a base; when users scan architectural elements such as the building itself, the rooftop, or reliefs, virtual information overlays are triggered. It supports layered decomposition of the rooftop 3D model and 'historical appearance comparison,' with virtual content anchored to physical objects to ensure precise positioning. The task system module designs layered tasks around rooftop knowledge; main tasks are set along the tour route to guide users in understanding rooftop structures, while side tasks are triggered randomly, with progress synchronized in real time to personal profiles to form an exploration trajectory. The social interaction module integrates a friend list, an all-platform leaderboard, and a UGC content square, supporting team collaboration to complete rooftop tasks, real-time leaderboard updates, and uploading AR creations to build a knowledge-sharing community. The study also designed a supporting AR content package centered on rooftop structures, including materials such as construction techniques and maintenance records. These were reviewed by experts and archival personnel to provide professional content support for the APP.

3. Expected Outcomes

The AR gamification activation system for the Old Library of Wuhan University developed in this study takes the software platform and data resources as its core support, constructing a collaborative

architecture of 'interactive entry - content supply.' The mobile AR interactive app serves as the core connection point between the system and users, employing cross-platform development technology to support both iOS and Android systems. It is optimized to use interface adaptive design, lightweight model loading, and other technologies to reduce hardware requirements and ensure smooth operation of core functions. Its functional modules revolve around the activation needs of the roof structure, integrating core functions such as AR scanning interaction, gamified task systems, and social interaction, achieving deep interaction between users and the architectural history, culture, and structure. The Old Library recognition database and AR content resource library form the core carriers of content supply: the recognition database collects multi-view images of the entire building as well as key roof components and façade reliefs using high-precision equipment; the AR content resource library uses the roof structure as the main line, integrating millimeter-precision layered 3D models of the roof, digitally restored historical images and repair videos, and task script resources designed based on roof knowledge. All resources undergo dual review by experts and the library archives department to ensure authenticity and professionalism. Together, they form the core operational foundation of the system, achieving a complete functional loop of 'user APP interaction' - system data service invocation (figure 3).



(a) (b) (c) (d)

Figure 3. Prototype outcomes (a: home page, b: scan page, c: task page, d: community page).

4. Conclusion

The AR gamification activation system developed for the old library of Wuhan University can achieve multi-dimensional value implementation, providing a practical reference for the revitalization and protection of historical architectural heritage. In terms of tourism experience, the system uses a mobile app to transform the historical context and rooftop structural knowledge of the building into perceivable real-time interpretations. Through gamified tasks, it encourages visitors to actively explore rooftop craftsmanship and decorations, shifting the experience from superficial sightseeing to deep cultural immersion. In the field of heritage protection, the system constructs a public participation mechanism through the 'AR Protection Challenge': users submit potential rooftop issues using AR markers, forming a 'crowdsourcing action,' and the data is fed back to the management and repair departments. This creates a virtuous cycle of 'public discovery - data feedback - professional improvement,' strengthening protection focus on key rooftop elements. In terms of cultural dissemination and IP incubation, the system supports user-generated AR UGC content related to

rooftops, which can be used as IP development material to incubate distinctive cultural and creative products, transforming architectural value into contemporary cultural symbols, expanding influence, and achieving living heritage transmission. In summary, through the integration of technology and content, the system forms collaboration across tourism, protection, and dissemination, deeply exploring architectural value and providing a professional and practical model for the activation and protection of similar historical buildings. In the future, the system's technical boundaries could be expanded, such as integrating AI intelligent guide functions to automatically push personalized rooftop structural knowledge based on user interests, or combining metaverse technology to create virtual roaming scenarios, allowing users to explore the complete appearance of the old library across different historical periods beyond the constraints of time and space. The system's model could also be replicated and adapted to other university historic buildings, urban historical landmarks, and individual heritage sites, forming a scalable ecosystem for historical building activation, making technological empowerment a lasting force for cultural heritage preservation.

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