A New Approach to Digitizing Cultural Heritage: Constructing Immersive VR Experiences of Traditional Huizhou Architecture

by

Ziqiao Wei

Department of Art, Art History and Visual Studies
Duke University

Date:_____

Approved:

_____
Paul B Jaskot, Supervisor

_____
Maurizio Forte

_____
Victoria E Szabo

_____
Augustus Wendell

Thesis submitted in partial fulfillment of
the requirements for the degree of
Master of Arts in the Department of
Art, Art History and Visual Studies in the Graduate School
of Duke University

2023

ABSTRACT

A New Approach to Digitizing Cultural Heritage: Constructing Immersive VR Experiences of Traditional Huizhou Architecture
by

Ziqiao Wei

Department of Art, Art History and Visual Studies
Duke University

Date:_____
Approved:

_____
Paul B Jaskot, Supervisor

_____
Maurizio Forte

_____
Victoria E Szabo

_____
Augustus Wendell

An abstract of a thesis submitted in partial
fulfillment of the requirements for the degree
of Master of Arts in the Department of
Art, Art History and Visual Studies in the Graduate School of
Duke University

2023

Abstract

Vernacular architectural studies are an integral part of the world's cultural heritage research. Compared with other tangible or intangible cultural heritage, the physical properties of vernacular architecture and its site-specific nature make it difficult to be physically exhibited in museums, thus limiting the dissemination of vernacular culture and impeding the potential conservation awareness of its audiences. The development of new media technology in the 21st century, represented by virtual reality in particular, has helped to alleviate this cultural communication deadlock. This thesis focuses on the traditional architecture of Huizhou, and consists of a written paper and a digital project. The written paper explores the origins of Huizhou culture and discusses how long-term developments in ethnography, social history, and the natural environment have influenced the unique appearance and design concepts of Huizhou architecture. Moreover, based on the spatial affordances of digital media, the paper discusses how virtual reality (VR) technology can enhance the experience of, accessibility to, and interactivity with Huizhou architecture as represented through 3D reconstruction. The digital part of the thesis is a VR application called "Virtual Huizhou," and was developed in Unreal Engine 5. This application is a 3D reconstruction of *Yin Yu Tang*. It will also demonstrate the role of VR in enhancing

visitors' interests and evoking cultural and emotional experiences through the following aspects: 3D models, interface design, and user experience functionalities.

Dedication

To my hometown, my family, and all the mentors and colleagues who have supported me on my journey.

Contents

List of Tables

List of Figures

Acknowledgements

I am writing to express my deepest gratitude to my committee members for their guidance throughout my research. Thanks to our Department of Art, Art History & Visual Studies for providing me with the equipment to complete my VR application.

I am also grateful to Boston Peabody Essex Museum for providing me with the inspiration for my digital project and the related supporting data.

1. Introduction

In the summer of 2022, I visited the Peabody Essex Museum in Boston to see the renowned *Yin Yu Tang*, an ancient Chinese residence located in the center of the museum, standing out from the other modern and minimalist building structures. This old house was the first Qing dynasty Huizhou architecture to be relocated from China overseas. *Yin Yu Tang* was originally a typical residence modeled on ancient traditions located in Huangcun, Xiuning County, Anhui Province. It was dismantled, transported to the United States, and reconstructed at the Peabody Essex Museum.[1] This daring attempt, which took seven years, allowed the old house, which might have been demolished due to excessive aging in its hometown, to be reborn in a foreign land.

In 1985, Nancy Berliner,[2] the director of the Chinese Art and Culture Department at the Peabody Essex Museum, traveled to Huangshan City. After visiting a unique Huizhou ancient village, she wanted to introduce Huizhou culture and art to the United States. She came up with the idea of moving one of the ancient houses to the States for restoration, reconstruction, and exhibition. At the end of the last century, as a symbol of China's regional civilization, Huizhou's ancient architecture did not attract as much

---

[1] "Visit the Yin Yu Tang House: Peabody Essex Museum." pem.org. Accessed March 13, 2023. https://www.pem.org/visit/yin-yu-tang.

[2] According to Dr. Berliner's biography, she is a scholar of Chinese studies from Harvard University. She came to Beijing to study Chinese art history at the Central Academy of Fine Arts back in the 1970s. Nancy Zeng Berliner, *Yin Yu Tang: The Architecture and Daily Life of a Chinese House* (Clarendon: Tuttle, 2014), 14-15.

attention from the Western world as it does today[3]. Although the cost of *Yin Yu Tang*'s physical reconstruction was enormous, it was the first time that Western audiences had the opportunity to come into close contact with the Huizhou architectural that has been passed down for thousands of years in inland China on the North American continent.

Yin Yu Tang's story gives me a glimpse into some of the difficulties of vernacular architecture[4] and cultural heritage sites in China. Their remote location, the huge size of buildings, and the fragility of their structures have prevented them from being included in any cultural and artistic exhibitions, and from becoming more widely known to the

---

[3] I came to this conclusion because during my research on Huizhou architecture and literature review, I found that 2000s was an important turning point for scholars' research on Huizhou culture. Part of the reason was the inclusion of the ancient villages of Xidi and Hongcun in Southern Anhui in the World Cultural Heritage List in 2000 and the Chinese's government's systematic efforts to protect Huizhou architecture and promote the related tourism industry, which increased its popularity to some extent. Prior to this, information on Huizhou architecture was scarce and mostly written by Chinese scholars. One of the few authoritative scholarly examples that I found which introduced this vernacular architecture was Ronald G. Knapp, *China's Vernacular Architecture: House Form and Culture* (Honolulu: Univ. of Hawaii Press, 2000), 221-298. In the Chapter "Dwellings in Southern China", the author provides a detailed account of the origin, design, and development of Huizhou architecture.

[4] "Vernacular" is often used to describe a local architectural style or language that has been developed in the context of the local environment and culture, reflecting the history and social characteristics of the area. "Vernacular architecture" refers to a style of architecture that has been developed in response to local conditions such as climate, topography, and natural resources. It is similar to "indigenous architecture", but "indigenous" is often used to describe the characteristic of its indigenous people. Many scholars have explored the difference between the two terms. In the book of C. Mileto, *Vernacular Architecture towards a Sustainable Future* (CRC Press Inc, 2014), 15., "vernacular architecture" is described as the term that "reflects the link between design, construction and the culture of the communities as an urban collective activity which practiced and learned to the new generations with some help from craftsmen." In Ronald G. Knapp, *China's Vernacular Architecture: House Form and Culture* (Honolulu: Univ. of Hawaii Press, 1989)., vernacular architecture has been seen as an "unselfconscious" expression of people's ideas. It's commonly still defined in terms of references to history, or tradition, or pre-modernity, in other words, in reference to past. In this sense, I use the term "vernacular architecture" to define Huizhou architecture because the historical resource shows that the community who designed and built Huizhou architecture was not the indigenous people of the region (i.e., Shanyue people mentioned in the historical context part), but the families who migrated from the central plains to this area, so the term "vernacular" is more appropriate to describe it.

public. In a time of information limitations, the dissemination of architectural cultures to the public relied mainly on architecture enthusiasts choosing to spread them through 2D images or videos, which was passive and not considered the best way to promote cultural understanding.

Luckily, the emergence of new communication tools has brought attention to these cultural predicaments. In the era of Web 1.0, the earliest version of the internet, some institutional museums began to transform their collection through access to no-threshold digital archives. In the era of Web 2.0, the explosion of information technology has transformed ordinary people from passive information receivers into producers of knowledge, especially through dynamic linked platforms. With the arrival of the Web 3.0 era, new technologies such as metaverse and VR make it easy for audiences to break through the limitations of space and time to explore knowledge more freely especially in immersive environments.[5]

Although rapidly advancing technology makes it easy to restore even the most remote or niche architecture, one of the notions that scholars need to be aware of is that architecture should be regarded as a complex of spatiality rather than a simple 3D mesh

[5] Giovanna F. Miranda, Francesca Gualtieri, and Paolo Coccia, "How the New Web Generations Are Changing Library and Information Services," *Medical Reference Services Quarterly* 29, no. 2 (2010): pp. 132-145, https://doi.org/10.1080/02763861003723200.

or a standalone object.[6] The spatiality of vernacular architecture is reflected in part by the important information it reveals about local climate, topography, and available resources. For example, the orientation of buildings, the use of materials, and the placement of doors and windows are all designed to respond to specific environmental conditions, such as sunlight exposure, wind direction, and rainfall. In addition, the analysis of spatiality can help viewers understand the relationship between architecture and the surrounding landscape, including the use of natural elements such as water, vegetation, and rocks in the design of buildings and residential areas. This can help to deepen our understanding of the ecological sustainability or cultural symbolic significance behind them. From the perspective of social history, analyzing the spatiality of vernacular architecture is crucial to a comprehensive understanding of its developmental history, because the spatial organization of a building or a residential area is closely related to its social, cultural, and economic background. The spatial layout of vernacular architecture reflects the way people live, work, and interact with each other in a specific environment. By studying the spatial organization of vernacular architecture, we can gain a deeper understanding of its underlying developmental history, social hierarchy, family structure, and community dynamics.

---

[6] I take this insight from Jin Duan and Minghao Jie 段进 & 揭明浩, 空间研究 4: 世界文化遗产宏村古村落空间解析 [*Urban Space: Spatial Analysis of the Ancient Village of Hongcun World Cultural Heritage*] (Nanjing: Southeast University Press 东南大学出版社, 2009).

The popularization of a specific architectural culture requires exploration of the specific material spatial conditions and aspects of sites that cannot be revealed through a mere link or typical website. In this sense, when designing and developing any metaverse or virtual application, a fundamental question is how to highlight its spatial affordances. With this question as a starting point, I will use *Yin Yu Tang*, which embodies the characteristics of Huizhou architecture, as my research target and digital project. My goal is to use VR techniques: to make a 3D reconstruction that allows for the experience of simulations of *Yin Yu Tang*; to explore the complex stories behind its involvement with nature, social history, and political ideology; to demonstrate a relatively easy-to-understand storytelling mode to convey and popularize Huizhou culture to Western audiences who are not familiar with Chinese vernacular culture; and to provide a model for the similar cultural heritage digitization or vernacular architecture reconstruction projects.

2. Historical Background and Related Concepts

2.1 Historical Context

The study of traditional Chinese residential settlements is a multifaceted and complex proposition, which includes people's knowledge of and practices for their surrounding environment, the influence of social history and culture, the needs of people's survival, production, and social interaction, as well as spiritual and aesthetic aspects of architectural design. In general, traditional architectural culture is not only made up of rigid historical conventions, but also is influenced by various factors such as ethnography, locality, ideology, and social psychology, and the analysis of architectural culture cannot be separated from the tracing of local natural, geographical, and social conditions. From this perspective, this section will present the regional origin, integration, and development of Huizhou culture, to help the audience comprehend the humanistic historical background behind the birth of Huizhou architecture.

2.1.1 The Origin of Huizhou and Huizhou Culture

Nowadays, "Huizhou" refers not to a specific administrative or geographic area, but rather to a cultural sphere within the context of Chinese traditional cultural history. From the establishment of Yi County (黟县) and She County (歙县) in the Qin Dynasty (秦朝) two thousand years ago to the announcement of the establishment of Huangshan

City (黄山市)[1] in 1988, the administrative jurisdiction of this region has changed several times. Historical records show that Huizhou was established in the Tang Dynasty (唐朝), with jurisdiction over She County, Xiuning County, Qimen County, Yixian County, Jixi County, and Wuyuan County (see fig.1).[2] Although this administrative division no longer exists today, experts and scholars still take Huizhou as an overall regional and cultural designation for academic research and are accustomed to referring to the above six counties collectively as Huizhou.

The emergence and development of Huizhou architectural culture is inseparable from the discussion of the political, economic, and social history of the region. Historical records show that the ancestors of ancient Huizhou were a mix of local aborigines and immigrants from the Central Plains of the Yellow River Basin with a long history. Huizhou was originally home to the Ancient Yue (Shanyue) people.[3] That culture was

---

[1] In Chinese, Huangshan translates to "Yellow Mountain." Huangshan located in southern Anhui Province, China, is a prefecture-level city named after the famous Yellow Mountains, which occupy a significant portion of the city's expansive geography. Huangshan, or Yellow Mountain was named after the mythical /historical Huang-di, Yellow Emperor, who ruled a small kingdom about 5000 years ago. He is credited with being extremely wise and giving the Chinese their distinctive title, the Yellow Race. Most of the current jurisdictional area of Huangshan City belongs to the Huizhou area of dynastic China. After the founding of People's Republic of China, the Huizhou was established, and in 1987, when it was upgraded from a prefecture to a city, it was renamed Huangshan City. Anna Leask and Alan Fyall, "World Heritage Listing: the Case of Huangshan (Yellow Mountain), China.," in *Managing World Heritage Sites* (Routledge, 2015), pp. 250-262.

[2] In Chinese, these six counties are called "歙县", "休宁县", "祁门县", "黟县", "婺源县", "绩溪县". From this time, the six counties' pattern continued until 1934, when Wuyuan County was placed under the jurisdiction of Jiangxi Province by the government of the Republic of China. Jin Duan and Minghao Jie 段进 & 揭明浩, 空间研究 4: 世界文化遗产宏村古村落空间解析 [*Urban Space: Spatial Analysis of the Ancient Village of Hongcun World Cultural Heritage*] (Nanjing: Southeast University Press 东南大学出版社, 2009), 1-2.

[3] It is also known as the Shanyue (山越) People, an ethnic subgroup of ancient China.

characterized by using symbols such as birds as totems, so-called nest residences,[4] tattoos, short hair, and living near water. In 1959, the Western Zhou (西周) Dynasty and Han Dynasty (汉朝) tombs were excavated in Tunxi County (屯溪县), Huangshan City, and this unearthed a wide range of pottery glazes and bronzes engraved with birds and beasts, proving that there was a relatively developed culture in this area for more than 2,000 years. In the past, the main cause of large-scale migration from the Central Plains to Huizhou was war. Historical records show that the earliest entry of residents from the Central Plains into Huizhou began in the Han Dynasty (汉朝), and the immigrants were mainly coming from the Wu, Fang, and Wang families. The peak of migration was in the Southern and Northern Dynasties (南北朝), the late Tang Dynasty (唐朝), and the Song Dynasty (宋朝).[5] The nobility and ordinary people from the Central Plains who suffered from the war might very well have longed for a peaceful land. Large-scale immigration not only changed the population structure of Huizhou but also brought great wealth, vast culture, and exquisite living skills from the Central Plains. It greatly promoted the development of productivity in the Huizhou area. As for the reason why they chose ancient Huizhou as their new residence, it was partially because Huizhou was

[4] Nest residence refers to the form of living in which the bottom floor of a house is elevated, and the upper floor is occupied by people. This is a primitive way of living for the aborigines in ancient China who were in the lower terrain and humid climate.
[5] Duan & Jie, *Urban Space*, 2.

surrounded by mountains, which means the terrain made it difficult for the enemy to attack this area.

Compared with the native Shanyue people in Huizhou, the immigrants from the Central Plains are obviously a strong ethnic group in terms of culture and productivity. In addition to the advanced manufacturing technology, it was particularly obvious that the influence of the Central Plains culture had an impact on local developments.[6] The big families who moved in with many clansmen adhered to: the patriarchal system of strengthening ethnic consciousness; the mature feudal ideology, such as living together, respecting ancestors, advocating filial piety, and discipline; and farming. In fact, all of the ethnic groups that have entered the area have had a prominent effect on the social system, housing culture, mode of production, and management strategy for the region. In general, immigrants and aborigines jointly promoted and developed Huizhou's economic, social and cultural development, which was linked by blood relations and assisted by geopolitics.

---

[6] As known as "Han Culture", It was the dominant culture in ancient China. It refers to the culture created by "Han Chinese". "Han Chinese" is the largest Chinese ethnic group in feudal dynastic China and contemporary China, claiming kinship to a common ancestor, the Yellow Emperor, Huangdi. Huangdi is hailed as the first ancestor of the Han Chinese that grew up around the Yellow River. The Han comprise about 91.9% of China's population. James Stuart Olson, *An Ethnohistorical Dictionary of China* (Westport: Conn, 1998), 54.

2.1.2 Architectural Philosophy and Chinese Feng Shui

When these Han families that moved into Yi County first set foot on the land, they needed a self-protection mechanism to resist the intrusion of indigenous people and families that moved in earlier. In addition to relying on the feudal regime, it was also necessary to rely on the power of the clan, that is, the formation of unity within the close-knit and interrelated families. This was complemented by the concept of patriarchal law that added to clan cohesion and guaranteed greater cohesion. The power of a family was limited, but the power of a clan acting cohesive together was enough to protect each member of the clan from the encroachment of foreign families. This also makes some clan members, even if they are limited by restricted natural resources, unwilling to move to other places since they want to survive under the shelter of the clan. Thus, the original small-scale village was gradually expanded and eventually formed into a large clan gathering place.[7]

In addition to being influenced by the clan concept, the site of the settlement was chosen with maximum reference to the traditional Chinese "Feng Shui" doctrine. Feng Shui (风水), or Chinese geomancy, is a traditional practice that claims to use "energy" to harmonize individuals with their surroundings. Feng Shui is one of the five ancient Chinese metaphysics techniques, like Western Astrology, which uses formulas and

---

[7] Wu Xufeng and Yu Zhihuai, in *United Nations Educational Scientific and Cultural Organization: Xidi Hongcun* (岭南美术出版社, 2011), 7-8.

calculations to observe and evaluate the appearance of buildings or landscapes, e.g. The practice of Feng Shui discusses the object being evaluated in terms of the "invisible forces" (called "Chi") that link the universe, the earth, and humans together.[8] Feng Shui has been widely used throughout Chinese history to determine the orientation of buildings in an auspicious way-usually for structures with spiritual significance, such as tombs, but also for residences and other structures. From the site and layout of the existing villages, people who moved from the Central Plains chose sites that backed up to the mountains and faced the water to build their architectural complex. This choice can be interpreted from a geomancy aspect, as it seems to regulate wind direction, temperature, humidity, and the formation of a mild microclimate. It also reflects the self-defense psychology of the residents using similar building practices to solidify their clan associations.

From a common-sense point of view, there may be no difficulty in selecting a site to build a house, but from the perspective of geomancy, the environment and its entire material conditions and possible functional uses must be evaluated for sufficient air, sunlight, water, and greenery. The natural environment is ever-changing, and Feng Shui calls for site selection that must be based on the Feng Shui concept of "Chi" as an important basis. From this perspective, Chi's gathering and dispersal properties can

[8] Wu & Yu, *Xidi Hongcun*, 9.

determine the prosperity and decline of villages and families. When people are mostly building houses near the mountains, Feng Shui produces many doctrines about the shape of the mountains. Choosing a place to live based on Feng Shui theory is one aspect of locating a house, but another aspect is the historical people's perception of the environment suitable for their own residence. Most people found a place to live based on their own preferences, and then used the Feng Shui theory to settle and find a reasonable explanation for their choices.[9]

When building a house, the historical Chinese must first determine the advantages and disadvantages of the house directions and then choose an auspicious day as the time to start work. Even under unfavorable land conditions, the main body of the house must be oriented in an auspicious direction. The orientation of the main body of the house is reflected in the orientation of the front door. Since the door is the entrance and exit, from a geomancy perspective, the door is also the entrance and exit of "Chi" and therefore has a special symbolic meaning. Ancient houses in Yi County rarely have doors open to the south, which can be explained by the traditional Chinese feudal system. In feudal society, many architectural features are distinguished as inferior or superior, even the direction of the southeast and northwest. Historical Chinese regarded the South as the supreme direction. This view can be seen from the fact that many

[9] *Ibid.*

palaces, temples, and imperial seats always face south. Therefore, ordinary people did not dare to orient their houses towards the south in dynastic times.[10]

The iconic embodiment of Feng Shui in traditional Chinese architecture, represented by Huizhou architecture, is the adoption of the "lightwell (天井)". In architecture, a lightwell, sky-well, or impluvium[11] is an unroofed external space provided within the volume of a large building to allow light and air to reach what would otherwise be a dark or unventilated area (see fig.2). The lightwell is one of the most characteristic elements of Huizhou-style architecture, and it is often small in size, usually located in front of the main hall, rectangular in shape, and narrow in width depending on the size of the overall living room; the length usually extends to the bedroom windows on both sides of the hall to allow sunlight to diffuse into the room. As a semi-open space, the lightwell allows all rainwater to flow into it, and clean rainwater can be collected in a water tank or stored in the underground pool and purified for drinking water. Analyzed from the perspective of use function and construction technology, the role of the lightwell is mainly reflected in the five functions

---

[10] *Ibid*, 10-11.

[11] In Western architecture, it is more likely to be called "impluvium", which is often mentioned in Greco-Roman architectural studies. According to Michael Gagarin, *The Oxford Encyclopedia of Ancient Greece and Rome* (Oxford: Oxford University Press, 2009), 175., In the study of Greek and Roman architecture, the term "impluvium" refers to the sunken part of the courtyard in a Greek or Roman house (domus), designed to collect rainwater that falls from the roof's inclined surface. Typically made of marble, it is located about 30 centimeters beneath the courtyard's floor and channels the water into an underground cistern. Unlike Chinese architecture, the use of this architectural structure in the West was often motivated by environmental and climatic considerations and the scientific nature of the house and did not involve the exploration of geomancy.

of space organization, natural lighting, ventilation, water supply and drainage, fire and theft prevention.[12] This design also has a symbolic meaning of "accumulating wealth" in Chinese Feng Shui. Since wealthy merchants were the primary builders of the exquisite Huizhou residences, collecting rainwater that fell from the sky into their own courtyards instead of letting it flow onto someone else's land represented a manifestation of "gathering wealth and preventing it from flowing outwards" for them.[13]

2.1.3 Huizhou Architecture and *Yin Yu Tang*

During the Ming and Qing dynasties, Huizhou art and culture reached its peak, and the flourishing Huizhou architectural culture during this period to some extent reflected and expressed the temperament and structure of the Ming and Qing societies, as well as the clan concepts of major families guided by Confucian culture. Although different Huizhou buildings had been adjusted in their internal structure and decoration based on new functional needs, the preferences of the house owners, customs, and other factors, the residents of the Huizhou region have maintained certain specific consistent features, creating a basic and widely accepted design concept and foundation for Huizhou architecture. These features include all rooms facing the central courtyard, important spaces facing south, horizontally symmetrical buildings with an odd number

[12] Ronald G. Knapp, *Chinese Houses: The Architectural Heritage of a Nation* (Singapore: Tuttle, 2018), 519-554.
[13] *Ibid*, 528.

of windowsills, wooden column-beam structures supporting the roof, and determining the direction and structure of the building based on the principles of Feng Shui.[14]

The cluster of architecture that embodies the aesthetic of Huizhou culture to its fullest is located in Hongcun (宏村) and Xidi (西递),[15] in the southern Anhui province of China. They are collectively known as the "Ancient Villages in Southern Anhui Province" and were inscribed on the UNESCO World Heritage List in 2000. With a history dating back to the 12th century and comprising 365 historical buildings from the Ming and Qing dynasties, the villages have become the main carrier of Huizhou culture in China.[16] Today, Hongcun and Xidi have become semi-residential, semi-commercial historical village clusters, with some elderly people still living in traditional Huizhou-style residences that have been passed down through generations. Others have transformed their properties into tourist attractions or homestay accommodations. Although their inclusion in the World Heritage List has increased their visibility and accelerated the economic development of the surrounding areas, the downside of over-commercialization cannot be ignored. While the lucrative profits from tourism can be used for the promotion of Huizhou culture and the restoration of the architecture, it is unfortunate that detailed data on the architecture of Hongcun and Xidi are not readily

---

[14] Ronald G. Knapp, *China's Vernacular Architecture: House Form and Culture* (Honolulu: Univ. of Hawaii Press, 2000), 246-253.
[15] They are located in Yi County and they are next door to each other. In Chinese, "cun" means "village".
[16] Wu & Yu, *Xidi Hongcun*, 2-5.

available online, beyond some promotional photographs and brochures. This also means that data collection and field investigations can be extremely challenging for foreign scholars or architects who wish to study Huizhou architecture.

The very limited information on the internet about the buildings of Hongcun and Xidi posed a great challenge to me during the preparation of my thesis project.[17] So I turned my attention to another architectural example called "Yin Yu Tang (荫余堂)"[18], located in a village called Huangcun[19] in Xiuning County. Excitingly, this building was moved to the United States in the 1990s with the assistance of Harvard scholars, local authorities, and descendants of the Huang family, and eventually rebuilt at the Peabody Essex Museum in Boston. It is also the only surviving Huizhou-style architecture in the Americas.[20] Yin Yu Tang dates back as far as the end of the 18th century when a

---

[17] In addition to the photos recorded during the visit to Yin Yu Tang, the print sources and online sources of Duke Library provide me with historical information, photo and video records, illustrations, archaeological logs, etc. of Huizhou architecture. For example, in Deqi Shan et al., 地方传统建筑：徽州地区 *[Traditional Architecture: Huizhou Region]* (Beijing: Ministry of Housing and Urban-Rural Development 中华人民共和国建设部, 2003), it records the roof structures, horse head wall types, door and window styles, screen walls, staircase and other common building structures of traditional Huizhou buildings with illustrations and rough measurement data, which provides a reference for my modeling of building details. However, all illustrations are black and white and cannot provide a reference for choices of textures. The reconstruction part of my digital project needs a lot of high-resolution images and more accurate measurements as the basis of 3D modeling.

[18] "Tang" means "House" in Chinese. The name "Yin Yu" for the house means that the owner wanted the house to shelter his descendants in the distant future. According to "Yin Yu Tang House Virtual Tour: Peabody Essex Museum," Virtual Tour: Yin Yu Tang (Peabody Essex Museum), accessed March 12, 2023, https://www.pem.org/visit/yin-yu-tang/yin-yu-tang-tour.

[19] This village is the gathering place of the Huang family.

[20] "Yin Yu Tang House Virtual Tour: Peabody Essex Museum." Peabody Essex Museum. Accessed March 12, 2023. https://www.pem.org/visit/yin-yu-tang/yin-yu-tang-tour.

merchant surnamed Huang[21] decided to build a residence in his hometown of Huangcun that could accommodate all his immediate family and, in the future, many of his descendants.

There are several basic residence layouts in Huizhou-style architecture. The first one is called the "ao (凹)-character"[22] type, and the remaining ones are the "kou (口)-character" type, the "H-character" type, and the "sun (阳)-character" type (see fig.3).[23] The "sun-character" residential architecture consists of a central building with a reception hall in the middle and bedrooms on either side. At the ends, the houses and roofs extend forward perpendicularly. The remaining space between the two extended parts becomes a courtyard or a yard. A wall passes through the courtyard, parallel to the main building, connecting the two expanded sections to provide privacy. The "kou-character" architecture is essentially two physical structures with a courtyard in between and covered stairs at both ends. The H-shaped house is basically two back-to-back "ao-character" houses. Apart from the layout differences of houses, the shape of the house and the number of windowsills will depend on the owner's personal preferences, economic capabilities, and the size and shape of the purchased property.[24] Yin Yu Tang

---

[21] He was the seventh son of a man whose name is no longer known.
[22] Also as known as the "U-character" style since "U" looks very alike "凹" in Chinese.
[23] You will find that these different layouts are characterized by similar-looking Chinese characters or letters to summarize the shape of the house. This is what today's Chinese architectural archaeologists have concluded after observing a large sample of houses.
[24] Berliner, *Yin Yu Tang*, 642 – 644.

eventually adopted the two-story house in the "kou-character" design because it provides more space than the common "ao-character" and "H-character" designs, which can accommodate at least five bay windows and eight bedrooms.[25]

The Yin Yu Tang physical reconstruction project was a preservation effort of a scale and magnitude not yet attempted between the United States and China, which meant that the over two-hundred-year-old Chinese vernacular home would be disassembled, shipped to the United States, documented in detail, preserved, and re-erected. In the process, the house would be transformed from an everyday multi-family dwelling into a museum that would be visited by thousands of people each year. However, throughout the project, researchers and archaeologists needed to do their best to preserve the house's characteristics and reflect its two-hundred-year history of use (see fig.4). The purpose of the relocation project was to spread Chinese culture in the Western world, with the goal of accurately interpreting all aspects of the Huang family house and its use. In preparation for the project, researchers from Historic Chinese Art Department of Peabody Essex Museum also drafted a mission statement identifying three goals for the project: to reconstruct and preserve the house, its contents, documentation, and history in the United States; to present the house as a representation of vernacular Chinese architecture and associated decorative arts and craftsmanship

[25] *Ibid*, 645.

through reconstruction and preservation efforts; and to provide a platform of Chinese culture for a diverse audience.[26]

After signing a cultural exchange agreement with the Huangshan City Municipality, Chinese artisans dismantled the entire house and shipped it to the United States in 19 40-foot shipping containers. The wood and other momentum components used to build the house arrived in Boston in late 1997. And in 1998, the museum commissioned John G. Waite Architects Associates to begin a three-year process of identifying, inventorying, and documenting the components, drawing detailed drawings of the house and components while gradually installing the architecture's sub-components together.[27] For the comfort and safety of visitors, the museum also added modern architectural systems to the original building, such as electrical wiring, lighting, and elevators on the second floor.

Yin Yu Tang's re-installation and preservation is considered an important and successful initiative for the preservation and popularization of cultural heritage. The project not only led to the cross-cultural relocation of the houses but also the process of disassembly, evaluation, and reassembly greatly increased the Western audience's understanding of Chinese indigenous architecture. Traditional architectural knowledge that had been hidden was revealed through the mechanism of reconstruction. Physically

---

[26] *Ibid*, 882-883.
[27] *Ibid*, 885.

visiting Yin Yu Tang provided me with the first-hand experience. I saw and felt the physical space and appreciated the intricate details of the structure. I had the opportunity to have social interaction and discussion with other visitors, as well as museum staff and experts. However, some measures based on the protection of ancient architecture also limit visitors' experiences. For example, each visitor can only have a maximum of 30 minutes on the visiting; there are not many spaces and rooms available for visitors to move freely; visitors cannot touch or interact with any structures and historical items at will. These restrictions have to some extent weakened the storytelling ability of Yin Yu Tang. When an ancient building born in China crosses the ocean to participate in an exhibition in the West, one issue that must be considered is how to recontextualize its historical and cultural context in a different cultural background. And I believe that VR technology can enhance this point from the derivation of multisensory and the design of different interaction modes.

Physical reconstruction of architecture involves the actual construction of structures using tools, machinery, and labor. It can be a time-consuming and costly process that requires a high level of expertise in architecture and engineering. One of the main differences between physical and VR reconstructions is the level of realism. Physical reconstruction allows individuals to experience the structure in real life, including all tactile and sensory details, while VR reconstruction provides a digitally based simulated experience. Compared to the latter, firsthand experience of physical

reconstruction is more friendly for audiences who are keen on exploring architectural culture but struggling with motion sickness caused by head-mounted displays (HMD).[28] However, the advantage of VR reconstruction is that it is easier to obtain and more cost-effective than physical reconstruction because it does not require any physical materials or labor. Another key point is the level of flexibility and control provided by VR reconstruction. With VR, curators can easily make changes to the design, test different ideas, and construct different interaction patterns without needing to physically modify the structure. This can save time and resources while allowing for more experimentation and creativity. My VR project, as a different model, primarily focuses on this second key point to explore and extend the physical reconstruction of Yin Yu Tang. Although the realism provided by VR reconstruction for the audience is currently not at the level of naked-eye pixel quality, VR technology can offer more accessible and flexible options for the audience, including but not limited to more free exploration, closer interaction with historic objects, and more encyclopedia-style presentation designs.

2.2 Literature Review

This section discusses the development of researchers' perceptions of the concept of "virtual museums (VM)", the different views on how to define "virtuality" and "new museology", and the rise of digital tourism for culture heritage within the paradigm of

---

[28] Vilar Elisaȇngela et al., *Virtual and Augmented Reality for Architecture and Design* (Boca Raton: CRC Press, Taylor & Francis Group, 2022), 143.

new museology. Based on the above concepts, this section will also discuss how the virtual museum has shifted from its traditional role as a technological and discipline-oriented elite institution to a social and cultural communication-oriented mass media? And what role new technologies, represented by virtual reality, augmented reality, and user interfaces have played in this transformation. Besides, this section will briefly demonstrate the use of novel learning methods such as gamification and serious games (SGs) in cultural heritage digitization.

2.2.1 Virtual Museums, Digital Culture Heritage, and Gamification in Digital Tourism

Previous research regarding the development of digital museum studies have set the framework for the establishment of a standard definition of "Virtual Museum (VM)" by examining the philosophical roots of the virtual museum, reviewing previous taxonomies and definitions, and proposing a classification system from both educational and constructive aspects.[29] VM can be described as a "personalized, immersive, interactive experience that enhances our broader understanding of the world around us."[30] The breadth of its definition and the diversity of the included typology give

---

[29] In Laia Pujol, "The Virtual Museum: a Quest for the Standard Definition," in *Archaeology in the Digital Era: Papers from the 40th Annual Conference of Computer Applications and Quantitative Methods in Archaeology (CAA)*, Southampton, 26-29 March 2012 (Amsterdam: Amsterdam University Press, 2013), pp. 40-48., the author looked back on the journal articles and books published between the 1990s to 2010s with regards to the roles transition of the museum and digital museology and had a broader discussion on scholars' changing perceptions on definitions of the museum and virtual museum.

[30] According to http://www.v-must.net/. V-Must is a Network aiming to provide the heritage sectors with the tools and support to develop Virtual Museums that are educational, enjoyable, long-lasting, and easy to

scholars an idea of the variability of the concepts collected under this label. The concept of VM arose spontaneously from a mixture of traditional museum practice, semiotic models of self-identities, market tightness, and various technological possibilities.[31]

As a result of a series of social and economic changes in the 20th century, the museum rethought its traditional role as a discipline-oriented, hierarchical, elitist institution designed to preserve antiquities.[32] The evolution of the museum's definition from 1947 to 1974 reflects this shift,[33] as the emphasis shifts from institutions and their preserved objects to social communication. Ideas from the formal learning environment were gradually incorporated in the 2007 definition, in which education now coincides the study and preservation of objects as the purpose of the museum.[34] In practice, the so-called "new museology"[35] applies the basic principles of constructivism, which includes the concept that the content is adapted to everyone. It encourages museums to present multiple perspectives and representations of concepts, to provide visitors with sessions of self-analysis, reflection, and awareness. According to the methodology of new

---

maintain funded by the European FP7 Network of Excellence (Grant Agreement 270404), focused on Virtual Museums.

[31] "Semiotic models of self-identities" could be interpreted as a shift in the role that people play in the process of cultural communication and dissemination. Anna Lorente Gall and Ioannis Kanellos, "What do we know about on-line museums? A study about current situation of virtual art museums," In *International Conference Transforming Culture in the Digital Age*, 208-219. 2010.

[32] Eilean Hooper-Greenhill, *Museums and their visitors* (Routledge, 2013).

[33] Kenneth Hudson, "The museum refuses to stand still," in *Museum international* 50, no. 1 (1998): 43-50.

[34] Laia Pujol, *The Virtual Museum*, 41.

[35] As known as the concept of Ecomuseums. According to Sánchez Laws and Ana Luisa, *Panamanian Museums and Historical Memory* (New York: Berghahn Books, 2011)., the term was first proposed publicly at ICOM's 9th International Conference in France in 1971.

museology, the learner adopts an active role rather than just absorbs passive meaning, which means communication with others is the primary condition of learning.

From an etymological and philosophical point of view, scholars' interpretations of the roots of VM point to its origin in the evolution and debates of the words "virtual" and "reality". The meaning of the word "virtual" is related to metaphysical arguments and has changed slightly over time.[36] In recent usage, "virtual" is not the opposite of "real" or "material", but rather "actual", and contributes to a better understanding of the nature and capabilities of several communication technologies or systems invented by humans.[37] In this sense, some scholars argue that VM is a concept that predates technology and designates the global museum field, and there is no possibility of opposition or substitution between physical museums and their possible technical versions since they are aspects of the same entity: the physical museum already has virtuality, and this virtuality also exists in the conceptual and technical basis of the

---

[36] Lana Pujol, *The Virtual Museum*, 41. In this journal article, the author cited various sources to explain the meaning transitions of "virtual" and "reality" from the 17th century to the 20th century. As Woolley mentioned in his book Benjamin Woolley, *El Universo virtual* (Madrid: Acento Editorial, 1994)., the evolution of the interpretation of the term "virtual" by modern scientists and scholars was the scientific revolution taken place in the 17th and 18th century which defined reality as a physical entity understood experimentally. In the 18th century, as synonym of visible but non-material, "virtual" was used in Optics in relation to reflect images; in the 19th and 20th centuries, this term related to specific non-visible elements or phenomena in mechanics and physics.

[37] Pierre Lévy, *Qu'est ce que levirtuel?* (Paris: La Découverte, 1995). For example, computers constitute the ultimate example of virtualization because they have become general-purpose machines capable of potentially performing functions previously corresponding to other derivatives. The same general concept can be applied to exhibitions proposed by John H Falk, and Lynn D. Dierking, *Learning from museums* (Rowman & Littlefield, 2018)., since the experience of visiting is defined as a permanent dialogue between the visitor, the object, and the intermediary.

virtual machine.[38] In the current museological debate on VM, the opposing view is that virtuality is a result of the application of information communication technologies (ICT), which aims to disseminate knowledge as widely as possible through digital means. Virtuality, therefore, has no separate philosophical standing but arises from changes in its technological supporting methods.[39]

Based on the above etymological and philosophical perspectives, scholars propose a new classification of "virtual museum". In this classification system, the communicational (or museological) paradigm of the VM is more "constructive" or more "instructive" depending on the overall goal, content, interaction style and role assigned to the user. The constructive focuses on the spatial, simulated dimensions and emphasizes the mutual interactions between the user and the VM.[40] Forte and Franzoni also proposed a definition that conforms to the above approach:

> By virtual museum, we understand a computational environment consisting of a hypertext and hypermedia structure and an interface system containing metaphors that use a more or less intuitive graphic

---

[38] Bernard Deloche, *Le musée virtuel: vers une éthique des nouvelles images* (Presses Universitaires de France-PUF, 2001).

[39] Corinne Welger-Barboza, "Le patrimoine à l'ère du document numérique", in *Du musée virtual au musée médiathèque, Patrimoines et Sociétés* (Paris: L' Harmattan, 2001). This position is by far the most common among museums professionals.

[40] There are some early examples of VM that are based on Multi-user Virtual Environments and Object-Oriented Multi-User Dungeons (MOOs) in which users can communicate with each other from distance and even modify the virtual space according to Sue Gordon, "The Virtual Museum - Who Needs It?", in *Archaeology in the Age of the Internet: CAA 97 Computer Applications and Quantitative Methods in Archaeology: Proceedings of the 25th Anniversary Conference University of Birmingham* (Oxford: Archaeopress, 1999).

> representation, this allows the visitor to perform actions and therefore to navigate within the context, to interact with it or even to modify it.[41]

On the other hand, "Instructiveness" represents another possibility. It presupposes "virtualization" as a synonym for "digitization", linked VM with online resources, and emphasized the use of new technological means to recontextualize and disseminate museum resources widely. However, in terms of creating a more active virtual learning environment, using a constructivist approach is more conducive to user learning. In order to cater to the principles of constructivism, museum could take into account how individual visitors learn, and acknowledge visitors' personal meaning-making processes as they interact with the exhibitions.

An example that embodies the principles of constructivism is the use of gamification and serious games (SGs) in digital tourism. Gamification refers to intentionally implementing game features in situations that are typically unrelated to games.[42] For example, cultural heritage sites incorporate gamification into their on-site or virtual tours, encouraging participants to examine history by completing game tasks, promoting cultural preservation awareness, and gaining a sense of satisfaction upon completing the game. Gamification has garnered widespread attention in academia in a short period of time. One of the most notable achievements is the implementation of

---

[41] Maurizio Forte, and Margherita Franzoni, "Il museo virtuale: comunicazione e metafore," *Sistemi intelligenti* 10, no. 2 (1998): 193-240.
[42] Deterding et al., "Gamification: Towards a Definition," in *CHI 2011 Gamification Workshop Proceedings* (Vancouver, BC, Canada, 2011).

"Serious Games (SGs)" in historical and cultural education.[43] SGs use an interdisciplinary approach to merge computer science, archaeology, history, geography, social sciences, and art, becoming a new trend in contemporary educational development. It promotes the integration of formal and informal pedagogical paradigms and is widely used in educational practices in schools, museums, cultural heritage sites, and other cultural institutions. Players can achieve the cultural institutions expected cultural popularization and cultural awareness improvement goals through learning by doing, digital simulations, narrative interactive activities, and collaboration among learners[44].

In "Unveiling California History through Serious Games: Fort Ross Virtual Warehouse," the authors provide us with an example of humanistic and heritage SGs. The research object of this SG is the Fort Ross Historic Park in California, which was once a Russian fur trade outpost and multicultural colony.[45] In this project, the researchers primarily developed the "Fort Ross Virtual Warehouse (FRVW)" game, targeting elementary school students, and evaluated its effectiveness. The article also describes how the researchers recontextualized history, promoted chronological and

---

[43] Fotis Liarokapis et al., "Multimodal Serious Games Technologies for Cultural Heritage," in *Mixed Reality and Gamification for Cultural Heritage* (SPRINGER, 2019), pp. 371-394, 371.
[44] Nicola Lercari, Michela Mortara, and Maurizio Forte, "Unveiling California History through Serious Games: Fort Ross Virtual Warehouse," *Lecture Notes in Computer Science*, 2014, pp. 236-251, https://doi.org/10.1007/978-3-319-12157-4_19.
[45] *Ibid*.

spatial thinking, and encouraged users' cultural diversity awareness through the design and game mechanics of FRVM. The initial design of FRVM included five player characters from different ethnic and national backgrounds to represent the diverse races and genders that interacted in the Fort Ross colony. Users can gain an enlightening understanding of this cultural historic site and achieve cultural and historical pedagogical significance by interacting with NPCs and completing rewarding tasks.[46] The constructive significance of this SG lies in the fact that the researchers, during the research phase of the project, deconstructed the different historical educational meanings of Fort Ross, a historic site, into different titles. They also incorporated these different titles into the design and implementation process of the game, using role-playing, NPC interactions, and reward mechanisms to reflect the cultural and historical significance of Fort Ross. Users have full autonomy during gameplay and interaction and can experience the different journeys of characters from diverse cultural backgrounds. In addition, the reward mechanism can further enhance their motivation to explore, making them truly active learners.

2.2.2 Digital Methods Transition in Culture Popularization

As one of the most promising tools for a variety of fields such as entertainment, health, training, and academic research, VR devices are a relatively new trend in

[46] *Ibid*.

enriching the way information is accessed and presented. From an academic perspective, VR simulation has also become a powerful tool for studying past, present, and even future scenarios in which new trends can be tested and new paradigms can be created. "Presence" is a critical concept in VR, and its significance is exemplified through the ability to transport individuals to a digital reality that they are not physically present in, but can experience as if they were there.[47] This sensation could be achieved through the use of various technologies such as 3D graphics, sound effects, haptic feedback, and motion tracking. The goal of achieving presence in VR is to create a more engaging experience, which can lead to increased learning and retention of information, as well as a greater sense of enjoyment and satisfaction. From past research experiences, Rebelo, Noriega, Duarte and Soares identify six categories related to developing a sense of presence: the first is the sense of presence as social richness, which means the degree to which a medium is perceived to be sociable, warm, sensitive, personal, or intimate when it is used to interact with others; the second is the sense of presence as realism -- the extent to which a medium can produce a seemingly accurate representation of objects, events, and people; the third embodiment is presence as transportation, which involves the idea of moving from/to, for example, teleportation in virtual reality; the fourth is

---

[47] Francisco Rebelo et al., "Using Virtual Reality to Assess User Experience." *Human Factors: The Journal of the Human Factors and Ergonomics Society* 54, no. 6 (2012): 964–82. https://doi.org/10.1177/0018720812465006.

related to physical existence as digital immersion, which emphasizes perceptual and psychological immersion in a way of sensory immersion in the virtual world — the higher the degree of isolation between the world, the higher the immersion/existence will be; the fifth is the presence of a social actor in the medium, which refers to the fact that the medium could be ignored when the actor and the user are not in the same location so that the user reacts to the actor (even the robot or avatar) as if they were together; the last is to be present in the medium as a social actor - that is when "basic social cues exhibited by the medium lead users to treat the medium as a social entity."[48]

According to Vilar and colleagues,[49] one of the most important features of virtual reality is its flexibility to produce many different (often utopian)[50] worlds suitable for the goals of studying, training, entertaining and so on. And with a higher degree of control over variables, which can otherwise be very difficult to achieve when using real-world settings as interactive environments. Some examples of this are exploring virtual environments (VEs), ranging from users exploring the virtual world in a self-centered way (close to the true perspective) to flying over the environment (something that cannot be done in real situations) to get an external point of view. For instance, in the

---

[48] *Ibid*.
[49] Elisângela Villar et al., "Virtual Reality in Architecture and Design: Twenty Years of Experience," *Virtual and Augmented Reality for Architecture and Design*, 2022, 1–16. https://doi.org/10.1201/9781003051381-1, 1.
[50] *Ibid*. Utopia here refers to the creation of a barrier free, immersive, desired conditions that apply to different VR usage goals. For example, in the article, the authors mention the example of firefighters using VR to train for simulated fires. The utopian nature of VR here is reflected in that it can simulate a fire scene with various dangerous situations in a completely safe reality, and enable firefighters to realize training and conduct various distress simulations while ensuring their own safety.

Tiber Valley project mentioned in *Digital Methods and Remote Sensing in Archaeology*, the researchers aim to build a VR application to disseminate and enhance the knowledge and interest towards the territory north of the country Rome, crossed by the Tiber river and by two important roman consular roads. Since this is a heritage landscape that has a long-term history, anthropological and natural transformation, the researchers design different avatars to guide visitors in the VR tour. Visitors can choose and move between different avatars, exploring the landscape of Tiber Valley in different time periods by flying, swimming, walking and other ways.[51]

What's more, interaction with VEs has been successfully applied to research in several research areas such as social/cognitive psychology, ergonomics, architecture, design and engineering, by offering a wide variety of technical solutions that can be found to meet the needs of researchers. Among the contributions that technology is making to these sectors, VR is creating immense opportunities for the tourism industries and historical site preservation during the pre-visit phase, during the trip, and at the post-visit stage. From an academic research perspective, considering the significant increase in the number of virtual reality-based methodological studies, scholarly papers

---

[51] Maurizio Forte and Stefano Campana, "From Remote to Embodied Sensing: New Perspectives for Virtual Museums and Archaeological Landscape Communication," in *Digital Methods and Remote Sensing in Archaeology Archaeology in the Age of Sensing* (Cham: Springer International Publishing AG, 2017), pp. 437-474.

published in the field of architecture from 2000 to 2017.[52] Some of these deal with users' participation, such as User-Centered Design and Participatory Design processes. Scholars argue that virtual reality provides an "invisible interface" for users to interact with the environment as if they were interacting in the real world, which makes VR-based methodology ideal for prototyping and evaluating products. Through VR, tasks that require intuitive and frequent manual interactions such as prototyping assembly methods can be simulated, thereby reducing the need for physical practice, and thus generating a wider range of design decisions. There is also scholarship based on VR methodology for construction training and educational purposes, with the former being used primarily for those working in demanding/costly construction environments, such as construction workers, firefighters, etc., and the latter being used more for construction/building/architecture safety education (e.g., fire, earthquake) and academic education.[53]

Nowadays, VR has become a preferred means for creating a deeper union between cultural contents, technologies, and audiences. The shift of VM from instructive approaches to constructive approaches means that it is not only a simple technology transfer dedicated to the reproduction of reality. In the transition from web 2.0 to web 3.0 era, researchers are more committed to exploring how technology can be used to

---

[52] Elisângela Villar et al., "Virtual Reality in Architecture and Design: Twenty Years of Experience," *Virtual and Augmented Reality for Architecture and Design*, 2022, 1–16. https://doi.org/10.1201/9781003051381-1, 5.
[53] *Ibid*, 10.

build a digital ecosystem of cultural heritage in order to recontextualize cultural content, enhance the user/visitor's understanding of the objects, their relationship to historical context, and narrative value.[54] In many cases, this results in the lack of VM's ability to connect with users and evoke an emotional response , which is largely a result of research grants targeting virtual heritage communication that is technology-driven and aimed at technological innovation rather than cultural communication. Moreover, cultural heritage can also be merely a tool for gaining resources and visibility, which has led to the over-deployment of technology in many projects that can also overshadow cultural outcomes. One solution for users is the example of a virtuous circle of communication, whether in a real or virtual museum, which must face the difficult task of creating metaphors and languages that can attract, motivate, and hold the attention of the public, evoke people's perceptions and self-identifications, and sort out different records, concepts, emotions, and subconscious agitations. Museum technology must be advanced, yet easy to use, sustainable, and robust to survive, which also implies the need to use technology at a deeper level to strengthen the relationship between the academy, the museum, and the public.

---

[54] Maurizio Forte and Stefano Campana, "From Remote to Embodied Sensing: New Perspectives for Virtual Museums and Archaeological Landscape Communication," in *Digital Methods and Remote Sensing in Archaeology Archaeology in the Age of Sensing* (Cham: Springer International Publishing AG, 2017), pp. 437-474.

Scholars have also provided several practical paradigms and possibilities for constructing a human-centered digital cultural heritage. The preliminary step is to recombine the fragmented exhibit sessions, encouraging cultural connections that are essential to understanding a cultural object. Within the museum, it is critical to focus not only on the digital applications themselves, but also on their connection to the physical space, the flow of visitors, the presence of artifacts nearby, and environmental conditions.[55] This will influence the choice and duration of content, the level of interactivity and interaction design, the pace and style of communication, and thus the ideal communication style and the most appropriate technology to employ. The second practical paradigm is the construction of alternation and rhythm variations in the virtual journey. This means that in the case of multiple applications or a unique complex installation, it is fundamental to take multiple combinations of different communication styles of narrative, educational, playful and evocative and to create a harmonious communicative space. This approach helps to attract audiences from different background and ages, to suggest different cultural relationships among exhibits to the

[55] A recent example of the practice of this paradigm is the *Cangjie* project created by two LA-based Chinese artists and media technology researchers. According to https://digitalartarchive.siggraph.org/artwork/weidi-zhang-donghao-ren-cangjie/, this naked-eye VR installation provides a data-driven interactive spatial visualization in semantic human-machine reality. Visitors will participate in a real-time experience of this VR installation in a relatively dark environment, where the viewer's movement will be captured by the camera as a real-time stream and then processed by a trained *Cangjie* neural network to generate a visualization of symbols similar to Chinese characters. This process was designed to simulate how the Chinese ancestry invented Chinese characters by means of exploring and observing animals'/or human-beings' daily activities and movements. Weidi Zhang and Donghao Ren, "Cangjie," *SIGGRAPH Asia 2020 Art Gallery*, April 2020, https://doi.org/10.1145/3414686.3427153.

public, and to stimulate different levels of participation and interaction.[56] A third practical possibility is to use a guided learning process throughout the virtual journal.[57] Although the great potential of virtual reality is to allow visitors to move and explore freely in the space, it is often the case that visitors are lost in the lack of guidance and instructions. There is a need to guide the user through the exploration and interpretation process with efficient tools such as virtual stories, pre-set camera paths (alternating with free exploration), and rules of the game, giving them progressive goals and incentives so that they do not feel bored, confused, or abandoned in such a complex world. The last potential paradigm proposed is to deploy body interactions as a leading storytelling technique and create a sensitive and emotionally evocative space.[58] For those audiences who are not familiar with VR technology, they still have problems manipulating common input devices to interact with digital artifacts in a 3D environment: joysticks, keyboards, and consoles are not natural interfaces, and they take time to become familiar with them. Gesture-based interaction, (more specifically, mid-air gesture-based interaction) where control in a virtual environment is guided by physical gestures offers

---

[56] Vilar Elisaîngela, Ernesto Filgueiras, and Francisco Rebelo, "Virtual and Augmented Reality for World Heritage Vernacular Architecture: The 3DPAST Project," in *Virtual and Augmented Reality for Architecture and Design* (Boca Raton: CRC Press, Taylor & Francis Group, 2022), pp. 155-79.
[57] Osten Bang Mah et al., "Generating a Virtual Tour for the Preservation of the (in)Tangible Cultural Heritage of Tampines Chinese Temple in Singapore," *Journal of Cultural Heritage* 39 (2019): pp. 202-211, https://doi.org/10.1016/j.culher.2019.04.004.
[58] Maurizio Forte and Stefano Campana, "From Remote to Embodied Sensing: New Perspectives for Virtual Museums and Archaeological Landscape Communication," in *Digital Methods and Remote Sensing in Archaeology Archaeology in the Age of Sensing* (Cham: Springer International Publishing AG, 2017), pp. 437-474.

the ultimate possibility of removing the material body from the confines of its immediate living space.

In general, in the past half-century of research on the transformation of museum roles and theories of new museology, the shift from technology-oriented instructive approaches to human-centered constructive approaches has been a major direction in the trends of virtual museums. The application of VR technology in this transition can be used in the creation of emotionally evocative paradigms for visitors. Although most of the sources cited examples of cultural heritage sites' virtual applications during the conducted research, very few of them involved case studies focusing on Chinese or Asian cultures (most case studies are from European archaeological examples). In the case of the project I'm working on – the regional architecture with Chinese characteristics—the difference in cultural concepts between the East and the West determines the difference in their respective understanding of architectural design. Considering that the potential target audience of this project is the western audience who are not necessarily familiar with the Chinese Huizhou architectural culture, another research focus or practical difficulty is showing how VR technology can serve as a cross-cultural bridge in terms of architecture studies, in addition to disseminating and helping to understand cultural content. For instance, Chinese architectural design has certain commonalities under the influence of Chinese history (and even the larger East Asian civilization), which means that even architectural cultures born in geographically

different locations have similarities in design concepts.[59] It is a big challenge to use VR-based narrative tools to articulate the similarities and differences and help audiences distinguish various indigenous architectural cultures.

2.3 Related Digital Projects

2.3.1 PEM – Yin Yu Tang

PEM - Yin Yu Tang is a virtual tour application based on photogrammetry technology, available as a web plugin on the Boston Peabody Essex Museum website. It allows visitors to take a 2D or VR tour of the physical *Yin Yu Tang*, which is located inside the museum.[60] The application is powered by *Matterport*, a 3D spatial capture platform that transforms real-life spaces into immersive digital twin models.[61] Photographers use *Matterport*'s Pro2 camera to capture physical space and visual textures in multiple locations inside the architecture. By connecting different rooms of the targeted architecture, *Matterport* creates truly interactive 3D spatial models.[62]

---

[59] For example, in Ronald G. Knapp, *China's Vernacular Architecture: House Form and Culture* (Honolulu: Univ. of Hawaii Press, 1989)., the author talks about China's residential houses from the northern (Siheyuan from Beijing) to the southern part (Huizhou architecture) of China. You can find both Huizhou dwelling house and Beijing Siheyuan have some common features such as the lightwell area, the orientation of building, the function of the reception hall, and so on. However, we can tell them apart by the architectural details and furnishings.

[60] "Yin Yu Tang House Virtual Tour: Peabody Essex Museum." Peabody Essex Museum. Accessed March 12, 2023. https://www.pem.org/visit/yin-yu-tang/yin-yu-tang-tour.

[61] According to Matterport platform, "A digital twin is a visually immersive, accurate, and interactive 3D model of a real-world space." "3D Digital Twin Technology," Matterport, accessed March 12, 2023, https://matterport.com/what-digital-twin.

[62] "How Matterport Works," Matterport, accessed March 12, 2023, https://matterport.com/how-it-works.

Visitors can see *Yin Yu Tang*'s 3D scanned images on the page. In addition to the ability to drag the mouse to move the view, visitors can also use the left-click to locate specific areas of the architecture for teleport. *Matterport* provides users with a variety of tools and features, such as displaying overall models, cross-sections, and top views of the building; measuring, marking, and sharing 3D models; supporting VR device access, and more. In terms of information communication and interaction, all architectural structures and objects of special historical significance are marked with red pinpoints, and visitors can click on the pinpoints to see the detailed annotated content (see fig.5).

The *Yin Yu Tang* virtual tour supported by *Matterport* provides a good example of a virtual museum of architecture with practical and easy-to-understand interactive features that allow visitors to get a general idea of places of interest, museums, exhibitions, etc. in a limited time.[63] However, there is room for improvement. The resolution of the 3D scanned images generated by *Matterport* is not high enough to meet the requirements of visitors to explore the details of the buildings. For instance, the carefully carved eaves, woodcarving windows, and doors, which are significant for the presentation of Huizhou culture, are difficult to present completely because the visitors' viewing area and viewpoints when exploring the virtual space are limited. In addition, considering the limitation of the platform for the size of the data source, the underlying

[63] The project can be accessed here: "Pem - Yin Yu Tang," Matterport Discover, accessed March 12, 2023, https://matterport.com/discover/space/kRixnE75JdY.

principle of *Matterport* is to generate the whole 3D building by stitching with scanned images,[64] so the level of realism presented by the virtual tour is not as expected. Therefore, *Yin Yu Tang*'s virtual tour is a useful tool to aid the tour but cannot enhance or replace the actual experience of the visitors.

2.3.2 The *Pure Land* Series

The *Pure Land* series comprises four distinct virtual and augmented reality installation that employ a range of experiential exhibition technologies. Based on the UNESCO World Heritage site of the Mogao Grottoes in the northwestern Chinese province of Gansu, the Pure Land projects concentrate on Cave 220, which boasts early Tang murals of great significance.[65] The project's research and immersive applications are centered on this particular cave. This series of projects provides a panoramic stereoscopic projection theatre, a mobile AR system, a wireless standalone VR system, and a cave dome to an identical archaeological site.[66] The series also provides new inspiration for museums and cultural heritage digitization: that is, curators can develop different strategies to present different aspects of cultural heritage landscapes, and

---

[64] The generated panoramic photos are stitched together to form a whole model of the architecture, instead of scanning the different structures of the architecture separately by photogrammetry. For the latter, the resulting model has more meshes and higher realism, but it also takes up a lot of memory space.
[65] Pure land: Inside the mogao grottoes at Dunghuang - Sarah Kenderdine, accessed March 23, 2023, https://sarahkenderdine.info/installations-and-curated-exhibitions/pure-land-inside-the-mogao-grottoes-at-dunghuang.
[66] *Ibid*.

digital replicas of cultural heritage can be reused and transformed to provide fresh and personal experiences for museum visitors.

The first part of the series is called *Pure Land: Inside the Mogao Grottoes at Dunhuang*. It is hosted within a 360 degree, panoramic, stereoscopic projection theatre in Hongkong, which offers a realistic experience of being inside a cave temple and viewing its grand Buddhist wall paintings at a 1:1 scale (see fig.6). The immersive virtual replica of *Pure Land* is created using high-resolution photography and laser-scanned models provided by the Dunhuang Academy, which provides an exquisite depiction of the vast collection of paintings and sculptures found in the Dunhuang caves. In addition, the curator enhances the interactive experience of the narrative cave paintings through animation, 3D modeling, image recoloring, and sound design. Visitors can use small LED flashlights provided by the museum to simulate a real cave exploration experience while visiting, and they can also zoom in and view the paintings in ultra-high resolution through a 3D lens with magnifying function.[67]

The second project of the series is *Pure Land AR*. In this exhibition, visitors' exploration tools became portable iPads. Full-size photos produced by the Dunhuang Academy covered the walls of the booth, displaying the black and white laser scan of Cave 220's mural paintings (see fig.7). This new technology rendering is made possible

[67] *Ibid.*

using infrared cameras, which accurately tracks the position and orientation of the iPads that visitors are manipulating. The cameras detect the iPads because they were attached with small optical markers on their frames. The computer then creates appropriately rendered actual Dunhuang cave views, which will be transmitted to the iPads via Wi-Fi.[68] At this point, visitors can see the wall painting details changing from black and white to full color on their screens, providing structural and aesthetic alignment between the room space and the cave space. This interactive technology creates a novel interactive experience centered around visitors' self-exploration, sparking spontaneous discussions among visitors and enthusiasm for taking photos.

The third attempt is called *Pure Land Unwired*, exhibited in San Francisco in 2015. It is a standalone VR system developed by Unity 3D, incorporating a wireless solution and relying on the Oculus Rift head-mounted display and depth-based Kinect 2 camera (see fig.8). This allows visitors to walk around Cave 220 at a 1:1 scale, fully immersed in virtual reality.[69]

The last project of the series is *Cave Dome*. *Cave Dome* utilizes the hemispherical curvature of a full dome projection system to provide an interactive representation of the "pyramidal" Cave 220, enabling users to fully navigate and experience the inside of

---

[68] Pure Land Ar - Sarah Kenderdine, accessed March 23, 2023, https://sarahkenderdine.info/installations-and-curated-exhibitions/pure-land-ar.
[69] Pure Land Unwired - Sarah kenderdine, accessed March 23, 2023, https://sarahkenderdine.info/installations-and-curated-exhibitions/pure-land-unwired.

the cave at a 1:1 scale.[70] What sets this exhibition apart is that, as the 3D imaging data is presented in a spherical exhibition hall, visitors can not only see the murals and exhibits on the surrounding walls, but also focus on the details of the murals on the cave ceiling (see fig.9).

In summary, we may find that the Pure Land series explores different focuses of an archaeological site through the combination of various technological means and presents them in different forms of exhibitions. I believe this is an advanced way of practicing the museum constructivism, using different interactive designs, technological choices, and exhibition designs in different contexts to achieve different immersive effects and novel storytelling modes. Although my project is not a series of immersive exhibitions, this provides a good reference for the future development of my own digital project. Technologies such as VR can not only be used as a standalone device to represent cultural heritage but can also complement the museum architecture itself.

[70] Cave dome - sarah kenderdine, accessed March 23, 2023, https://sarahkenderdine.info/installations-and-curated-exhibitions/cave-dome.

3. Virtual Huizhou App, Affordance, and Design Choices

3.1 Explore the Spatial Affordance of Virtual Culture Heritage

A central concept in the study of human-computer interaction and advanced digital technology is that of "affordances," which refers to the user's understanding of how objects in the (digital) world can be used. Based on the previous research, this term can be interpreted in two ways: it can pertain to the ways objects can be used within a specific environment regardless of a designer's intent or obvious uses, or, on the other hand, it can be used to describe how the appearance of an object provides perceptible clues as to its intended uses.[1] In the book *Inventing the Medium*, Dr. Janet Murray presents four categories of affordances for the digital medium.[2] Murray argues that these four affordances of digital media are essential for understanding the unique capabilities and potentials of digital technologies. By designing digital experiences that leverage these affordances, creators can unlock new possibilities for storytelling, learning, and creative expression. One of the pioneering concepts is about the spatial affordance of digital media, which means that the innovation of digital media technology breaks the

---

[1] William R. Sherman and Alan B. Craig, *Understanding Virtual Reality: Interface, Application, and Design* (Cambridge, MA: Morgan Kaufmann, 2019), 109-187.

[2] Those are encyclopedic, procedural, participatory, and spatial affordances. Encyclopedic means digital medium has the ability to contain vast amount of information and can organize it in various ways, allowing users to navigate and explore complex datasets. Procedural affordance enables it to be programmed to respond to users' actions, allowing for the creation of complex simulations. Participatory affordance enhances the audience's collaboration and social interaction. Janet Horowitz Murray, *Inventing the Medium: Principles of Interaction Design as a Cultural Practice* (Cambridge, Mass: MIT Press, 2012), 51-71.

temporal and spatial characteristics of the real world. In this sense, a specific space, object, or knowledge can be delivered to the audience through more novel and immersive means. Similarly, I believe that the application of virtual reality to depict spatial relations breaks the boundaries set by the institutional disciplines of museology, architecture, and history for the public, as it complements and improves the realism, accessibility, and interactivity of cultural heritage architectures. This is also the core question that I want to explore in my whole thesis project, that is, how virtual reality can compensate for a lack of information that might compromise the audience's spatial awareness or, conversely, how it can enhance the audience's understanding of the spatial relationships within Huizhou architectures.

3.1.1 Working Towards Realism and Accuracy: 3D Reconstruction Methodology

One of the most intuitive examples of demonstrating the spatial qualities of digital media is the enhancement of realism in VR applications. In my digital project, realism is achieved through a workflow of spatial measurement (data acquisition) - 3D modeling and sculpting - acquisition of highly simulated textures. In the pre-reconstruction phase, all dimensional data of the building structures and historical objects were manually measured online. In the above description for the *PEM - Yin Yu Tang* online digital museum project, I mentioned the "Measurement Mode" feature that the *Matterport* platform offers to its clients (see fig.10). *Matterport* gives users the ability to synchronize data from their fieldwork, which also means that users can manually

measure any building structure on the PC side using its electronic measurement function.[3] I refer to the entire process of measurement and recording as a simple "anatomical survey" because the specific nature of architectural models requires learners to go beyond what is visible on the surface of the building and explore the structural elements of the building, i.e. the intimate make-up of the architectural organism.[4] I believe that this step helped me understand the structure of the house from the perspective of an architect. It also provided me with an opportunity to learn the layout of the entire building and the positioning of different structural components in different spaces in a more comprehensive way, which aided me in devising an effective modeling plan. Furthermore, it made me think about the following questions: how can the entire building be dissected and broken down into different structures and modules

---

[3] I also refer to a rare illustrated book entitled *Huizhou Ming Dynasty Residence*, published by the Chinese Academy of Architectural Sciences in 1957 and drawn from the authors' 1954 survey and investigation reports of twenty residences in six counties of Huizhou. The book clearly shows the general layout, exterior design, structure, and decorative parts of the different buildings, with extensive textual notes. Zhang, Zhongyi 张仲一, ed. 徽州明代住宅 *[Ming Dynasty Huizhou Residences*]. Beijing Jianzhu Gongcheng Chubanshe 北京建筑工程出版社, 1957.

[4] M. Centofanti et al. discussed the concept of an "anatomical survey" in their paper "Architectural Heritage and 3D Models." In formal digital archaeology and historic architecture reconstruction planning, this concept may be more complex. It involves creating a descriptive model of the target building's exterior and internal structure during the research phase. These models integrate researchers' revelations of geometric, dimensional data, and spatial values, and provide an analysis of material and structural features. This lays the groundwork for restoration or reconstruction projects. However, since my data collection for Yin Yu Tang only involved measurement and layout analysis, I referred to my process as a simple "anatomical survey." Mario Centofanti, Stefano Brusaporci, and Vittorio Lucchese, "Architectural Heritage and 3D Models," In *Computational Modeling of Objects Presented in Images: Fundamentals, Methods and Applications*, edit by Paolo Di Giamberardino et al. (Springer, 2014): 34-35.

in a 3D modeling software? How can these structures and modules be effectively recombined on a game engine platform?

When setting up the specific modeling plan, I considered two options. The first was to build a single model of the entire target building and then add details such as structural elements, decorative objects, and historic items within this model. The second option was to divide the target building into five separate spaces: the courtyard, the reception hall, the corridors, the lightwell area, and the second-floor spaces, and then add details to each one individually. I ultimately chose the second option because, compared to other architectural styles, Huizhou architecture can be understood as a type of assembled construction, meaning that the building's main structure is not made up of stacked materials, but rather is assembled by putting wooden materials together like a jigsaw puzzle. Creating a single model of the entire building could lead to errors. For example, modeling errors in the reception hall space could affect the floor area size of other spaces and the placement of subsequent historic objects. Splitting the entire building into five separate spaces and modeling them one by one can help me minimize this type of error as much as possible.

In the process of 3D reconstruction, in addition to using Maya 3D software to model simple objects and architectural structures, for some objects of higher complexity,

I migrated to Zbrush software[5] for processing. Taking how to make detailed representations of wood carving windows and doors as an example, Zbrush supports the import of Huizhou style wood carving as an Alpha grayscale map,[6] and its "Bas relief" function (see fig.11) can quickly generate and ray cast matching carving patterns on the target model, which also reduces my workload in reconstruction, while ensuring the appearance of the structures details on the 3D polygon.

The last step of reconstruction is to select and attach high-fidelity surface textures to plain models. The surface texture repository that I referenced belongs to Quixel Bridge[7] under the Unreal Engine 5 (see fig.12). This library manages all texture resources according to different materials such as wood, cement, bricks, and metal, and is easy to search and download 4k resolution images. In order to ensure the rigor of the modeling process and to maximize the accuracy of the building's actual material, I searched and used the architectural material that is closest to the historical records in this texture's library. According to the historical records,[8] for instance, the stone used in Yin Yu Tang is primarily a kind of sandstone that is easily procurable in Huizhou. It's similar to the brownstone of many residences in New York City. In this sense, I mainly used the

---

[5] A 3D software for digital sculting and painting.
[6] Here is the documentation of how this function works. "Documentation | Bas Relief." ZBrush Docs. Accessed March 13, 2023. http://docs.pixologic.com/user-guide/3d-modeling/sculpting/bas-relief/.
[7] It can be regarded as a UE5 plug-in, providing high-quality 3D and 2D assets.
[8] Nancy Zeng Berliner, *Yin Yu Tang: The Architecture and Daily Life of a Chinese House* (Clarendon: Tuttle, 2014), 662-671.

keywords of "sandstone" or "brownstone" to search for materials. For architectural structures where it is difficult to find historical records or relevant high-resolution texture images, I also attempted to create my own surface textures based on the pictures I took during my on-site inspections and the images provided by the *PEM-Yin Yu Tang* panoramic project. For example, the exterior walls of Huizhou architecture are mostly mottled white walls. This is because the architects primarily built the walls using bricks and reinforced them with concrete cement, then coated the exterior walls with white paint.[9] Over time, under different weather conditions, the walls developed varying degrees of wear and tear, which is why most historic Huizhou architecture has a black-and-white appearance on the exterior walls. To achieve this visual effect, I searched for high-resolution pictures with keywords such as "concrete" and "cement" in copyright-free resource libraries, and then used different brushes in Photoshop to further process them to achieve an old and worn visual effect (see fig.13).

3.1.2 Accessibility: Creating the Borderless Traditional Architecture

If the assistance of virtual reality in restoring and enhancing realism is based on creating the photorealistic visual effects, then "accessibility" deals with more profound issues. Since the 1970s, when scholars first proposed the concept of museums transitioning from an institution to a "virtual" entity, several decades of digital media

[9] *Ibid.*

development have provided us with numerous practical examples of "virtual museums" and "digital archives", which also involve the exploration of accessibility in virtual reality.

At a basic level, accessibility can be understood as the ability to transcend temporal and spatial limitations. For example, a virtual tour of Huizhou architecture can allow western visitors to experience the embodiment of the aesthetic philosophy of Eastern architecture without leaving their homes. This is similar to a virtual *Baalbek Reborn: Temple* tour[10] that can enable enthusiasts of ancient Roman architecture living in the 21st century to see the ruins of Baalbek temples in their original state without a time machine. Online museums can provide assistive device support such as screen readers various haptic functions, or hands-free controllers[11] to help people with disabilities access knowledge and provide all users more ways to access information.

With these examples in mind, accessibility implies a change in the way digital archive designers organize and visualize information, a change that allows information science concepts or conventions to become known to the public in a more accessible

---

[10] This is is a project of a virtual museum that showcases the temple complex of the Roman period and contrasts the architecture of the past and present, developed by the German Archaeological Institute, the General Directorate of Antiquities of the Lebanese Ministry of Culture, and Flyover Zone. "Baalbek Reborn Temple," Flyover Zone, January 25, 2023, https://www.flyoverzone.com/baalbek-reborn-temples/. Access the game throught its steam page: "Baalbek Reborn: Temples on Steam," Baalbek Reborn: Temples on Steam, accessed March 12, 2023, https://store.steampowered.com/app/1370800/Baalbek_Reborn_Temples/.

[11] A currently implemented hands-free solution relies on the eye tracking feature to help the disabled people interact with the target interface. Wecapable.com, "Virtual Reality and Persons with Disability." Accessed Mar 25, 2023. https://wecapable.com/virtual-reality-disabled-persons/.

way. We might relate this to what museology researchers Rose Parry and John Hopwood have called a new concept of museums in the early 21st century, the “soft museum”.[12] I interpret this term as a trend: that is, the gradual blurring of the boundaries of museums and the gradual lowering of the threshold that previously limited access. These two researchers argue that virtual reality can be used to create a more engaging museum experience. Creating a borderless museum can be interpreted as a means to achieve the "soft" characteristics of a museum. The concept of “borderless” can be related to spatial concepts, or seen as a reconfiguration of space.[13] Traditional museum spaces are limited, and curators may have to look for a linear, logical, time-based, or geographically arranged storytelling mode to convey knowledge to visitors as much as possible within the limited space. However, the emergence of new technologies has disrupted, reimagined, and reconfigured museum spaces. With the space allowed by equipment and platform storage, designers can use an infinite space, which is reflected in their ability to organize their storytelling patterns in more diverse ways, even using multiple parallel narrative structures. Most physical museums today plan different exhibits and exhibition areas by region. For example, if visitors want to learn about East Asian culture, they must go to the museum’s Asian area, where exhibits unearthed from different sub-areas or discovered in different historical periods are presented in turn.

---

[12] Rose Parry and John Hopwood, “Virtual Reality and the ‘Soft’ Museum: A Call for Further Research,” *Journal of Museum Ethnography* 16 (2004): pp. 69-78, https://doi.org/10.7551/mitpress/11836.003.0013, 70.
[13] *Ibid.*

However, virtual museums with the assistance of new technologies such as WebGL, VR, and AR have to some extent changed this traditional mode, realizing the recontextualization, reorganization, and quick retrieval of exhibits in different contexts. For example, in the Museum of the World online platform created by the collaboration of the British Museum and Google Arts and Culture, visitors can quickly locate exhibits through filters and categories.[14] Designers have created at least three forms of recontextualization modes on this platform (see fig.14): quick retrieval by region, quick retrieval by time period, and exhibit retrieval by five major themes of "art and design," "living and dying," "power and identity," "religion and belief," and "trade and conflict." This kind of digitization is a change in information architecture patterns and an exploration of different recontextualization, which also transforms the museum from a well-arranged, displayed space into a "soft" space. "Soft" here means making the museum a negotiable and discussable space. Visitors can choose the recontextualization mode that they feel comfortable with and efficient for exploring specific cultures on their own.

I also tried to incorporate this shift to "soft" into my information/knowledge organization and interface design for the VR Huizhou project. When designing this VR application, my aim was to create a tool that could be used by the public, particularly

[14] The Museum of the World (Google), accessed March 23, 2023, https://britishmuseum.withgoogle.com/.

those who are not familiar with Huizhou culture. It can serve as a substitute for physical visits to Huizhou architecture or as a complementary tool for museum exhibitions. To achieve this goal, I focused on creating a coherent and intuitive interface that reflects the richness and depth of Huizhou culture (see fig.15), rather than simply offering a standalone virtual tour, the application provides users with the opportunity to choose their own way of exploring that they feel comfortable.

My plan is to create a separate method for organizing the modules information in order to maximize visitors' exploration freedom, which is mainly reflected in the design of the main menu/lobby of the VR project. Apart from the "Start the journey" button on the main menu interface, I added the other three modules: "Instructions for VR", "Gallery", and "Historical Background" (see fig.16 for the entire App wireframing).[15] The "instructions for VR" module is designed to provide information on basic interaction buttons for visitors who are not familiar with Oculus Quest 2 controllers. "Gallery" module showcases a range of photographs of Huizhou architectures which I took in my past travels. These photos are divided into three categories: Huizhou residential houses, Huizhou ancestral halls, and Huizhou Paifang

[15] Joy Wei, "VR Huizhou Application Overview," YouTube Video, 3:34, Mar 29, 2023, https://www.youtube.com/watch?v=rIoqhbENZf4. This is a video demonstration of the VR project, the main interface showcase is at the beginning of the video.

(Memorial Archway Gate). The rationale for this design is that the physical architecture referenced in this project falls under the category of residential house. However, the ancestral halls and Paifang belong to two other representative types of Huizhou architecture.[16] Although they are not directly related to this project, I believe that adding them to the gallery will help to avoid the misconception that Huizhou architecture is only a type of dwellings. The "Historical Background" module offers a comprehensive overview of Huizhou culture, from its origins to the development of its architectural philosophy under the influence of traditional Chinese beliefs. This module then goes on to demonstrate the overview of the project, and how the Huizhou architectural philosophy is reflected in the design of *Yin Yu Tang*'s layout, orientation, and indoor decoration. Both the Gallery and Historical Background modules are composed of 2D images and text, which help visitors to understand the original intent and purpose of the application. By providing visitors with a more comprehensive and informative experience, I hope to encourage a deeper appreciation and understanding of the richness and diversity of vernacular culture.

Last but not least, another approach by which VR technology is practicing "soft" museum is by transforming the user's identity from a passive recipient to an active explorer. This identity shift is accomplished through the deployment of various

[16] Wu & Yu, *Xidi Hongcun*, 4.

interactive capabilities. A “soft” museum combines the physicality of a traditional museum with the interactivity and accessibility of a virtual one. It can also be regarded as a combination of a virtual museum and a museum without walls. In terms of the virtual Huizhou App that I developed, I hope it can become a digital platform that provides an immersive experience of exploring Huizhou architectural exhibits. Visitors can view exhibits, read descriptions, and even interact with some of the displays, all from the comfort of their own devices. On the other hand, I hope it can be used as an example of a “museum” without walls. This not only means that it does not need to have a permanent physical location for the exhibit, but also that it can take on multiple roles such as cultural education, promoting conservation awareness, and fostering harmony among community members.

3.1.3 Virtual Reality: Interactions with Digital Spaces

In the project of *Virtual Huizhou*, virtual reality serves as a means of human interaction and possesses distinct qualities that can facilitate captivating and all-encompassing encounters. To create compelling VR experiences, one must first comprehend the characteristics of communication media as well as the part VR plays in it. This necessitates a study of its past, terminology, storytelling methods, categories, and

interfaces.[17] In my practice of digital project simulation, I use Figma[18] for product prototyping and wireframing. In this sense, this section will discuss how I tried to present an informative Huizhou architectural culture storytelling mode from the perspective of human-computer interaction by combining and showcasing my mind mapping in the digital design tool.

According to Vilar and colleagues' research, one of the most important features of VR is its flexibility, which allows for a wide range of options that are tailored to the research objective and have greater control over variables, which can be difficult to achieve when using real-world environments as the interaction environment. However, options that are not possible or difficult to execute in the real interaction environment can be complemented by the interaction design in the virtual environment.[19] They also act as agents within the immersive environment, enhancing the feeling of presence and immersion, which in turn facilitates learning. Teleportation and object interaction are the two main practices that I explore mainly at the user experience and interaction design level. Teleportation means visitors can push the trigger on the controller to move to a specified area instantly (see fig.17). The adoption of the teleporting function came from

---

[17] From my perspective, understanding a targeted culture's history, terminology, and storytelling methods can help a designer to shape the specific experience for a culture product. William R. Sherman and Alan B. Craig, *Understanding Virtual Reality: Interface, Application, and Design* (Cambridge, MA: Morgan Kaufmann, 2019), 2-41.

[18] A cloud-based design and prototyping tool which enables different stakeholders to collaborate. It offers interactive prototypes service and can generate design specifications.

[19] Vilar Elisa̋ngela et al., *Virtual and Augmented Reality for Architecture and Design* (Boca Raton: CRC Press, Taylor & Francis Group, 2022), 4.

the consideration of visitor comfort and the difference between the way of moving in a VR environment and traditional games or real space. In traditional games, the player can control the movement of the character with a joystick or WASD keys. However, if the same approach is used in VR, it may lead to motion sickness and other discomforts. For this reason, many VR applications use teleporting, which allows visitors to move by specifying a destination in VR space. In addition, by allowing the user some ability to move around, rather than remaining in a fixed location, the teleporting feature allows visitors to explore the virtual environment more freely in a limited realistic space, enhancing immersion and realism of the environment.

The other practice to achieve a dynamic experience is to deploy the object interaction function. Object interaction refers to the ability of visitors to interact with virtual objects within the VR environment. This can include picking up objects, spinning them around, and manipulating them in various ways. Object interaction is critical for creating a sense of presence within the VR environment and even meeting the demand for up-close interaction that cannot be achieved in the real life, as it allows the user to engage with and affect their surroundings in a virtual way. To implement object interaction, I utilized various input devices such as hand controllers or hand tracking technology. By using these devices, users can physically reach out and manipulate virtual objects in a way that feels intuitive and natural. Another way to accomplish object interaction is to put several map markers in the environment which serve as a role

of indicators to remind visitors to interact with objects of special historical significance, visitors can click on the map markers floating on the object to open the corresponding history information interface (see fig.18).[20] I implemented map markers to the two targeted areas and four targeted models. The two targeted areas are the semi-opened lightwell area and the mall hall/reception hall of the architecture. when visitors click on these two map markers, the information widgets that are opened with images and texts that explain the functions of the areas. Of course, it would be very general to discuss only the two main areas, and the remaining map markers for specific models complement these two areas to some extent, which are the screen wall and the decorative furnishings in the main hall, and the two wells, the woodcarving used to decorate the windows and doors in the lightwell area. The combination of space map markers and object annotations is also based on considerations of users' comprehension of spatial relationships. I noticed that in the *PEM-Yin Yu Tang* photogrammetry project, designers also used map markers to convey information, but their annotations were limited to specific objects. Users can click on the object to know what it is but may not have a clear understanding of its relationship with the space it is in and its function within that space. Therefore, in my project, different spaces and objects within those

[20] 1:57-2:49 of the demonstration video shows the whole process of interacting with map markers. Joy Wei, "VR Huizhou Application Overview."

spaces are more closely linked through this type of individual space and object's annotation.

Overall, the inclusion of teleportation and object interaction are vital factors for the development of a VR application that delivers an exceptional user experience. Through prioritizing user comfort and employing user-friendly input methods, I was able to design a virtual environment that not only provides an immersive experience but also accommodates the needs of a diverse user base.

3.2 VR App Implementation

3.2.1 Choices of Platform VR Equipment

As this VR project must be developed on a game engine platform, I have tried both Unity and Unreal Engine 5 (UE5), which are two mainstream game engine platforms that are frequently used in virtual museum projects (see table.1). I compared the attributes of these two systems according to the goals of my project.

Considering the pursuit of virtual tour realism, this project requires a platform that could support more realistic rendering, high-quality graphics, and more powerful physics simulation. In terms of lighting, Unity makes extensive use of the "Global Illumination" system, which is a series of methods to pre-process the lighting calculations needed in the game, rather than during the game.[21] On the other hand, UE5

[21] "Introduction to Lighting and Rendering," Unity Learn, accessed March 14, 2023, https://learn.unity.com/tutorial/introduction-to-lighting-and-rendering.

uses a technology called “Ray tracing”, which can simulate the propagation and reflection of light more accurately, thus achieving a more accurate and quality lighting effect than Unity.[22] In terms of rendering, UE5 uses a global lighting solution called “Lumen” that adaptively calculates lighting and reflections and renders in real-time at runtime to improve rendering efficiency and quality (see fig.19 and fig.20).[23] Unity uses a rendering technology called “Progressive Lightmapper” that calculates lighting and shadows at the pre-processing time to improve rendering efficiency and stability. However, this approach can lead to lighting inaccuracies in some cases.

In terms of development language and editor difficulties, some researchers or 3D artists favors Unity as being better suited for novices because it has a shallow learning curve.[24] However, the Unreal Engine also offers a solution for beginners without the requirement to master a programming language, which is “Blueprint”. As a visual scripting system in UE5, it is used to create game logic and interactivity. It allows developers to use drag-and-drop nodes to design and implement game features without writing traditional code. In addition, Blueprint provides tools for creating custom visual effects, animations, and materials.[25] After considering the actual features of both

---

[22] “Lighting the Environment,” in Unreal Engine | Unreal Engine 5.1 Documentation, accessed March 14, 2023, https://docs.unrealengine.com/5.1/en-US/lighting-the-environment-in-unreal-engine/.
[23] *Ibid*.
[24] Ciekanowska et al., “Comparative Analysis of Unity and Unreal Engine Efficiency in Creating Virtual Exhibitions of 3D Scanned Models.” *Journal of Computer Sciences Institute* 20, (2021): 247-253.
[25] “Blueprints Visual Scripting,” in Unreal Engine | Unreal Engine 5.0 Documentation, accessed March 14, 2023, https://docs.unrealengine.com/5.0/en-US/blueprints-visual-scripting-in-unreal-engine/.

platforms and my project goals, I chose Unreal Engine as the development engine for my project.

Table 1: Comparisons Between Unity and UE5

Feature	Unity	Unreal Engine 5
Supported platforms	Windows, macOS, Linux, iOS, Android, WebGL, PlayStation, Xbox, Nintendo Switch, and more	Windows, macOS, Linux, iOS, Android, PlayStation, Xbox, and more
Programming language	C#, UnityScript (JavaScript-like language), Boo	C++, Blueprints (visual scripting language), C#
Graphic and rendering	Good graphics and rendering capabilities, with support for real-time lighting and shadows, post-processing effects, and HDRP (High-Definition Render Pipeline)	Advanced graphics and rendering capabilities, with support for real-time ray tracing, global illumination, and Nanite (geometry streaming technology)
Physics engine	Rigid body dynamics, collisions, and joints	UE5 adopted the physics engine PhysX

In the choice of VR headset equipment, I mainly tested the popular Oculus Quest 2 and HTC Vive Pro (see table.2). Since this digital project is ultimately positioned as a cultural product for the public, I put user experience at the top of my list. Considering the user's comfort in experiencing the virtual tour, the portability of the equipment, and the performance of the graphics of the desktop available in the lab, I think Oculus Quest

2 is the more cost-effective choice. One of the decisive features that made me choose it was its built-in tracker and controllers, which allows users to automatically shift and lock the view through head movement in a hand-free situation, providing a better mobile and interactive experience to those who are not familiar with VR headset.[26]

Table 2: Comparisons Between Oculus Quest 2 and HTC Vive Pro

Feature	Oculus Quest 2	HTC Vive Pro
Display	1832 x 1920 per eye, LCD, 90Hz	1440 x 1600 per eye, AMOLED, 90Hz
Weight/Comfort	Light and comfortable	Can be heavy and lead to motion sickness after extended use
Tracking	Inside-out, 6DoF (head and hands)	Outside-in, 6DoF (head and hands)
Content Library	It has Large and growing application stores	Smaller and limited
Supporting System	OpenXR	SteamVR
Standalone	Yes	No, it requires PC to connect
Wireless Streaming	Yes, with Oculus link	No

[26] "Meta Quest 2: Our Most Advanced New All-in-One VR Headset | Oculus," accessed March 13, 2023, https://www.meta.com/quest/products/quest-2/tech-specs/.

3.2.2 Implementation of Interface, Teleporting System, and User-Objects Interactivity

All the user interfaces and user experience features in *Virtual Huizhou* were created and written through Blueprints. To help the audience better understand the workflow of the implementation, I classified all the functions of the whole virtual tour into three categories: firstly, the buttons that help users to transit between pages and scenes; secondly, the teleportation functions that assist users to move around in the limited real space; and finally, the interaction functions with the historical objects that have detailed introduction pages (see fig. 21). I have summarized the steps to achieve these functions in table 3.

Table 3: Workflow of Implementing Functionalities

Functions	Step 1	Step 2	Step 3
Interfaces	Create a new GameMode Blueprint	Assign UI widgets to GameMode Blueprint	Find "HUD Class"
Teleportation	Create Teleport Blueprint	Add Event BeginPlay, Teleport, and Line Trace by Channel	Connect the above nodes; add the related buttons to the nodes
Interaction	Add Interaction Component	Create a widget to connect the targeted object and the information page	Assign the widget as "Interaction Widge"

My demonstration YouTube video "VR Guizhou Application Overview" presents a complete virtual tour after configuring various functions.[27] In the entire process of implementing the application, I gave the digital project a constructive significance by giving visitors a high degree of freedom to explore and become active learners. At the same time, the appearance selection and interaction design of the main menu, widgets, and buttons are easy to understand. After launching the application, visitors will enter a lobby where there are four modules and an exit application button, which I emphasized in the interface design section. In the video, I demonstrated the appearance and functions of each module in sequence, and visitors can click on different modules to learn based on their preferences and understanding of Huizhou culture. In the formal virtual journey part, I chose to not guide visitors on which specific area to explore first but simply set the default start point in the courtyard. This also simulates my real experience as a visitor exploring Yin Yu Tang on site: entering the courtyard directly from the museum and then exploring inside. In terms of interactions, besides the teleporting and map marker functions that I described in detail in the design section, visitors will notice that two white-colored laser pointers follow the virtual controllers throughout the entire tour. This is mainly for debugging purposes, helping visitors

[27] Joy Wei, "VR Huizhou Application Overview," YouTube Video, 3:34, Mar 29, 2023, https://www.youtube.com/watch?v=rIoqhbENZf4.

locate whether they touch the correct button when opening the interface and completing their instructions.

4. Discussion and Future Possibilities

Since *Virtual Huizhou* VR App exists as a digital project to support my thesis research, I focused on developing it to demonstrate the critical features of photorealism, accessibility, and interoperability of the virtual reality device during the design and implementation process. This section will discuss some of the areas for improvement of this digital project based on several audiences' feedback and the comparison with other similar applications.

4.1 Navigation System

First, a feature that has been neglected in the development process is the navigation and wayfinding system, which are also two essential components of a virtual tour. A well-designed navigation system helps visitors move smoothly through the virtual environment and find what they are looking for.

The reason I did not use a navigation system in this project is that my digital reconstruction target is a single building rather than an architectural complex. Moreover, this project only exhibits three main spaces, the courtyard, the main hall and the lightwell, so most of the volunteers who tried this VR application did not get lost in the exploration. However, considering the possibility of the long-term development of the project, if the digitally reconstructed object becomes a free-standing monument or a building complex with multiple floors and complicated layouts, a sophisticated wayfinding system that mitigates motion sickness is necessary.

The following are two types of wayfinding systems that could be practiced in the future: first, the use of maps and compasses. Maps can mark important landmarks or points of interest, especially for Huizhou architecture, which incorporates the concept of orientation into architectural Feng Shui ideology, helping users know where they are currently facing can be particularly supportive in large, complex environments. Sensory feedback is another practicable category, which involves audio cues and haptic feedback, with out-of-picture sounds and vibration effects to indicate whether the user has reached a specific area.

4.2 Interface and Interactivity

In the section of User Interface and User Experience Design, I showcase the application structure design mind map that was created during the design phase of the project, and on which I refined my ideas about the organization of the application features at the end of the project (see fig.22).

First of all, I believe the inclusion of audio guidance is crucial as it not only helps visitors navigate the pathway but also contributes to the overall continuity and coherence of the virtual tour. Regrettably, no audio resources pertaining to the reference buildings were discovered during the data collection stage. Nonetheless, the presence of this feature could serve as a significant criterion for evaluating the comprehensiveness of online architectural museums.

At the level of how visitors interact with targeted objects, I considered a more detailed design solution. Instead of clicking the floating pinpoint on the objects to go directly to the object-information page, it seems more reasonable and easier to understand to create an associated object inventory page. The inventory will categorize all interactive objects according to different functions such as architectural structures, decorations, antiques, etc., thus helping visitors unfamiliar with Huizhou culture to understand the historical heritage more effortlessly.

4.3 Immersion Enhancement

The immersion and "realism" of a VR application are critical factors in determining whether users are willing to use and engage with it. For the VR application of Huizhou architecture, the enhanced immersion creates a better visual and emotional experience,[1] thereby increasing the possibility of encouraging relations to user memory and thus increasing engagement.

In the initial preparation phase of the thesis digital project, I listed high-fidelity 3D reconstruction as the priority of the project. To achieve this goal, I planned to use photogrammetric models, but this plan fell through due to technical issues.[2] Therefore,

---

[1]VR can allow audiences to experience the world through the eyes of another person or creature, which can create empathy and understanding. This can be particularly effective in educational and social contexts, where VR can help people understand perspectives that they may not have been exposed to otherwise.
[2] I visited Yin Yu Tang at the Peabody Essex Museum in May 2022, and although the museum allows photographs, visitors cannot take videos or use panoramic cameras for more sophisticated capturing. In addition, due to the 30-minute visit time limit for each visitor, I was unable to capture enough photos of the target objects to complete the 3D reconstruction. There is also a problem with the size of the application. I

except for obtaining 3D modeling resources from limited open-source websites, most of the modeling work was done in Maya, which resulted in lower quality and resolution than expected. Without considering device configuration and game engine size limitations, I would prefer to use photogrammetric models to complete the virtual construction of the entire architecture in the future. Of course, we cannot ignore the benefits of low-polygon models. The main advantage of these models is the performance cost and file size, which can be greatly reduced compared to high-resolution polygon counts. Furthermore, lighter models can avoid frame loss or lag in the 3D world and can be well integrated into mobile platforms since they use less computing power.[3]Therefore, it is a good choice to use models of different qualities for different platforms and their memory sizes. Another possibility is to combine high-polygon and low-polygon models and place them in different stages of the virtual tour. For example, in the PEM-Yin Yu Tang project, a low-poly house model was presented as a separate module, where visitors can click on this tiny house model to locate and zoom in on different areas of the house (see fig. 23).

---

noticed that UE5 spends a lot of time on rendering models with rich meshes, and the limited hardware of the device makes it impossible to put a lot of high-resolution models in the application, otherwise, there will be a risk of the program crashing or VR monitor lagging.

[3] "Why You Need Both Low-Poly and High-Poly 3D Models for Virtual Reality," We Design Virtual, June 2, 2021, http://wedesignvirtual.com/why-you-need-both-low-poly-and-high-poly-3d-models-for-virtual-reality/.

Another parameter that affects user immersion is the design of realistic physical characteristics and visual effects. The former can reproduce the physical characteristics of a building, such as gravity, resistance, and friction, to provide users with a more realistic experience during their interaction with the architectural structure. Another way to enhance immersion is to work on sound effects. Developers can use 3D sound technology to simulate the environmental sounds of Huizhou architecture, such as bird songs, water sounds, and wind sounds. The visual effects design of the environment complements the sound effects. For instance, with the support of the advanced global illumination system of the Unreal Engine platform, some game designers create and introduce virtual weather systems into their games based on UE5's simulation and performance capabilities of different particle effects, lighting effects, and dynamic weather. The richer weather system in video games can assist in pushing the game's plot,[4] and in the case of a virtual architectural museum, it can better simulate the visual effects of a building in different weather conditions.[5]

---

[4] In a 2017 experiment on Unreal Engine weather system simulation, researchers organized a video game virtual environment immersion and realism experience with 37 participants. The study was divided into two control groups, the first being a game that simply had a static weather system and the second being a game environment that would simulate a constantly changing storm. The results of the study showed that most players had a strong preference for a rich weather simulation compared to a static environment. Scott Roborts and Dale Patterson, "Virtual Weather Systems," in *Proceedings of the Australasian Computer Science Week Multiconference*, 2017. https://doi.org/10.1145/3014812.3014878.

[5] If visitors are to make a field trip to a cultural heritage site, the environmental landscape they experience is bound to be affected by unavoidable factors such as weather, and the accessibility of the virtual museum is reflected in the possibility that visitors have the option to experience a visit in different environments/weather.

5. Conclusion

In the past, when I thought about architectural studies or architectural history, I would envision sacred palaces or solemn chapels. Even when it comes to museums, I would also tacitly agree that this is an institution that has a threshold of participation and requires its audience to have a certain knowledge reserve in order to make sense of he cultural information. Excitingly, the development of information technology and changes in media functions have gradually altered the public's stereotypes of museums or architecture, erasing the distance of architectural "majesty" from broader public access. One reason for this change is that technology has made information and knowledge more transparent, increasing our accessibility to unfamiliar niche architectural cultures, making the world thousands of kilometers away more accessible to us, giving us more options, and turning us from passive receivers to active learners.

However, despite this, we cannot take vernacular architecture or cultural heritage sites too easily for granted in a process of virtual migration. Architecture, especially vernacular architecture, is a collection of all spatial relationships that have been baptized over time and can be considered as an object of study across multiple disciplines. Especially for the traditional architecture of Huizhou, a symbol of cultural conventions that have been developed for thousands of years, we cannot explore it without considering the different spatial relationships between it and its generations of inhabitants. We also need to consider the different social and historical periods that

influenced it and the changing natural environment around it. This characteristic of architecture and regional culture makes them a difficult object of cross-cultural communication and learning even today when new means of communication are flourishing. But these dilemmas do not mean that the cross-cultural dissemination of indigenous cultures is completely impossible. In the five decades since the birth of VR, scientists and researchers have been searching for the ideal solution to this problem, and they have proposed a transformation of the role of museums and historical sites: using emerging technologies to facilitate the transformation of these sites from scientific, educational, and passive settings into empathetic, emotionally evocative, and culturally resonant places that inspire audiences.

These transformations are also taking place online. From previous researchers' practice of virtual reconstruction of museums, architectural complexes, and cultural sites, we can find that people's demand for virtual cultural products has expanded from the pursuit of high fidelity to the pursuit of richer interactive functions, deeper emotional resonance, and the pursuit of the realization and perfection of their spatial affordance. In related studies, most research comes from examples of European archaeology or more representative types of architecture in East Asia, such as Buddhist temples and palaces in northern China, and so on. The project I worked on is a study of regional architecture with Chinese characteristics. I learned that the difference in cultural concepts between the East and the West may lead to different understandings of

architectural design. Although all types of architecture involve the use of tools, machinery, and labor to construct various materials, the emphasis of Huizhou architecture is on organization, combination, and the way in which the pieces are carefully put together. From this perspective, another research focus or practical difficulty of this project is to demonstrate how virtual reality technology can serve as a cross-cultural bridge in architectural research, while conveying and helping to understand cultural content. The target audience of this project is Western viewers who are not familiar with the architectural culture of Huizhou, which means that as a designer in the digital project's design and implementation process, I cannot make any cognitive predictions about the audience group. This requires me to introduce the appearance, layout, and decoration of the target architecture in the most intuitive and easy-to-understand way, while distinguishing the target architecture from other common types of architecture in China or East Asia.

My thesis project starts from this level, taking *Yin Yu Tang* as the research object, and explores how to stimulate the audience's curiosity through the presentation of visual effects, the design of the interface, and the application of interaction. With these means, I attempt to realize intercultural communication with the example of vernacular architectural culture and an iterative storytelling model. The achievement of visual effects in virtual environments and the creation of a sense of presence for the audience depend heavily on the pursuit of realism during the modeling phase. In terms of digital

modeling, I have learned to analyze an entire building from an anatomical perspective, breaking it down into different spaces and studying how these spaces are combined with the building structure and historic objects. This is an important part of constructing their spatial relationships. Using the anatomical perspective to break down the building into its spatial components is the foundation for digital modeling different building structures. Adding details based on historical records and assigning textures to 3D polygons is the finishing touch that enhances the visual appeal of the models.

Another focus of this project is using virtual reality to promote accessibility and interactivity in order to create a "soft" and "borderless" architectural experience. Accessibility not only refers to providing users with a high degree of freedom to explore across time and space, but also means integrating a large amount of historical background information about the target architecture through different information architectural patterns and creating multi-perspective narrative modes about it. Users can filter out the information they don't need and choose the information that helps them better comprehend the development of the target architecture within a limited time. This approach can be used in the reconstruction of a building, as well as in the curation of museums or cultural heritage sites with various technological supports. In this project, accessibility is mainly facilitated through interface design. Interaction design is another aspect, and its role throughout the virtual App is to enhance presence and immersion, and serve as users' constructive learning agency. In this project, the deployment of

functions such as teleportation, navigation, grabbing, and map markers is an important aspect that promotes project interactivity, enhances storytelling continuity, and arouses users' exploration interest.

The digital component of the thesis project represents only a fundamental prototype of the potential research in digital architecture and cultural heritage. As technology advances, the boundaries between knowledge and culture will gradually dissolve, making concepts like "soft museums" and "borderless architecture" increasingly feasible. By leveraging digital technology, people can connect and share experiences across different spaces and times, fostering closer relationships and a more integrated world. As digital cultural heritage continues to evolve, I believe cultural differences will no longer be a source of division but rather an opportunity to deepen our understanding and respect for other cultures. This, in turn, will help build a more diverse and inclusive society, where individuals from different backgrounds can move forward in harmony and mutual understanding.

Appendix: Photos and Illustrations

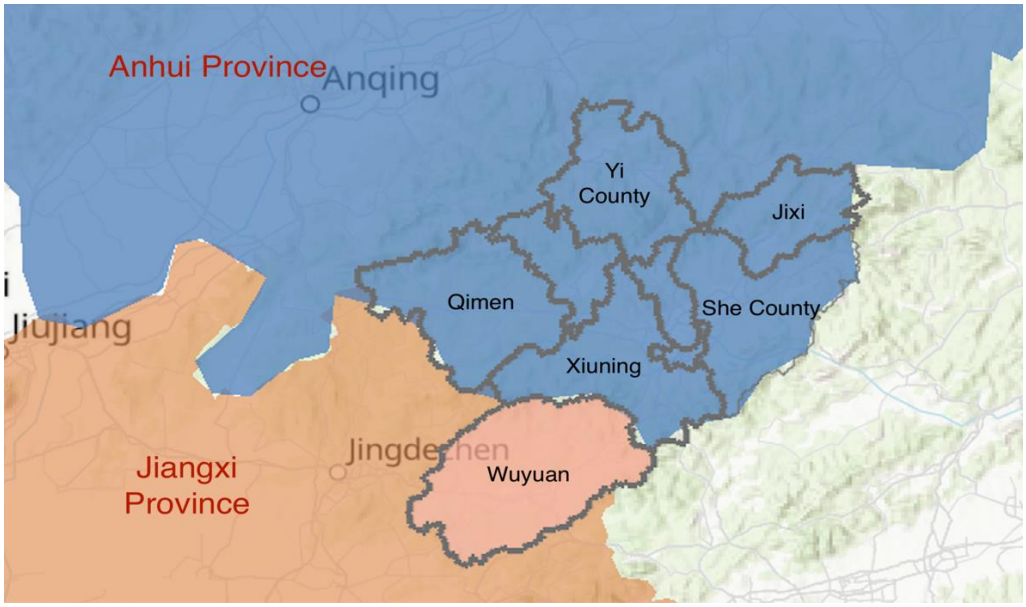

Figure 1: Ancient Administrative Divisions of Huizhou

Figure 2: Lightwell in Yin Yu Tang

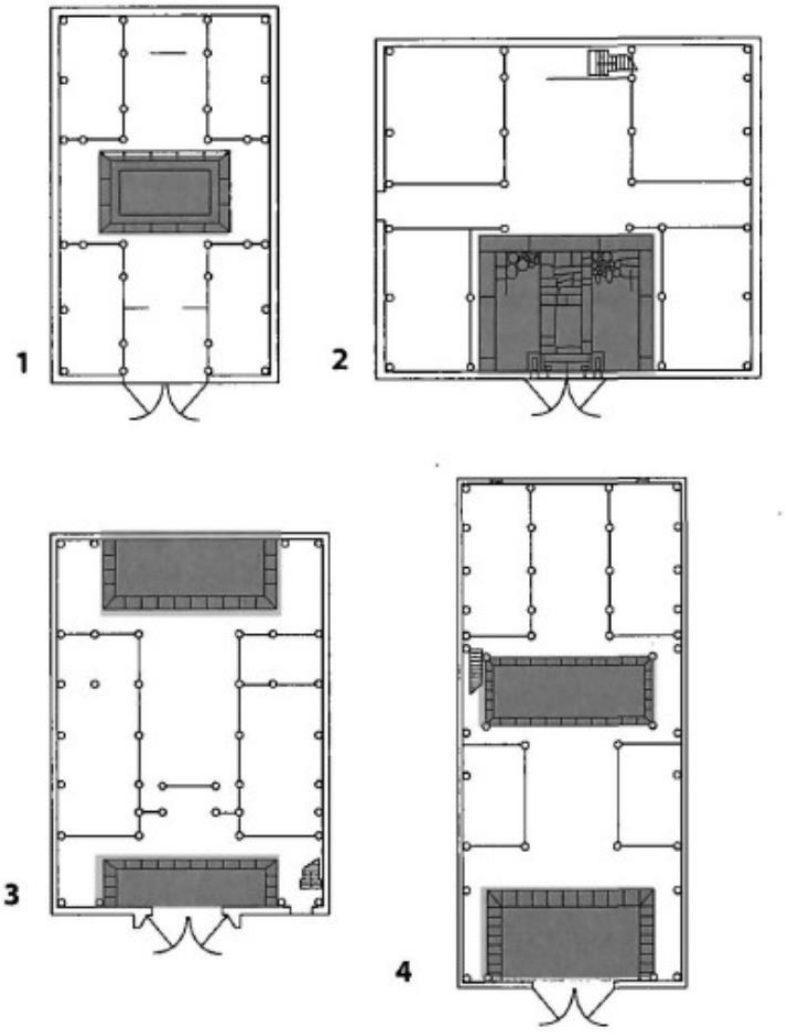

Figure 3: Four Different Layouts of Huizhou Architecture[1]

[1] Nancy Zeng Berliner, *Yin Yu Tang: The Architecture and Daily Life of a Chinese House* (Clarendon: Tuttle, 2014), 643.

Figure 4: Front Facade and Entryway of Yin Yu Tang Before Relocation[2]

[2] Nancy Zeng Berliner, *Yin Yu Tang: The Architecture and Daily Life of a Chinese House* (Clarendon: Tuttle, 2014), 751.

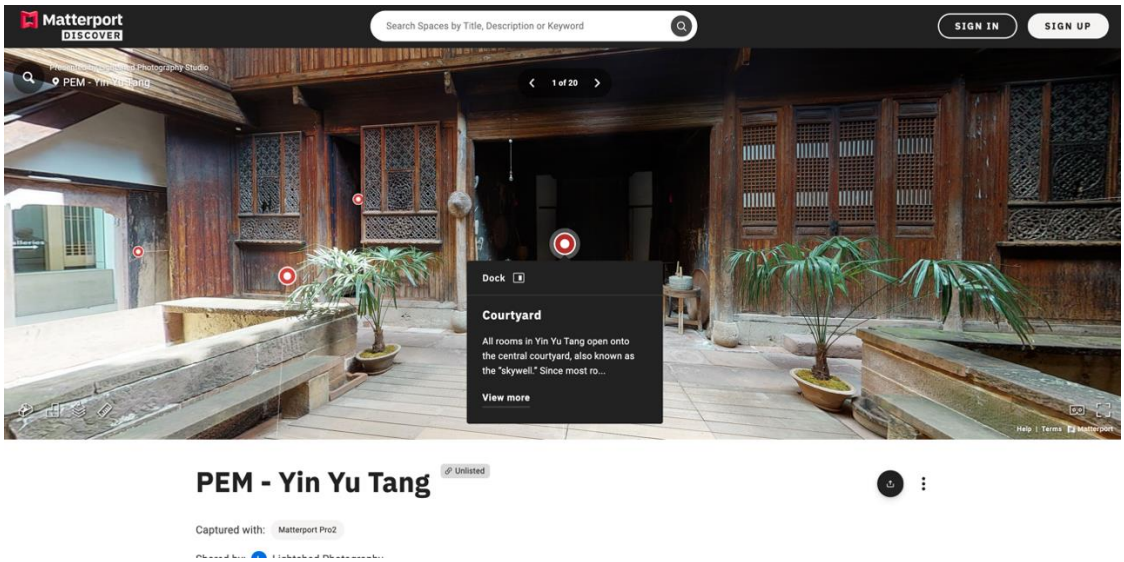

Figure 5: PEM - Yin Yu Tang Virtual Tour Interface

Figure 6: Pure Land Inside the Mogao Grottoes at Dunhuang[3]

[3] Pure land: Inside the mogao grottoes at Dunghuang - Sarah Kenderdine, accessed April 3, 2023, https://sarahkenderdine.info/installations-and-curated-exhibitions/pure-land-inside-the-mogao-grottoes-at-dunghuang.

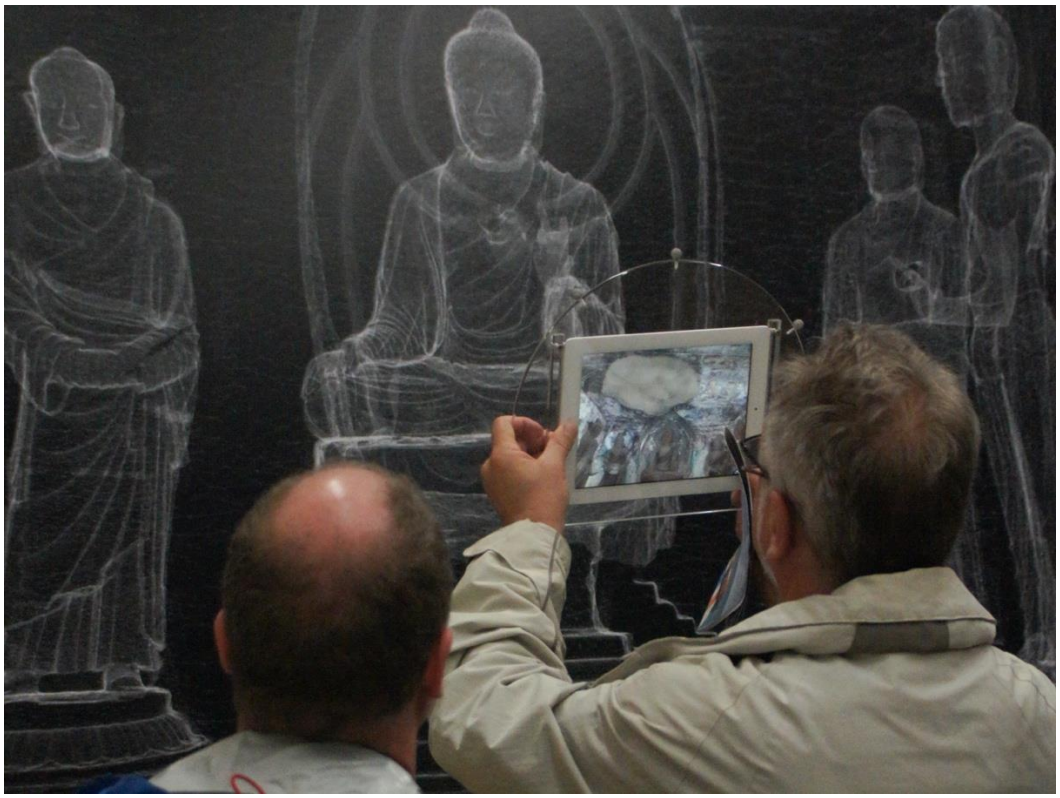

Figure 7: Pure Land AR Exhibition[4]

[4] Pure Land Ar - Sarah Kenderdine, accessed April 3, 2023, https://sarahkenderdine.info/installations-and-curated-exhibitions/pure-land-ar.

Figure 8: Pure Land VR Exhibition[5]

[5] Pure Land Unwired - Sarah kenderdine, accessed April 3, 2023, https://sarahkenderdine.info/installations-and-curated-exhibitions/pure-land-unwired.

Figure 9: Pure Land Cave Dome[6]

[6] Cave dome - sarah kenderdine, accessed April 3, 2023, https://sarahkenderdine.info/installations-and-curated-exhibitions/cave-dome.

Figure 10: PEM - Yin Yu Tang Measurement Function

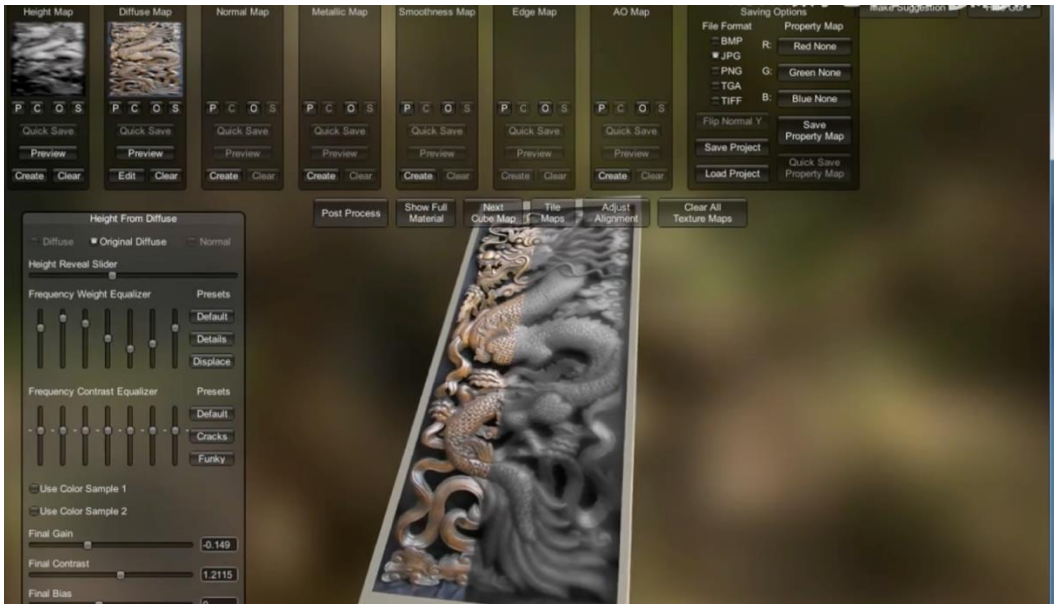

Figure 11: Zbrush Bas Relief Function

Figure 12: Quixel Bridge Surface Textures Categories

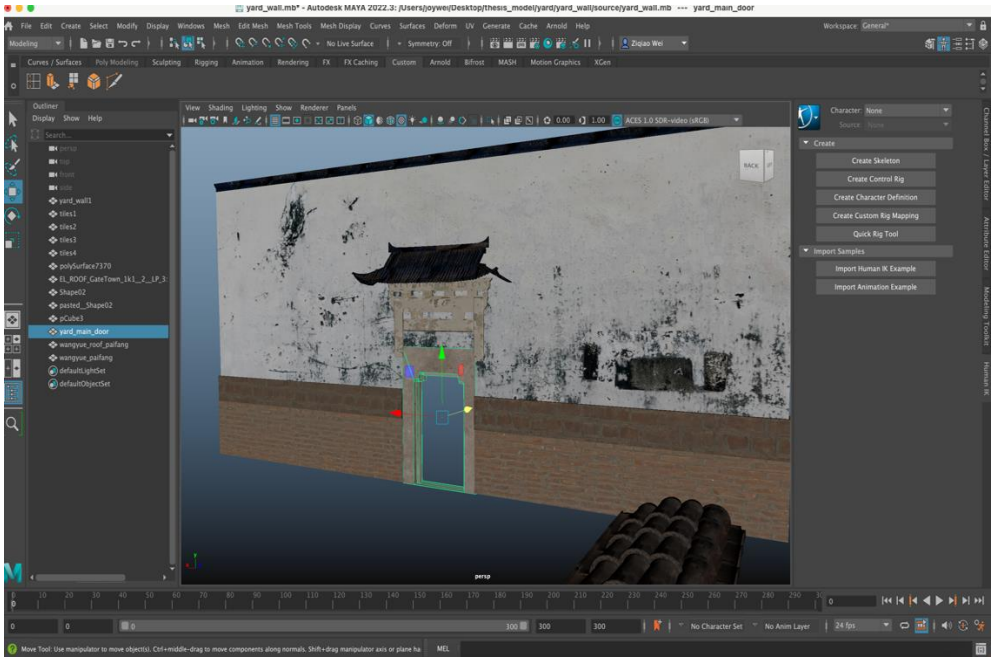

Figure 13: The Wall Model Using My Own Texture, the Screenshot from Maya

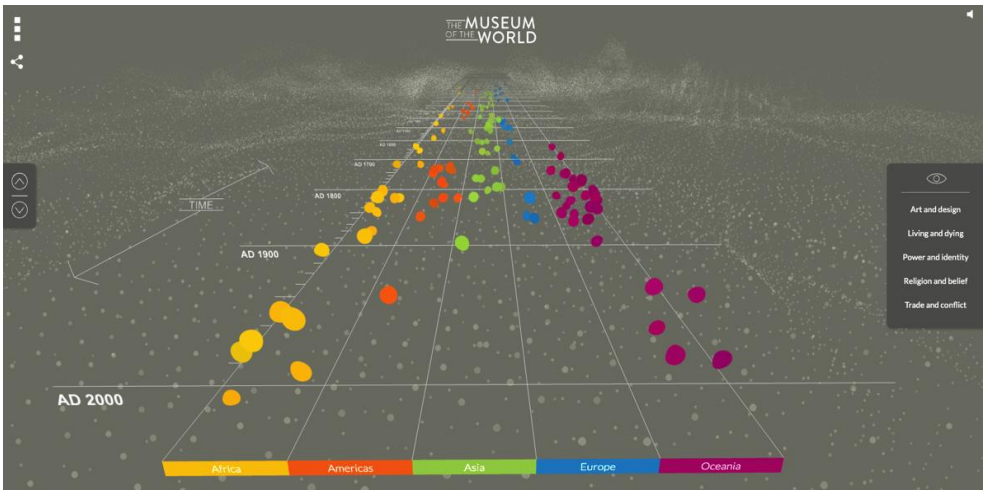

Figure 14: the Screenshot from the Museum of the World Interface

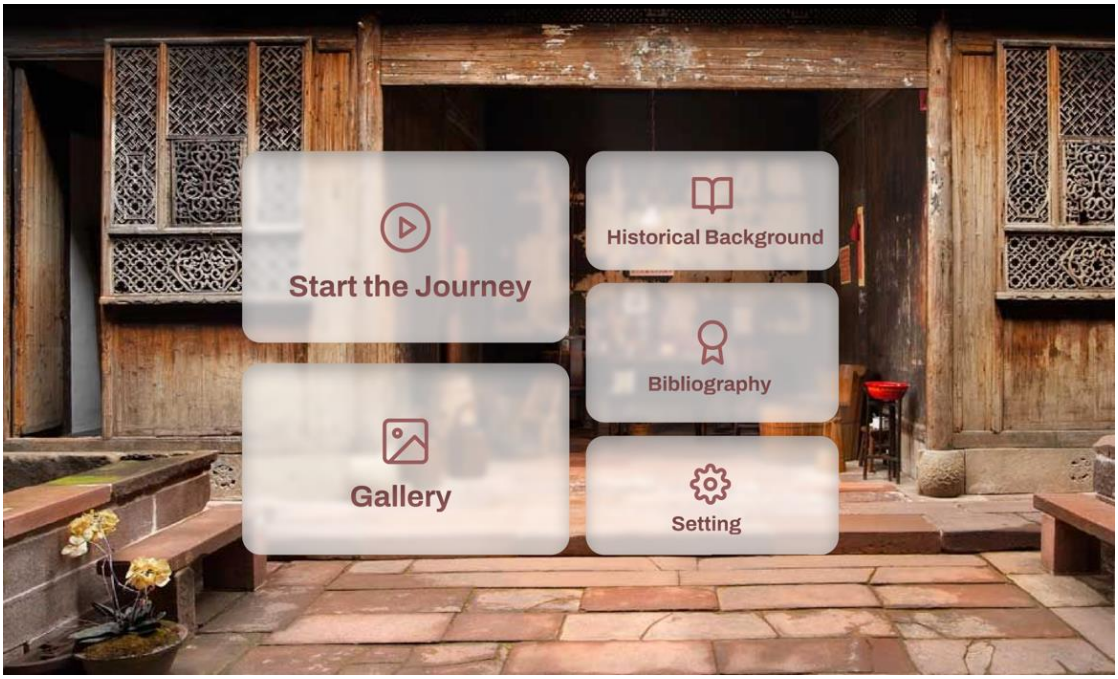

Figure 15: Virtual Huizhou App Main Menu

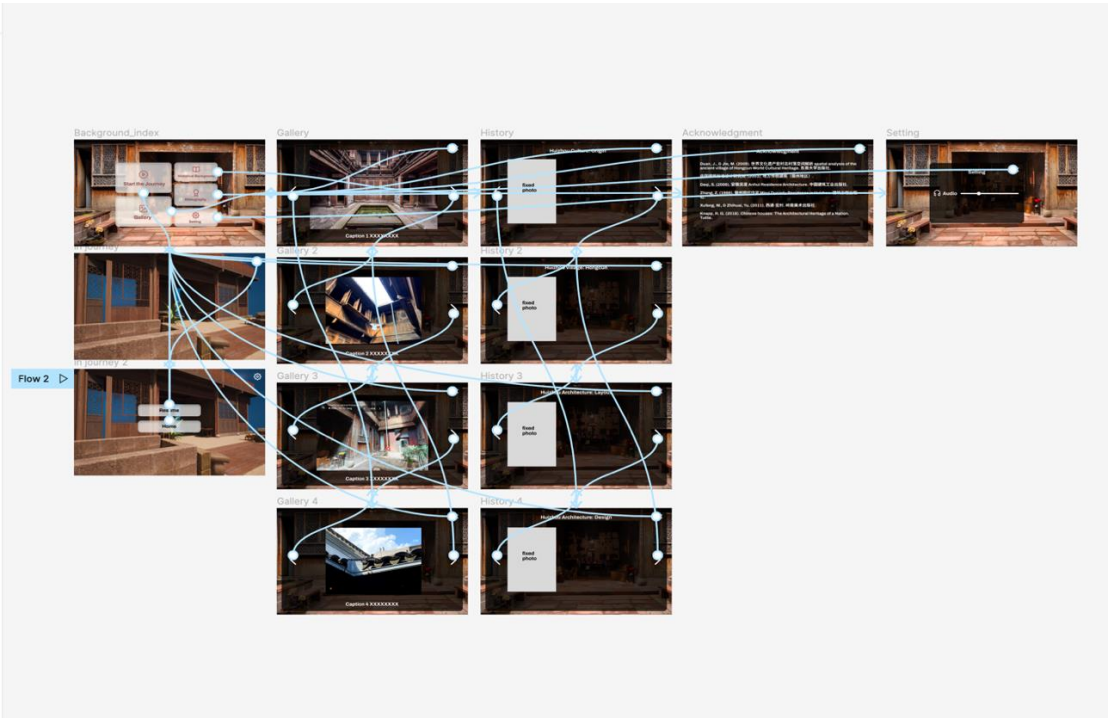

Figure 16: Virtual Huizhou App Wireframing in Figma

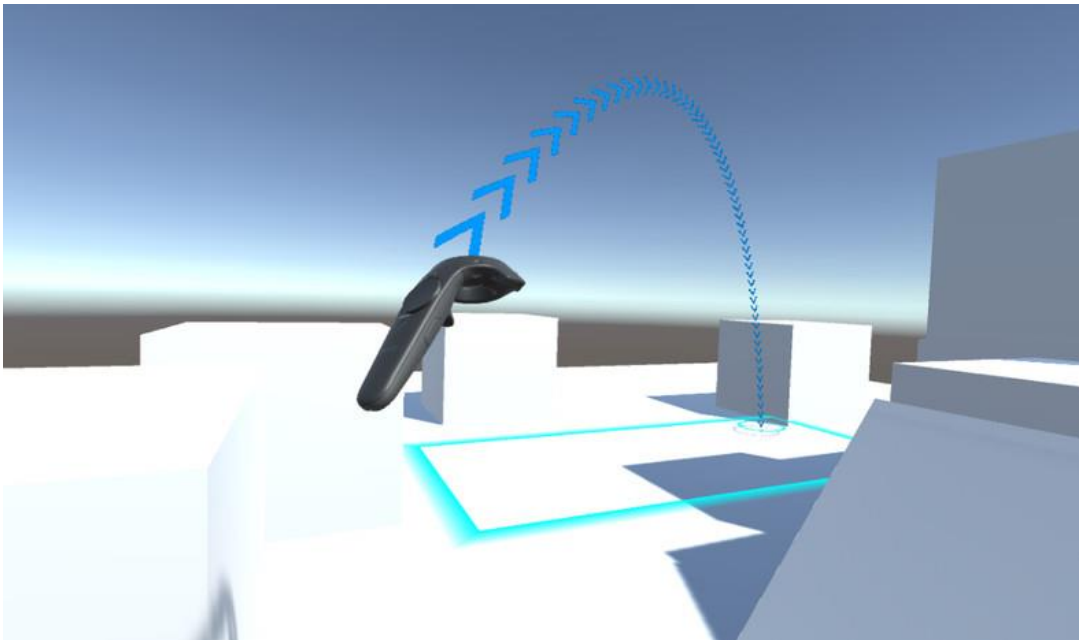

Figure 17: Simulation of Teleporting in UE5 VR Example

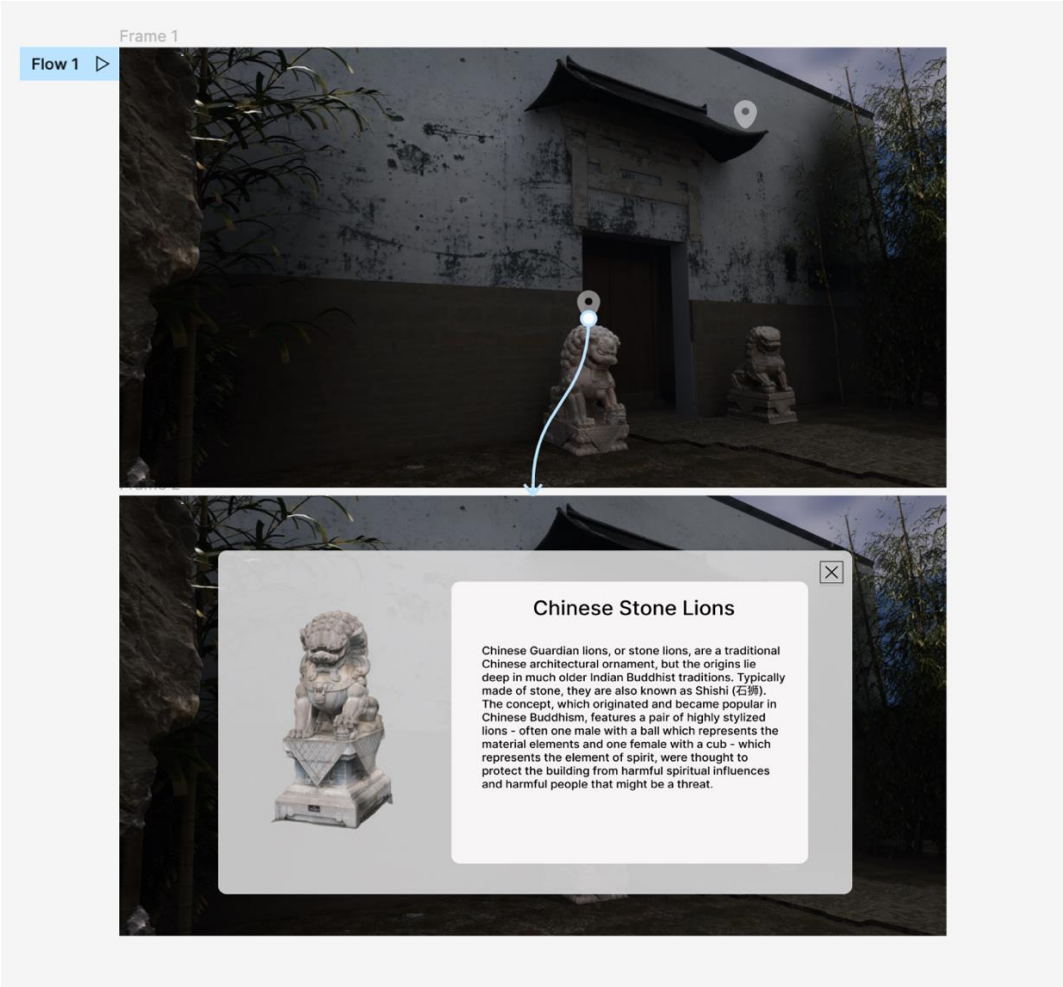

Figure 18: Virtual Huizhou App Pinpoint Interaction System (Prototyping in Figma)

Figure 19: Screenshot from UE5 in-game Environment 1

Figure 20: Screenshot from UE5 in-game Environment 2

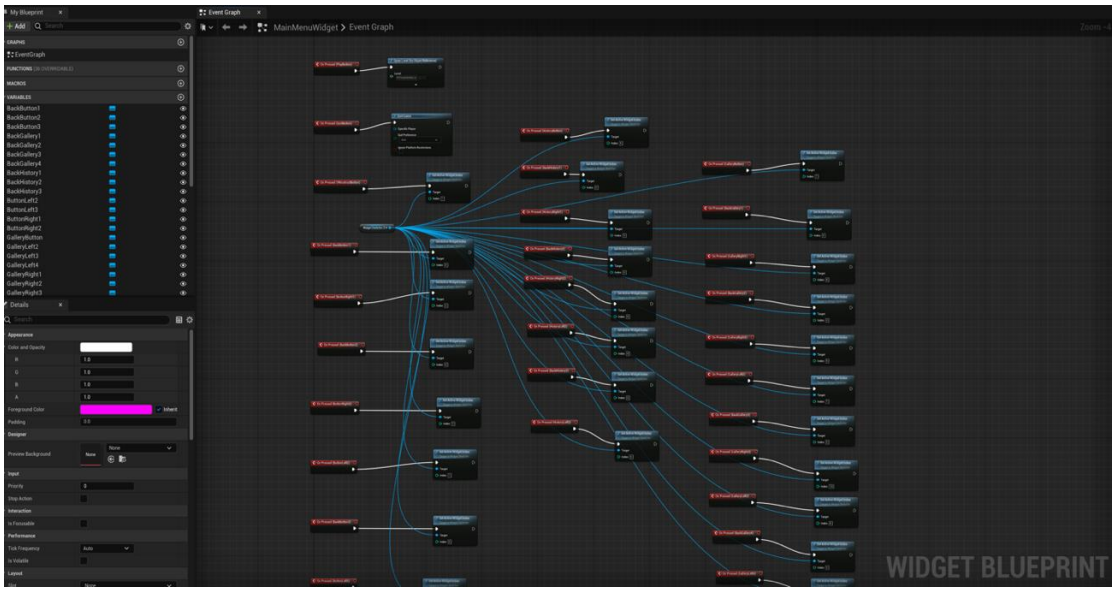

Figure 21: UE5 Main Menu Blueprints

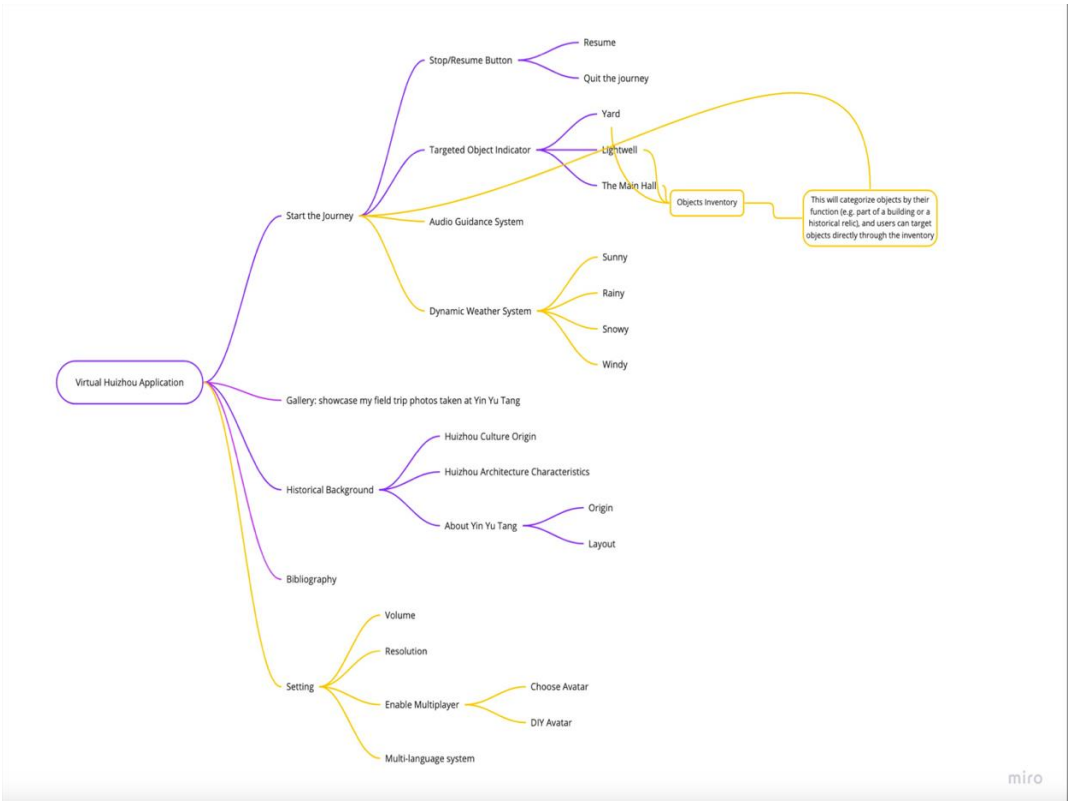

Figure 22: VR Huizhou Menu Structure 2.0 Version

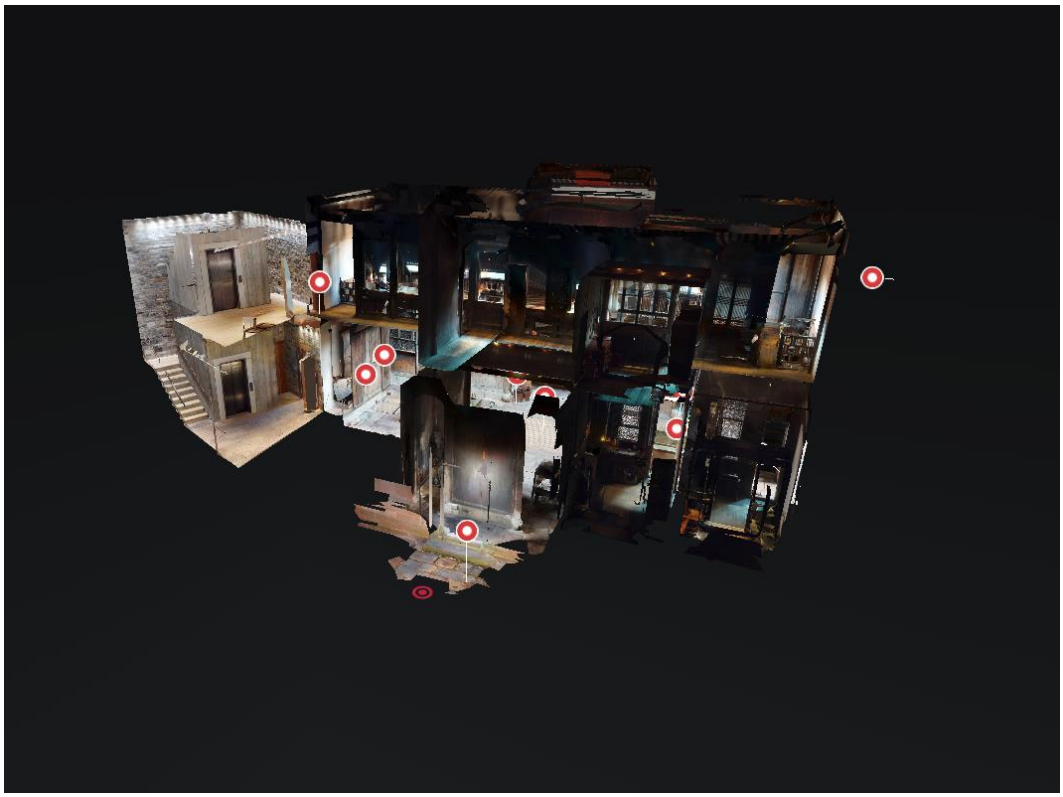

Figure 23: Dollhouse View of *PEM-Yin Yu Tang*

Appendix A: Media Resource and Written for the Digital Component of the Thesis

I recorded I recorded the entire tour of the *Virtual Huizhou* App as a video, which viewers can access via the YouTube link:

https://www.youtube.com/watch?v=rIoqhbENZf4.

When users open the application, they will see the main interface (lobby) with five buttons on it. Users can click each button to enter different modules of the application (see fig.24).

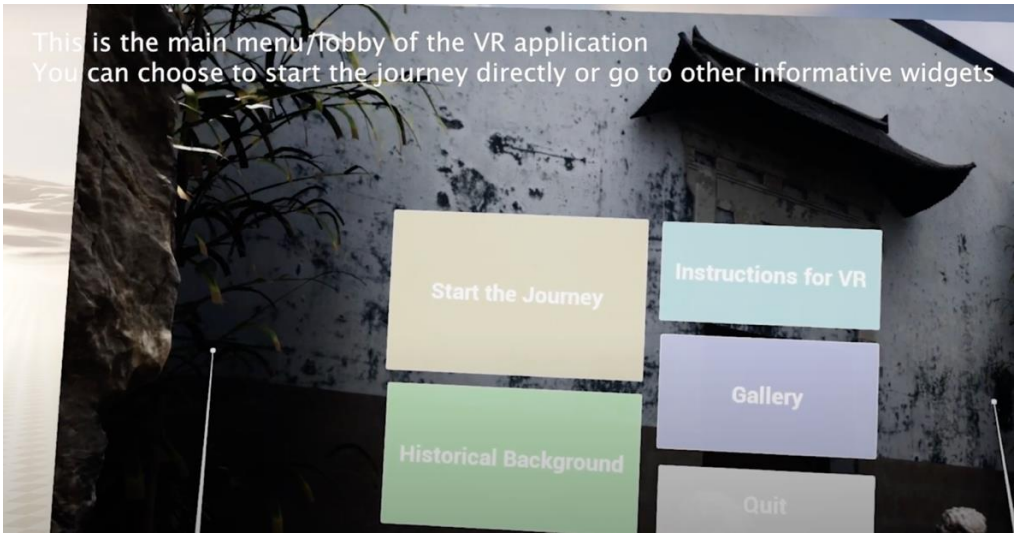

Figure 24: Screenshot of the Main Menu Interface

Users can get into the immersive world directly to click on the "Start the Journey" button (see fig.25).

Figure 25: Screenshot of the Starting Point View

I designed the module of the instruction for VR because I considered there will be a part of the users who are not very familiar with controllers. This module will teach users different functionality of the three main buttons on the controllers (see fig.26).

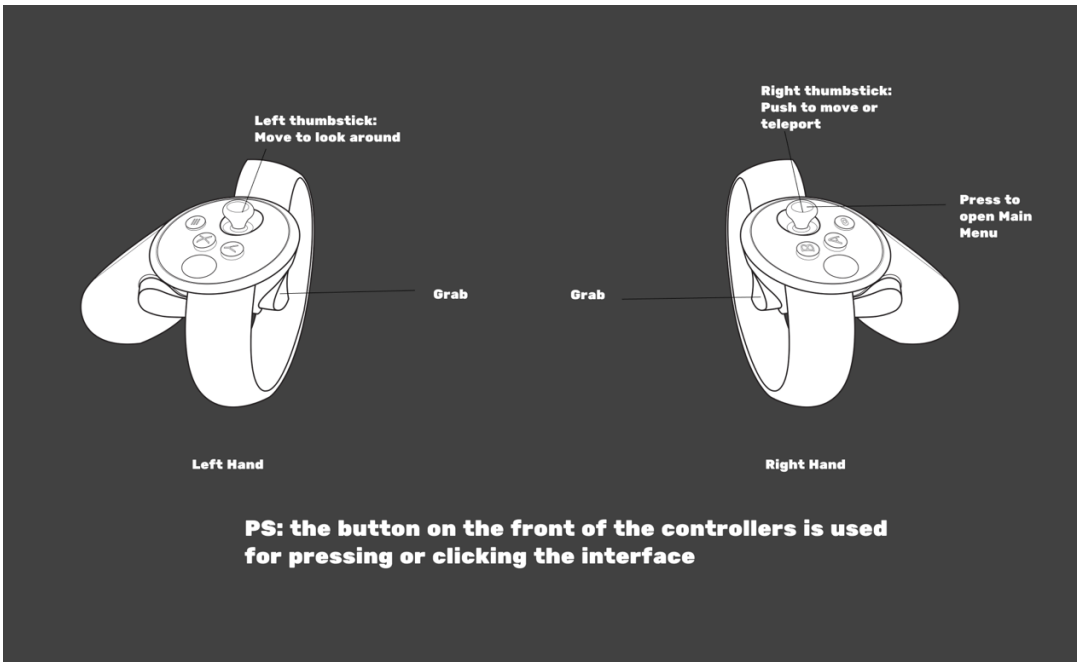

Figure 26: Figma Prototyping of Instructions Page

History background and Gallery module can be regarded as a very brief, concise version of the historical context part of my paper (see fig.27 and fig.28). Users can learn the history of Huizhou, the main features of its architecture, and the about page / introduction of my digital project.

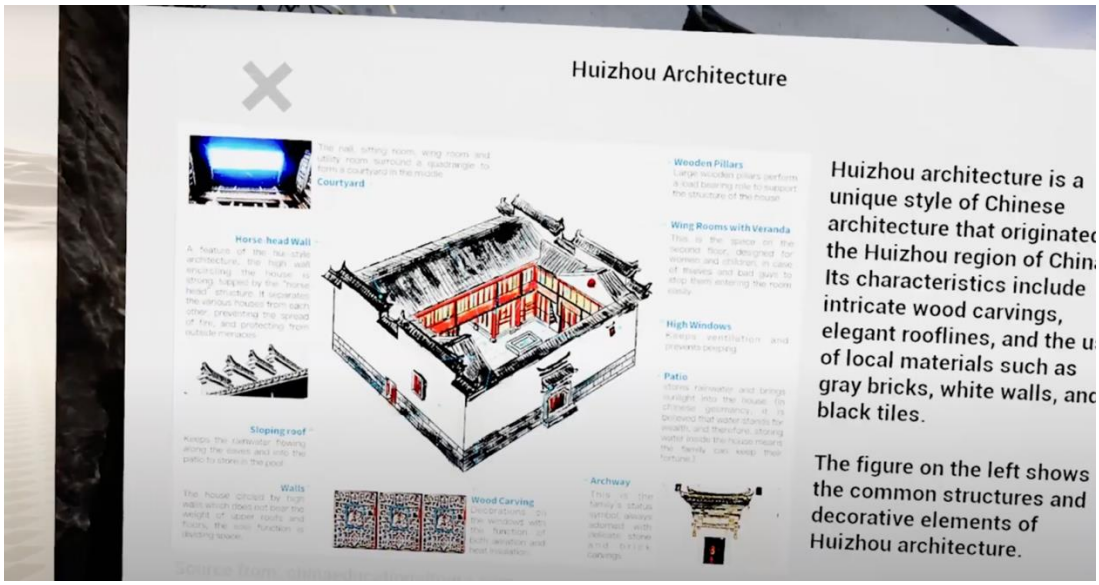

Figure 27: Screenshot of the Historical Background Page

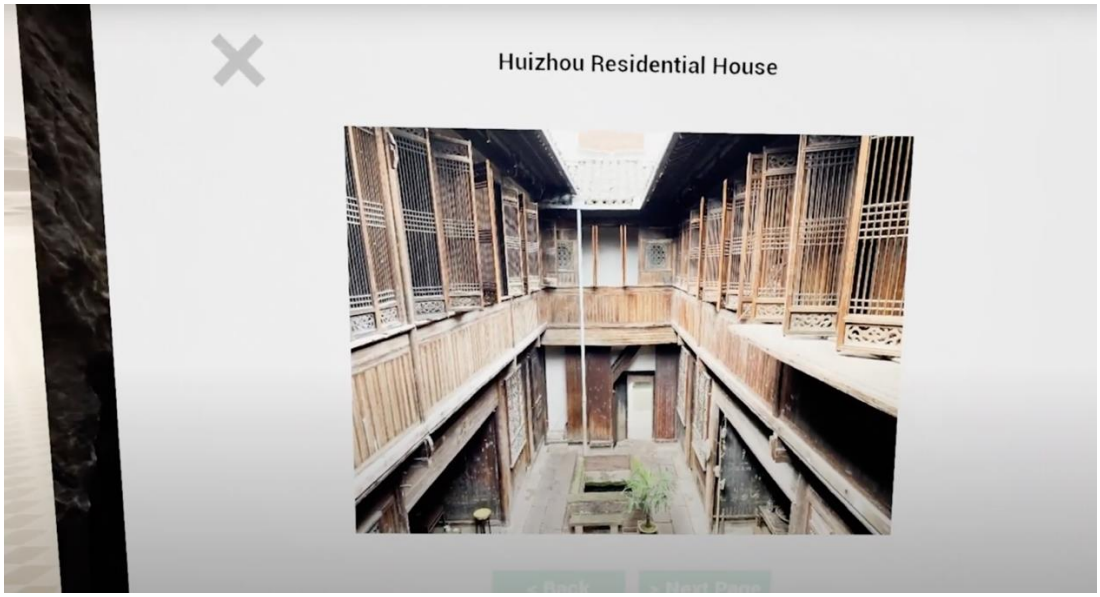

Figure 28: Screenshot of the Gallery Page

In the journey, users can navigate and teleport (see fig.29), interact with small objects (see fig.30), and interact with the map markers (see fig.31).

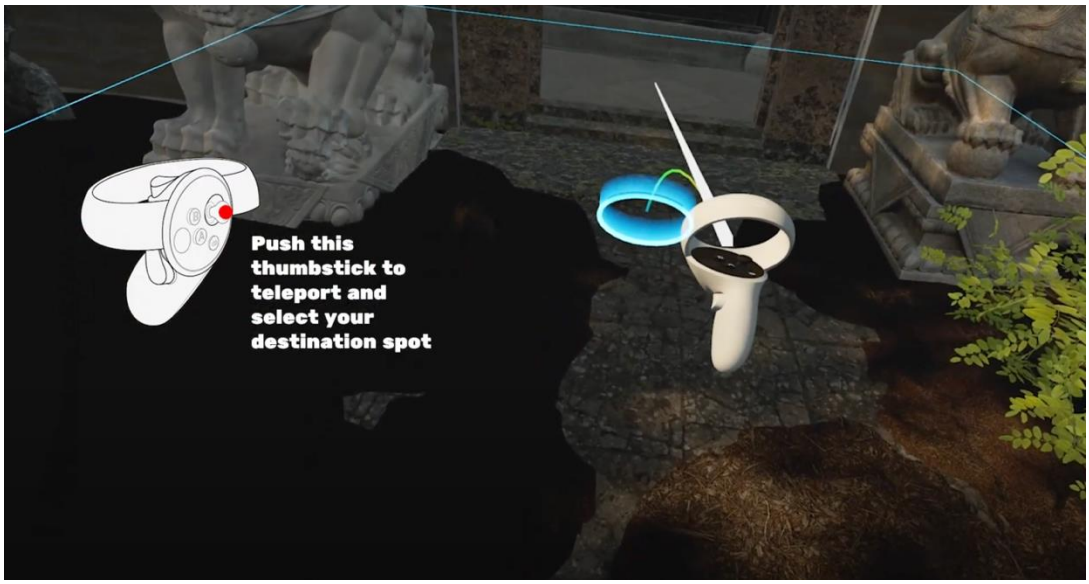

Figure 29: Teleportation

Figure 30: Grabbing the Item

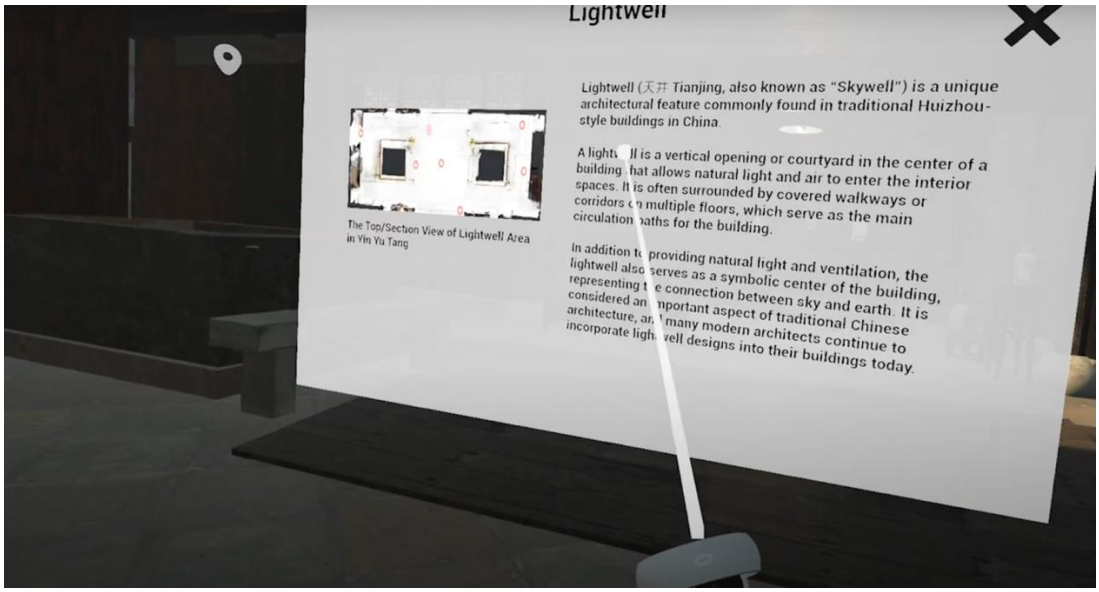

Figure 31: Opening a Map Marker

Bibliography

"3D Digital Twin Technology." Matterport. Accessed March 12, 2023. https://matterport.com/what-digital-twin.

"Baalbek Reborn Temple." Flyover Zone, January 25, 2023. https://www.flyoverzone.com/baalbek-reborn-temples/.

"Baalbek Reborn: Temples on Steam." Baalbek Reborn: Temples on Steam. Accessed March 12, 2023. https://store.steampowered.com/app/1370800/Baalbek_Reborn_Temples/.

Berliner, Nancy Zeng. *Yin Yu Tang: The Architecture and Daily Life of a Chinese House*. Clarendon: Tuttle, 2014.

"Blueprints Visual Scripting." in Unreal Engine | Unreal Engine 5.0 Documentation. Accessed March 14, 2023. https://docs.unrealengine.com/5.0/en-US/blueprints-visual-scripting-in-unreal-engine/.

Cave dome - sarah kenderdine. Accessed April 3, 2023. https://sarahkenderdine.info/installations-and-curated-exhibitions/cave-dome.

UNESCO World Heritage Centre. "Baalbek." UNESCO World Heritage Centre. Accessed March 12, 2023. https://whc.unesco.org/en/list/294/.

"Documentation | Bas Relief." ZBrush Docs. Accessed March 13, 2023. http://docs.pixologic.com/user-guide/3d-modeling/sculpting/bas-relief/.

Dowson, Thomas. "Baalbek Reborn: Take a Virtual Tour of Baalbek Ruins." Archaeology Travel, December 16, 2021. https://archaeology-travel.com/reviews/virtual-tour-baalbek/.

Duan, Jin., & Joe, Minghao 段进 & 揭明浩. 空间研究 4: 世界文化遗产宏村古村落空间解析 [*Urban Space: Spatial Analysis of the Ancient Village of Hongcun World Cultural Heritage*]. Southeast University Press 东南大学出版社, 2009.

Gordon, Sue. "The Virtual Museum - Who Needs It?" Essay. In *Archaeology in the Age of the Internet: CAA 97 Computer Applications and Quantitative Methods in Archaeology: Proceedings of the 25th Anniversary Conference University of Birmingham, April 1997*. Oxford: Archaeopress, 1999.

"How Matterport Works." Matterport. Accessed March 12, 2023. https://matterport.com/how-it-works.

"Introduction to Lighting and Rendering." Unity Learn. Accessed March 13, 2023. https://learn.unity.com/tutorial/introduction-to-lighting-and-rendering.

Knapp, Ronald G. *Chinese Houses: The Architectural Heritage of a Nation*. Singapore: Tuttle, 2018.

"Lighting the Environment." in Unreal Engine | Unreal Engine 5.1 Documentation. Accessed March 14, 2023. https://docs.unrealengine.com/5.1/en-US/lighting-the-environment-in-unreal-engine/.

Lercari, Nicola, Michela Mortara, and Maurizio Forte. "Unveiling California History through Serious Games: Fort Ross Virtual Warehouse." Lecture Notes in Computer Science, 2014, 236–51. https://doi.org/10.1007/978-3-319-12157-4_19.

Mah, Osten Bang, Yingwei Yan, Jonathan Song Tan, Yi-Xuan Tan, Geralyn Qi Tay, Da Jian Chiam, Yi-Chen Wang, Kenneth Dean, and Chen-Chieh Feng. "Generating a Virtual Tour for the Preservation of the (in)Tangible Cultural Heritage of Tampines Chinese Temple in Singapore." *Journal of Cultural Heritage* 39 (2019): 202–11. https://doi.org/10.1016/j.culher.2019.04.004.

"Meta Quest 2: Our Most Advanced New All-in-One VR Headset | Oculus." Accessed March 13, 2023. https://www.meta.com/quest/products/quest-2/tech-specs/.

Miranda, Giovanna F., Francesca Gualtieri, and Paolo Coccia. "How the New Web Generations Are Changing Library and Information Services." *Medical Reference Services Quarterly* 29, no. 2 (2010): 132–45. https://doi.org/10.1080/02763861003723200.

Murray, Janet Horowitz. *Inventing the Medium: Principles of Interaction Design as a Cultural Practice*. Cambridge, Mass: MIT Press, 2012.

Parry, Rose, and John Hopwood. "Virtual Reality and the 'Soft' Museum: A Call for Further Research." *Journal of Museum Ethnography* 16 (2004): 69–78. https://doi.org/10.7551/mitpress/11836.003.0013.

"Pem - Yin Yu Tang." Matterport Discover. Accessed March 12, 2023. https://matterport.com/discover/space/kRixnE75JdY.

Pure Land Ar - Sarah Kenderdine. Accessed April 3, 2023. https://sarahkenderdine.info/installations-and-curated-exhibitions/pure-land-ar.

Pure Land Unwired - Sarah kenderdine. Accessed April 3, 2023. https://sarahkenderdine.info/installations-and-curated-exhibitions/pure-land-unwired.

Pure land: Inside the mogao grottoes at Dunghuang - Sarah Kenderdine. Accessed April 3, 2023. https://sarahkenderdine.info/installations-and-curated-exhibitions/pure-land-inside-the-mogao-grottoes-at-dunghuang.

Shan, Deqi 单德启. 安徽民居 [*Anhui Ancient Residences*]. China Architecture & Building Press 中国建筑工业出版社, 2010.

Shan, Deqi 单德启 et al. 地方传统建筑：徽州地区 [*Traditional Architecture: Huizhou Region*]. Beijing: Ministry of Housing and Urban-Rural Development 中华人民共和国建设部, 2003.

Rebelo, Francisco, Paulo Noriega, Emília Duarte, and Marcelo Soares. "Using Virtual Reality to Assess User Experience." *Human Factors: The Journal of the Human Factors and Ergonomics Society* 54, no. 6 (2012): 964–82. https://doi.org/10.1177/0018720812465006.

Roberts, Scott, and Dale Patterson. "Virtual Weather Systems." *Proceedings of the Australasian Computer Science Week Multiconference*, 2017. https://doi.org/10.1145/3014812.3014878.

Joy Wei, "VR Huizhou Application Overview," YouTube Video, 3:34, Mar 29, 2023, https://www.youtube.com/watch?v=rIoqhbENZf4.

Sherman, William R., and Alan B. Craig. *Understanding Virtual Reality: Interface, Application, and Design*. Cambridge, MA: Morgan Kaufmann, 2019.

"Unreal Engine 5 Documentation." Unreal Engine 5.0 Documentation. Accessed March 13, 2023. https://docs.unrealengine.com/5.0/en-US/.

Vilar, Elisângela, Francisco Rebelo, Paulo Noriega, Ernesto Filgueiras, and Emília Duarte. "Virtual Reality in Architecture and Design: Twenty Years of Experience." *Virtual and Augmented Reality for Architecture and Design*, 2022, 1–16. https://doi.org/10.1201/9781003051381-1.

"Visit the Yin Yu Tang House: Peabody Essex Museum." pem.org. Accessed March 13, 2023. https://www.pem.org/visit/yin-yu-tang.

"Vive Pro 2 Specs: Vive United States." VIVE. Accessed March 13, 2023. https://www.vive.com/us/product/vive-pro2/specs/.

Wang, Annie, Meredith Thompson, Cigdem Uz-Bilgin, and Eric Klopfer. "Authenticity, Interactivity, and Collaboration in Virtual Reality Games: Best Practices and Lessons Learned." *Frontiers in Virtual Reality* 2 (2021). https://doi.org/10.3389/frvir.2021.734083.

"Weidi Zhang, Donghao Ren: Cangjie." ACM SIGGRAPH ART SHOW ARCHIVES. Accessed March 12, 2023. https://digitalartarchive.siggraph.org/artwork/weidi-zhang-donghao-ren-cangjie/.

Wu, Xufeng., & Yu, Zhihuai 武旭峰 & 余治淮. 中国十佳魅力古镇世界文化遗产：西递宏村 [*United Nations Educational Scientific and Cultural Organization: Xidi Hongcun*]. 岭南美术出版社, 2011.

"Yin Yu Tang House Virtual Tour: Peabody Essex Museum." Virtual Tour: Yin Yu Tang. Peabody Essex Museum. Accessed March 12, 2023. https://www.pem.org/visit/yin-yu-tang/yin-yu-tang-tour.

Zhang, Zhongyi 张仲一, ed. 徽州明代住宅 [*Ming Dynasty Huizhou Residences*]. Beijing Jianzhu Gongcheng Chubanshe 北京建筑工程出版社, 1957.