INTEGRATING HERITAGE PRESERVATION AND CITY DEVELOPMENT

A Design Framework for Digital Interactive System Based on Augmented Reality for the World Cultural Heritage Grand Canal

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Abstract. ICOMOS has pointed out that digital technologies have become important ways to protect heritages. Existing researches focus on the digital reconstruction of heritage in virtual spaces. Less attention is paid to the utilization of heritage entities and the potential for virtual heritage interaction to present complex values of heritages. Augmented reality (AR) can integrate text, images, and models into digital information to add to heritages in real sites. This paper takes the Grand Canal， a great masterpiece of Chinese civilization and even human history, as a research object. With the acceleration of the urbanization process and the change in transportation patterns, the contradiction between the preservation of it and urban development has become increasingly prominent. Based on the analysis of heritage values, this research reconstructs digital models of heritages and develops interactions with them in the Unreal Engine, relying on mobile AR to create a novel cultural landscape through a combination of virtual and real Grand Canal. This research contributes to improving the material and cultural living standards of citizens by integrating heritage preservation and urban design through the design and development of this digital system.

Keywords. Digital Heritage Preservation, Augmented Reality, Heritage Value, The Grand Canal, Cultural Landscape.

1. Introduction

As a witness to history, cultural heritage is a precious non-renewable resource. The display and interpretation of heritage is an important way to enhance the public's awareness of the value of heritage itself and thus promote heritage preservation(Neil A. Silberman, 2008). With flexibility and information integration, various digital technologies have been used to display. Nowadays, specialists in architecture and other relative areas have seen heritage as a kind of social infrastructure. However, through

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rapid urbanization, the contradiction between the preservation of architectural heritage and the development of urban space has gradually become prominent(Mason, 2006). Based on the principle that an augmented reality(AR) system can superimpose virtual content on real scenes, this paper tries to resolve the contradiction through a well-designed and developed AR system.

Figure 1 shows the Wusha Shipyard alongside the Grand Canal, one of the greatest masterpieces of hydraulic engineering in human history(UNESCO, 2014), as the research object. In the past, many shipyards were built on the riverside, including the Wusha Shipyard. Those shipyard architectures and shipbuilding techniques also became part of the civilization of the Grand Canal. In modern times, however, the waterway could no longer accommodate the manufacture and transportation of large vessels. Wusha shipyard gradually fell out of use. Nowadays, as a registered historic building, the reconstruction of the Wusha Shipyard and its surroundings is strictly restricted by regulations. This paper attempts to introduce AR into the urban design of this historic area, and discuss the process to design and develop a novel cultural landscape combining virtual history and real space through an in-situ digital system.

Figure 1 Photo of Wusha Shipyard

2. Related Research and Works

Augmented reality has been widely used in various disciplines including heritage display and urban design. Review and evaluation of these cases contain the specific technology used, real scene augmented, and virtual contents generated.

2.1. AR SYSTEM FOR HERITAGE PRESERVATION

The concept of information augmented on heritages for the exhibition has been around for a long time. In the Heidentor ruins in Australia, its missing forms are complemented by setting up transparent acrylic panels with an intact outline at fixed points (Ledermann and Schmalstieg, 2003). Through the applications of AR, IntraCom developed an electronic guide system for monuments that provided on-site restoration of ancient Greek monuments(Gleue and Dähne, 2001). There also has been a restoration of the mottled and mutilated frescoes on the vault of the Basilica in Brasilia(Portal´ es et al., 2009). These researches focus on recreating the physical forms or materials that heritage used to be. However, it is difficult to interpret the rich value of the heritage by simply recreating its physical components. Studies have also been conducted to superimpose virtual living scenes of the past on real space(Papagiannakis et al., 2005). This enabled audiences to gain a deeper understanding of the culture embedded in the architectural heritage.

These in-situ AR systems for heritage preservation are still in academic research and have not been widely used. However, most of the applications in practice take specific objects in reality like postcards as AR markers instead of heritage itself. Researchers have already developed interactive virtual heritage in AR applications through game engines such as Unity3D to represent internal structures of the architectural heritage(Nagakura and Sung, 2017) or the design and construction process(Niblock et al., 2022). Though these practices dismiss a possible connection between real and virtual components for heritages, their concentration on interaction with virtual objects can truly increase users' understanding of history(Kapell and Elliott, 2013). As values of heritage are multi-dimensional, it is difficult to represent the rich culture that heritage contains. As a result, a relatively integrated and comprehensive system for heritage presentation is urgently needed.

2.2. AR SYSTEM FOR URBAN ENVIRONMENT

Real environments superimposed by fantastic virtual have been imaged in many pieces of research. Keiichi Matsuda proposed a city in augmented space containing compound functions like entertainment, guidance, advertisement, communication, and so on(Matsuda, 2010). Nowadays, with the development of both software and hardware, it is possible for real-time data transmission and rendering of massive images, which are important in an AR system for the urban environment. Therefore, numerous applications have been released on the market and come into citizens' daily life.

The accessibility and interactivity of mobile AR can enable a closer relationship between the public and urban environment including heritages(Chandini Pendit et al., 2014). Digital platforms can open up various virtual content to people with different identities, and promote heritage conservation and urban development through their systemic co-construction in a further step. Hence, some governments have regarded the AR system for heritage preservation as a part of smart city projects (Batchelor and Schnabel, 2021).

3. Research Content and Methodology

There are complex factors about heritage preservation and urban design to consider, therefore, it is necessary to identify specific aspects of design contents. Meanwhile, as a digital project, this research focuses on not only the design framework but also the technical development process of the AR system.

3.1. DESIGN ASPECTS

According to the characteristics of AR, two levels of design were required primarily. One is the real scene chosen to be augmented, and the other is corresponding virtual content superimposed on reality. That is, the virtual content should be tightly relative to the theme of the real scene, instead of a fantastic but irrelative one. It is challenging that the selection of the most representative real space is decided by the value of heritage, as well as its augmented virtual content, which requests a comprehensive understanding of heritage and its culture contained.

Furthermore, this paper focuses more on the processing of diverse virtual content than real space. For heritages like the Wusha Shipyard, there are different forms of

resources to present, including introductive texts, documents or literature, drawings or photos, media like videos or audio, and so on. It is difficult to use suitable kinds of resources corresponding to the real scene. Accordingly, the integration of different kinds of resources is also important, as they can make a joint effort on enriching reality. Interactive operations of these virtual objects should also be taken into consideration to help users operate easily and understand the culture interestingly.

3.2. TECHNICAL DEVELOPMENT

The system was designed in traditional methods, and the resources were researched and processed in both real and virtual terms. At the same time, virtual construction is modelled for the architecture of the Wusha Shipyard and its surroundings in 3D software like Rhino.

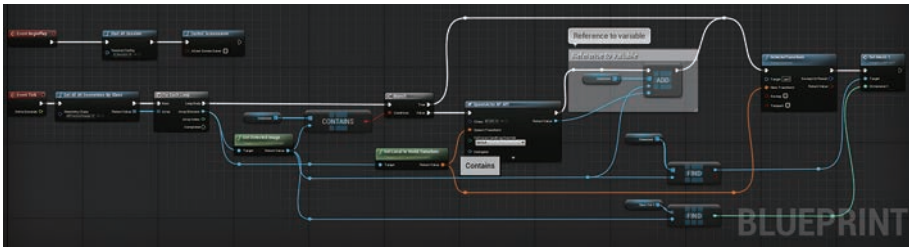

Figure 2 Blueprint for matching virtual object with the real scene

Although most AR systems are developed using Unity3D and ARKit, this paper tries Unreal Engine and ARCore for convenience and free accessibility. Unreal Engine is a game engine for developing systems with immersive and interactive manipulation. Its capability of 3D rendering can realistically reconstruct virtual objects. Most importantly, its visual programming named Blueprint greatly reduces the technical threshold and provides the possibility for an architect to engage in programming. Thus it is likely to meet the development needs of multi-disciplinary collaboration. In this research, the resources collected are imported into Unreal Engine 4.6.2 to render and make interactive manipulation programming through Blueprint shown in Figure 2. 3D models can be imported through a plugin called Datasmith. This version of Unreal Engine has inserted plugins for both ARkit and ARCore to develop and output.

4. Design Framework and Contents

Faced with the complex composition and surrounding environment of the Wusha Shipyard, the design of the system framework and specific concepts of scenes are based on its heritage values. Furthermore, this paper designs the presentation methods and interactive operations according to the characteristics of the contents.

4.1. THEME PLANNING

We first analyze the value of the Wusha shipyard as a heritage in three dimensions: historical, scientific, and artistic. Figure 3 shows the process of corresponding the intangible value of Wusha Shipyard to specific tangible objects in the real environment.

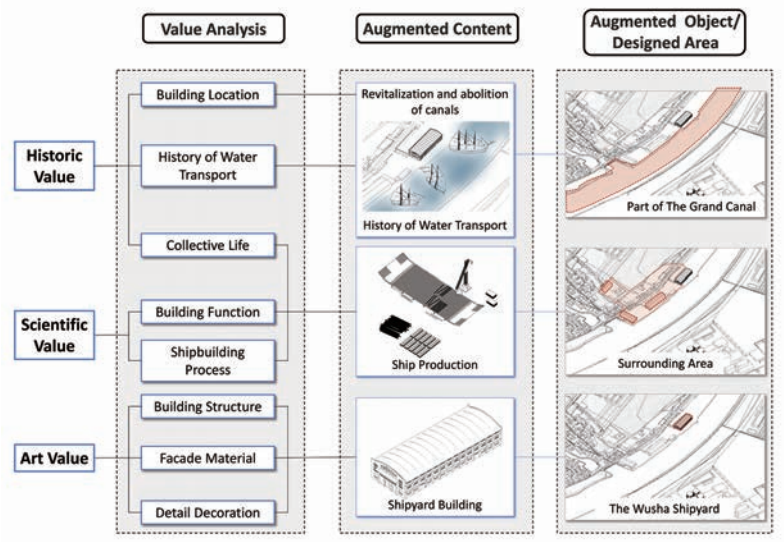

Figure 3 Exhibition Theme and Function Planning

Artistic value can be shown by the specific structural or detailed forms of the Wusha Shipyard architecture. Its main structure is an old-style row frame with a steel truss roof. In the north and south elevations is its red clay brick façade with a grey clay brick base. Rhythmic row-frame columns and window openings form the main image of this architectural heritage. Also, large windows and embellishments on the gable walls reflect the typical style of factory buildings in the local area at the time.

For its scientific value, the shipyard and its surroundings can reflect the technical processes of the shipbuilding industry. Its large span structure required for shipbuilding, the launching of the shipyard (now destroyed) in old historical photographs, and the scenes of the life of the shipyard workers, can all provide information for the study of modern ship production activities in the factory.

Compared with the artistic and scientific values carried by tangible material objects, historical values are more abstract. They are analyzed in terms of two aspects. One is Huai'an's existence as the hub of canal transport throughout the entire route of the Grand Canal. The other is the rise and fall of the Li Canal, a part of the Grand Canal, along with the construction of the shipyard. This part is overarching in the system, and the presentation of this civilization is intended to use the river as an augmented object.

4.2. AUGMENTED SCENE AND INTERACTION DESIGN

The image recognition used in AR systems is a marker-based technology, requiring only a limited amount of the user's field of view (FoV) to be rendered with computer-generated graphics(Kasapakis et al., 2016). Based on the above themes, Figure 4 shows suitable scenes and perspectives to be recognized in reality that can present the corresponding heritage values for the specific design. As for the values of Wusha Shipyard displayed mainly in the virtual system, real space can be planned for other functions under the upper planning.

Information that can be augmented is diverse. It used to be a simple overlay of text, 2D images, and videos, which are much easier to recognize. Interaction especially with 3D models takes more time and effort but can make visitors easy to understand. Figure 4 also shows the virtual recreated scenes and the interactive operations with each kind of resource.

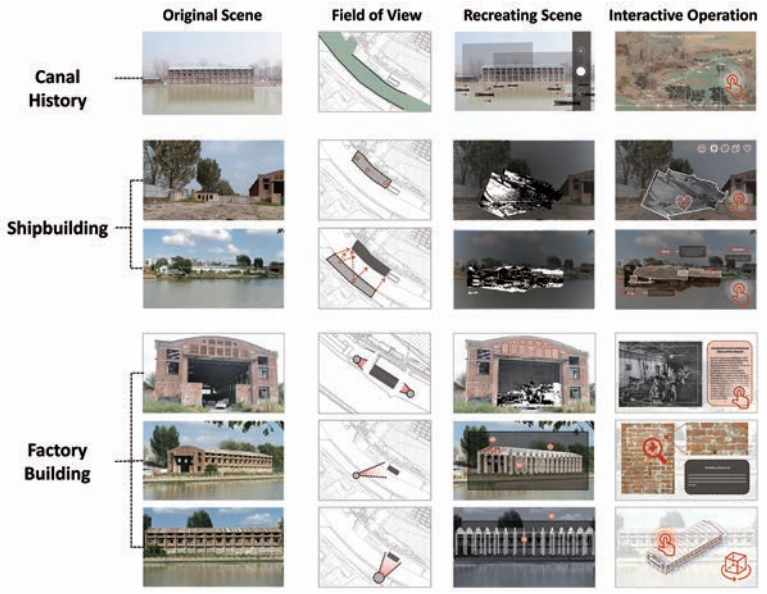

Figure 4 Specific Scenario and Interaction Design

4.2.1. Chronological overlay of canal history

The existing canal is no longer used for transport and production functions. In the augmented interface, the virtual Grand Canal shows a history dominated by canal transportation. This system is planned to restore the scenes of boats traveling on the Grand Canal as shown in Figure 5, supplemented by text and historical maps to introduce the history. In the upper planning, it is designed as an ecological landscape river. Therefore, it is mainly retained for water purification and treatment.

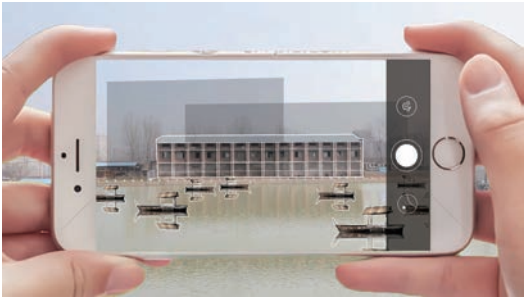

Figure 5 scenes of boats traveling on the Grand Canal

As the beginning parts of the application, these augmented scenes of different dynasties can be switched through timeline buttons to show the rich history. Interactive operations in this part are basic with relevant text and introductory notes.

4.2.2. Historical representation of industrial production

This session deals with the procedures of shipbuilding and the life of staff in the factory in the 1960s. A combination of texts, historical photographs, and videos is used to show residents' memories at that time. In the past, the shipbuilding process was mainly conducted outdoors, where the dockyard and the platform no longer exist today. The system recreates the equipment and structures required for the shipbuilding in virtual space based on the original layout in reality.

The interactive experience is only available inside the site and integrated with real urban space. In this area, parts of the ship to be constructed and assembled in digital forms are scattered at the starting point and can be put down in the right location virtually. This interesting interaction acts as a guidance system to instruct visitors to walk following the construction process. Through in-situ augmented experience on a real scale, visitors can acquire a relatively authentic understanding of the shipbuilding process and outdoor space around the shipyard.

Meanwhile, the real space can be used for other functions to serve citizens or visitors instead of the exhibition, as the information about Wusha Shipyard is presented virtually. This area in reality is designed as waterfront green space, setting hard court leisure spaces at locations of the best view to imply there exist interactions.

4.2.3. 3D enhancement of shipyard architecture

The display of the shipyard buildings focuses on architectural details. As the shipyard architecture is preserved well in reality, the virtual presentation of the shipyard is mainly aimed at the urban space distant from it. In this way, the attractiveness of the whole area surrounding Wusha Shipyard can be enhanced. Following interactive operations are proposed for visitors' better understanding of this 3D architecture.

(1) Extraction of structural elements: In real space or photography, the steel frame structure with large and dense trusses is often hidden beneath the skin of the building. In this system, the AR system can generate and render the virtual steel frame structure of the shipyard as a virtual model and make it visible above the skin of the building.

(2) Enlargement of the facade details: Compared to the huge volume of the shipyard building, small-scale facade decorations are invisible to the naked eye. Highlighting details of the window and decorations on the digital interface suggests they can be interacted with. Clicking on the highlighted section allows users to zoom in and see these details of the construction more clearly.

(3) Rotation of the building model: In reality, the grant size of the building also makes it difficult to see all angles of it from limited positions. However, a virtual building model can make different angles of the roof, foundations, opposite sides, etc. visible through operations such as rotation.

5. Discussions

As is shown in Figure 6, this research finally proposes a framework for the design and development of an AR interactive system that combines the historic values of architectural heritages and the development of urban spaces. Through this framework, heritage can be preserved without overexploitation. Meanwhile, it can be made full use of as social infrastructure in urban design, both in virtual and real spaces through AR and interactive operations. The effects of the system should be evaluated from two aspects including heritage preservation and urban development respectively. There also exist some limitations to break through in future research.

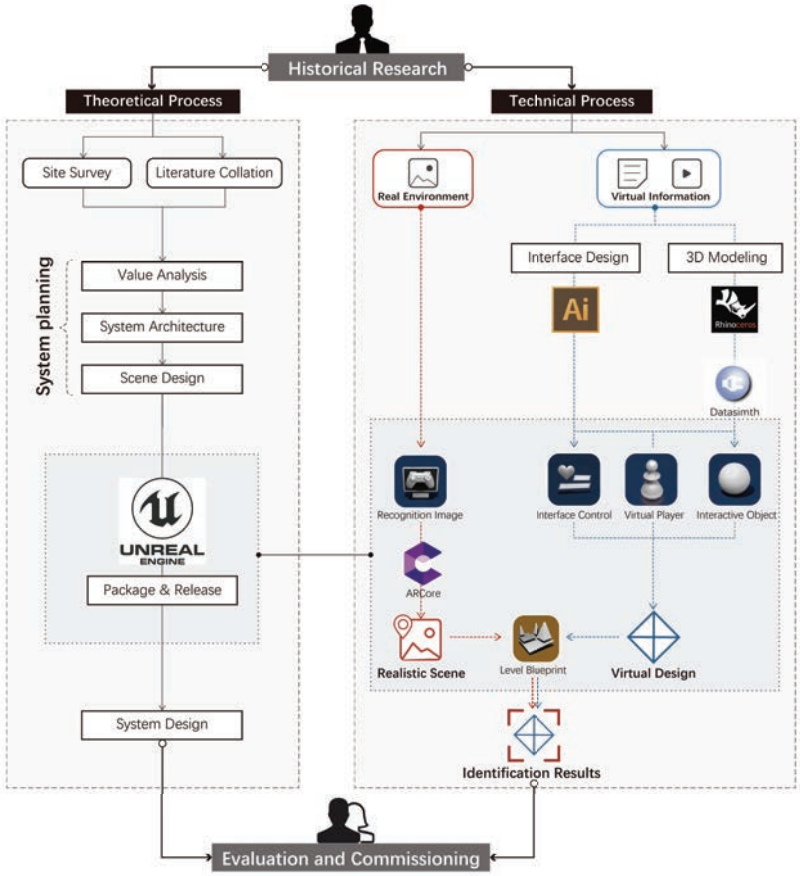

Figure 6. Diagram for design and development process

5.1. INNOVATION IN HERITAGE PRESERVATION

This in-situ AR system can complement and enrich heritage entities with intangible cultural contents that is difficult to present. This leads to minimal disturbance to the heritage entities, as the extent of reconstruction of existing heritages and their surroundings has always been controversial.

Based on heritages in reality, the system also works as a digital platform to assemble different types of information that can document and display the values of heritages. Visitors can get access to the information in an organized approach through interactive operations with virtual objects, strengthen their understanding of heritage, and enhance their awareness of heritage preservation.

5.2. INFLUENCE ON CITY DEVELOPMENT

The system ensures minimal disturbance to the local landscape by making full use of heritage as a kind of social infrastructure. As most cities along the canal are saturated with construction, there are few undeveloped lands. Restoring the historical buildings through AR can save the land and reduce the development cost and the disturbance to the current life of residents.

In addition, the combination of virtual scenes and real sites creates a novel kind of urban landscape. Citizens can experience both fantastic historic circumstances and realistic present sceneries, which enriches the spatial dimension of the city.

The role of the digital economy cannot be underestimated. The application of the system can inject fresh energy into the city's tourism as well, and enable visitors to gradually expand their knowledge of heritage as a whole. As The Grand Canal was a cross-regional link for economic and cultural exchange in ancient times, this system will reinvent this function. It can transcend the limits of time and space to enable the exchange and interaction of different people.

More than just an exhibition of historical information, the system has the potential to work as a part of a smart city system, as the content of the virtual system can be expanded without restriction. The easy access and operation also facilitate the participation of all levels of people and the variety of activities.

5.3. LIMITATIONS AND FURTHER WORK

There still exist several limitations in both research and the system. The research focuses mainly on the design of virtual aspects, while the real space can also be used to suggest the interaction of virtual objects through forms of landscape or architectural design such as paving. Thus, the design of the real urban environment is equally prominent, and the approaches to it will be further researched.

The current AR system is under experiment, so there still exist some technical problems to solve. For example, the obstacles in the field of view can negatively affect the recognition of a specific scene, along with users' virtual experience. Also, the effects of this augmented system request to be examined more scientifically through in-situ experiments and user interviews.

6. Conclusion

Faced with the contradiction between heritage preservation and city development, the design framework of an augmented system is based on diverse values of heritage. All these values, including historic, scientific, and artistic ones, along with contemporary values proposed recently, correspond to social awareness of history and willingness for urban life. Augmented reality provides an opportunity to convey and present these

values to the public. Through the superimposing of virtual objects on real scenes and interactive operations, this AR interactive system is prospected to work on integrating the two factors and improving both of them.

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