VIRTUAL REALITY AND HISTORIC PRESERVATION

A Thesis

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of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Master of Arts in Historic Preservation Planning

by

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ABSTRACT

This thesis explores the factors involved in the application of virtual reality technology to historic preservation through a review of the literature on the history of virtual reality, two case studies on the use of virtual reality at Chinese heritage sites, and a social science experiment. The results indicate that virtual reality can facilitate heritage preservation through improved visual presentation and interpretation of site content, tourism management, documentation technology, public participation, and cross-cultural communication. Virtual reality technology challenges traditional preservation norms as it generates an immersive environment that meets the needs of a wider audience, regardless of place and time. Virtual reality technology enhances the interactive experience between heritage objects and users. As is the case for all human-computer interactions, virtual reality technology has a cultural component, which requires further research.

BIOGRAPHICAL SKETCH

Lei Yang was born in Xi'an, China. After finishing her undergraduate degree in Urban Planning in China, she was sent to the US by her parents in 2012 to pursue further education. Between 2012 and 2014, she studied Architecture Design in Washington University in St Louis, MO and earned her Masters of Architecture degree in summer 2014. Living alone in another culture for the first time gradually enlarged her seeing points of view. To further her architecture career, she joined Historic Preservation Planning (HPP) program in Cornell University in August 2014, another life adventure she could not have foreseen. During her study in HPP Cornell, she constantly got involved and challenged by western and eastern thinking. The most memorable and inspiring experience to her is the numbered field trips with other HPP students led by program professors Dr. Tomlan and Prof. Chusid during 2014 to 2016, which exposed her to the diverse local culture of this country. She also spent her summer in the Israel Museum, in Jerusalem as an intern in 2015, which enabled her seeing other prospective career field. Lei Yang is currently working in New York City as a preservation architect. With specific interest in "Virtual Reality" she looks forward to creatively implementing her preservation thought into practice with this new medium in the future.

To My Parents

ACKNOWLEDGMENTS

I would like to first give my thanks to my thesis advisor Dr. Michael Tomlan of the HPP Program at Cornell University. He consistently allowed this paper to be my own work, but steered me in the right direction whenever he thought I needed advice. As the program director teaching several courses, he is still willing to put aside his busy work and set up a time meeting with me regularly, to answer my naïve questions regarding my thesis topic and preservation in general during my two-years in the Historic Preservation program. I am very thankful for him being patient to educate me and push me further than I thought I could go.

I would also like to thank Assistant Professor Erik Anderson and his undergraduate student Alan Chen in Computer Science Department at Cornell University, who has been involved in the Virtual Reality experiment and the survey from 2015 to 2016. Without their passionate input, the experiment and the survey could not have been successfully conducted.

Finally I must express my profound gratitude to my parents for providing me with continuous encouragement throughout my years of study and the process of writing this thesis. This accomplishment would not have been possible without them. Thank you.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

VR	Virtual Reality Environment
VRE	Virtual Reality Environment
Non-VRE	None-Virtual Reality Environment
RCA	Radio Corporation of America
NBC	National Broadcast Company
CBS	Columbia Broadcasting Company
VHF	Very High Frequency
UHF	Ultra High Frequency
FRC	Federal Radio Commission
FCC	Federal Communication Commission

INTRODUCTION

Humans view the world in a completely different way from other animals, such as dogs, cats, and birds. We see a certain amount of the available wavelengths of lights as colors, for example, while many of animals do not have the ability to see in color. On the other hand, they have capabilities we do not have. This shows that what we and these other creatures visually perceive is sensory data, rather than real properties of objects.

In today's Arts and Humanities research, the tendency to obtain and process a large amounts of data is increasing, thanks to ever more powerful computerization. The data is drawn from disparate locations, and concerns objects, properties, landscapes, monuments, and current human behaviors. All of these are unique to preservation research, because in today's strategy the past is still appreciated and appropriated through the archives. Some of this data is only sensory, however it can be manipulated to provide alternative views of realities, and explore histories for which the physical evidence is fragmentary. For heritage, visualization technology provide power to enhance people sense of presence, as if one is being immersed in a psychological state where, "virtual objects are experienced as actual objects in either sensory or non sensory ways," or "a state of consciousness, the (psychological) sense of being in the virtual environment." It is therefore an increasingly to understand the virtual reality as the advanced visualization technology in heritage professionals.

This thesis focuses is primarily on virtual reality as a presentation media and how this media facilitates preservation advocacy by providing additional content, bringing to life the documentation contained in the archives and libraries. The emphasis also brings a new tool and added convenience to heritage management.

The principal methods used in this work are qualitative. They include a review of the literature that describes virtual reality from a theoretical and applied perspective, focusing on the last three decades. The references can be found chiefly in Cornell University Library database. This includes academic and commercial sources. The additional method included a questionnaire survey to gather from select participants in an experiment to test the cultural values in a virtual reality environment. The questionnaire followed up the experiment conducted in May 2016 in the Information Science Department in Gates Hall and in the Department of City and Regional Planning in West Sibley Hall at Cornell University.

The thesis begins with looking at the development history of virtual reality technology and its general implementation in the historic preservation field. From the idea emerging from the film industry in 1950 to the first attempt demonstrated in 1970 by computer scientists, and to today's virtual reality headset in the market, the Virtual Reality concept has been reinforced after half century's trial. Groups from different backgrounds become interested in the application of this technology as well. They have dedicated their wisdom and made assumptions on the potential benefits in historic preservation field.

The second chapter seeks the root of virtual reality technology from a mechanical perspective. By reviewing developments that begin with the first telecommunication tool, the telegraph, it is clear to see that Virtual Reality is a higher level of electronic communication form. The future application of this new medium could empirically diminish the use of the lower quality of previous one and absorb the essence of it to generate an enhanced interactive telecommunication form.

The third chapter discusses the significance of human vision in facilitating perception of the world. Various optical methods are invented in different time periods to satisfy human being's need of the realities, as is reflected in art, such as through painting,

and in technology, such as through photography and motion pictures. Virtual Reality in this respect, is part of the field with upgraded vision-based technology.

The fourth and fifth chapters present two case studies on the implementation of virtual reality technology in China. The fourth chapter describes the Dunhuang Grotto heritage project and focuses on the possibility of using virtual reality to facilitate heritage documentation, interpretation and tourist site management. The fifth chapter explores the significance and inspiration of a shikumen project in Shanghai through heritage documentation and public participation. Though the two projects are in different scales, the application of virtual reality indicates that this so called "high technology" is both accessible to professional and non-experts in documenting and presenting historic sites for different appropriate purposes.

In light of the theoretical statements above, how can a virtual environment impact humans' experience of cross-cultural content? Given the fact that anyone involved in historic preservation is inevitably confronted with single or multiple cultures, how can a virtual environment be influencing peoples' perception of cultural content? Although psychology and communications researchers have been studying the impact of virtual reality on the sense of presence and cognition of human beings, there is still a dearth of research focusing on cross-cultural situations. The fifth chapter is the report of an experiment conducted to address this question. It consists of three parts: a literature review, a description of the experiment, and an analysis of the results. Evidence exists to demonstrate that an immersive virtual environment is relatively powerful than a traditional non-virtual presentation environment.

The last chapter is the general conclusion of the thesis. It summarizes each chapter's findings, describes the omissions and shortcomings of the current work, and explores the possibility of utilizing virtual reality in future heritage preservation work.

CHAPTER 1

A BRIEF OVERVIEW OF VIRTUAL REALITY

1. Virtual Reality as an Illusion

Virtual reality creates a world that is a product of the human imagination. It is, thus, as old as human history. Indeed, long before the rise of modern technology, human beings were creating virtual experiences through literature and art. Through looking at the paintings, carvings, texts, and objects that record human thoughts and stories we can participate in a kind of virtual reality experience. In modern times and historically, humans have turned to naturally occurring psychoactive substances, hallucinogens, and manufactured pharmaceuticals to have or enhance these experiences. Not all of the experiences of alternate realities are voluntary. Some psychiatric disorders cause hallucinations that can be mistaken by the sufferer as real. Whether through art, drugs, or illness, the human brain is capable of experiencing reality as different from what it actually is.

Historically, virtual reality was perhaps most commonly used by religion as a method to convey the experience of a divine, righteous, and eternal spiritual world to those existing in the physical world.[1] Religious architecture stirs visitors' emotions and turns their thoughts to the spiritual realm through the composition of the structure and through the use of light, shadow, art, and music. For thousands of years, human beings

[1] Blascovich, Jim, and Jeremy Bailenson. *Infinite Reality*, New York: HarperCollins Publishers, 2011, p. 22.

have used these methods in an attempt to create what modern people might call a virtual experience.

2. A Brief Definition of Virtual Reality

Today the most important tool for creating virtual experiences is media-based. According to some scholars, virtual reality is defined as "a technology that convinces the participant that he or she is actually in another place by substituting the primary sensory input with sensory data produced by a computer."[2] Virtual reality can also describe a workspace wherein the user identifies with a virtual body and feels a sense of belonging towards a virtual community.[3]

2.1. Pre-1960's: From Imagination to Optical Equipment

In the 1950s, cinematographer Morton Heilig, with the ambition of creating a "cinema of the future," attempted to build a multi-sensory experience, which he called the Sensorama. The Sensorama consisted of a seat and a semi-enclosed, three-sided box where a user could insert his head to enjoy the immersive experience. With a vision that future theater would effectively engage all the senses, Heilig included sights, sounds, aromas, vibrations, and touch sensations (e.g. wind) in the Sensorama. The Sensorama is one of the earliest known examples of a multimodal technology.

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[2] Heim, Michael. *Virtual Realism*, p. 221. New York: Oxford University Press, 1998.
[3] Ropolyi, László. "Virtuality and Plurality. In virtual Reality: cognitive Foundations, Technological Issues and Philosophical Implications." Edited by Alexender Riegler, Markus F. Peschl, Karl Edlinger, Gunther Fleck and Walter Feigl, p. 167-187. Frankfurt am Main: Peter Lang Publishing, 2001.

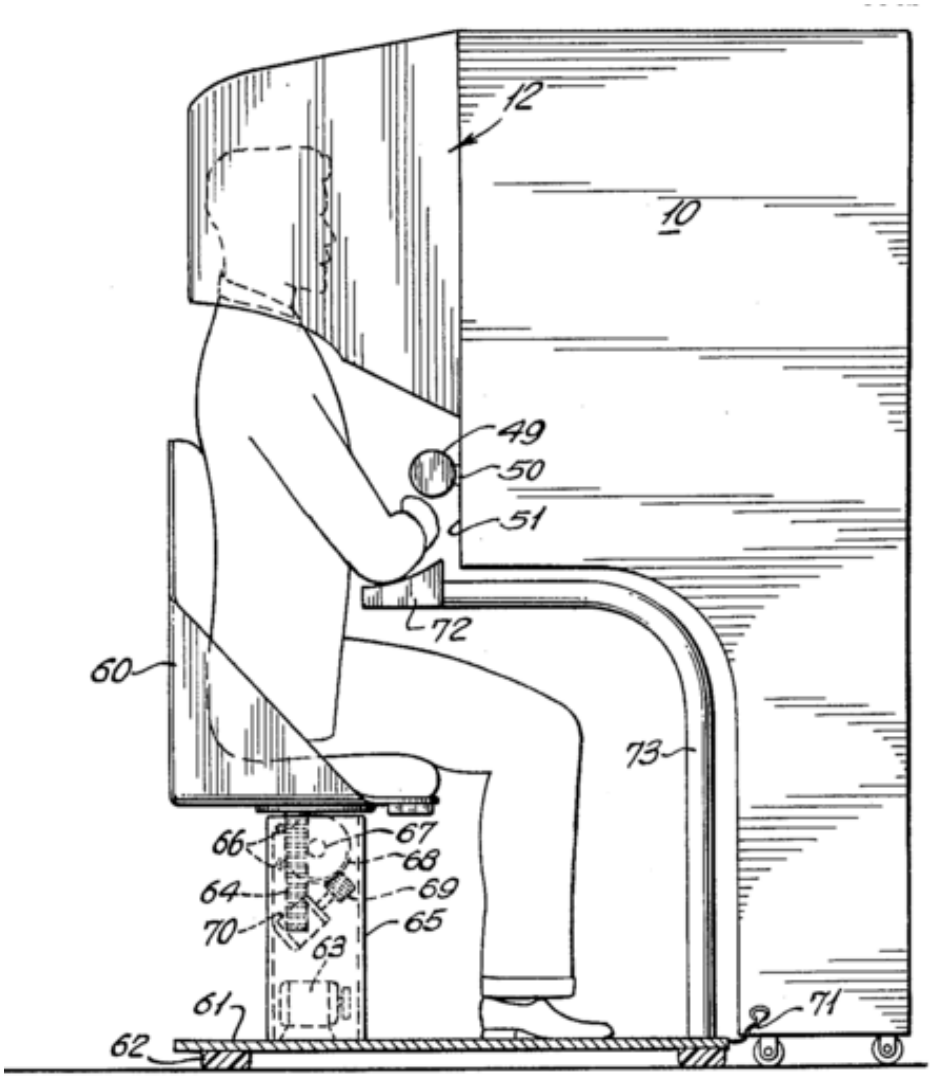

Figure 1.1: The Sensorama Machine. Photo Source: U.S. Patent #3050870

Figure 1.2: A user is experiencing the Sensorama.
Photo Source: http://www.mortonheilig.com/InventorVR.html
(Accessed by July 04, 2017)

2.2 1960's-1990's: The Development of HDM and CAVE

Even though the term "Virtual Reality" is relatively new, the technology is almost as old as the history of computer graphics. People used a "Head Mounted display" to describe the immersive experience of putting devices on the head and seeing images in them. The development of image processing systems and display hardwares laid the foundation of the development of VR technology in which several computer scientists' contribution cannot be neglected.

2.2.1 Computer graphics and Virtual environment

In the 20th century, human inventiveness led to the technological advances that allowed people to use computers to perform the complex calculation work. When the vacuum tube computer *Whirlwind* was invented in the early 1940s it was used to receive and transfer a series of radar data and display the vector results on the screen. Some researchers, inventors and even filmmakers then realized that computers could be used to display images interactively and to make the complex information understandable. This stimulated the development of computer graphics over the next decades. This also includes the early work in as graphic displays for air traffic control and gunfire control, and later work such as graphic design and rendering to simulate reality. Thus, the first computer graphics can be considered part of the history of Virtual Reality.

From the 1960's to the 1980's, research into computer graphics and animation grew rapidly, leading to numerous practical applications. In 1965, the computer scientist

Ivan Sutherland proposed the "Ultimate Display" concept.[4] He envisioned that in the future computers would be able to use complex mathematics to generate imagery and expressive worlds. In the late 1960's, Sutherland and David Evans, then working as computer science professors at the University of Utah, drove the study of computer science (CS) and computer graphics (CG) toward the generation of real-looking worlds by joining traditional animation with computer science.

During late 1960s to late 1970s, University of Utah-based researchers contributed a number of exploratory systems in computer graphics. One of the significance breakthroughs was the development of a fast algorithm to solve the visibility problem, a conceptual framework named "Hidden Surface Determination." This allowed the computer to determine which surface of the 3D object is behind from the viewer's perspective and should be hidden when the computer generates the image. This concept became the foundation for many future developments in CG field.

Following the development of CG, many firms emerged, including Adobe System, Silicon Graphics, and Pixar. In the late 1970's, with the growing entertainment economy, real-time renderings of 2D and 3D graphics on personal computers began to evolve.[5] In the film industry the public was fascinated by the 3D cyberspace world generated by computer graphics, represented by Star Wars in 1977 and the Lawnmower Man in 1992.

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[4] Sutherland, Ivan E. *The Ultimate Display.* Information Processing Techniques Office, ARPA, OSD: Proceedings of the IFIP Congress, pp. 506-508, 1965.

[5] "Part I. The Foundations of Virtuality." In *The Oxford Handbook of Virtuality*, edited by Mark Grimshaw, p. 19-20. Oxford University Press, 2014.

2.2.2 Head Mounted Device (HDM)

Beyond the software advances in computer graphics, the development of VR has also reflected the underlying improvements in the computer hardware that enhanced the capabilities and reduced the costs.

In 1961, the first Head Mounted Device (HDM), called Headsight, was invented by the employees Comeau and Bryan at the Philco Corporation, designed and to be worn by a pilot in dangerous situations. This enabled the pilot to acquire a real-time view of a place from a remote distance. The Headsight consisted of a helmet with a video screen and a head movement tracking system. The content displayed on the video screen is the actual video from a remotely mounted camera. The camera changes the shooting angle according to the user's head position, creating a sense of telepresence. For example, the HMDs linked to infrared cameras were used by US military pilots to aid with flight in a dark environment.

Some experiments were carried out to test the power of this immersive experience. In one experiment the user experienced virtual space when wearing a HDM device that was linked to an outdoor video camera. When the camera started shooting videos, the moving images were simultaneously displayed in front of the user's view. When a ball was thrown toward the camera screen, the user wearing HDM indoor panicked.[6] In spite

[6] National Research Council, Computer Science and Telecommunications Board, Committee on Innovations in Computing and Communications: Lessons from History. "Chapter: 10 Virtual Reality Comes of Age." *Funding a Revolution: Government Support for Computing Research*, p. 236. Washington, D.C.: The National Academies Press, 1999.

of these developments, the computer imaging generation and devices need to be further developed.

In 1968, Ivan Sutherland with the assistance of his student Bob Sproull at MIT's Lincoln Laboratory, created the first virtual reality (VR) and augmented reality (AR) head-mounted display (HMD) system. Since the device is partially see-through and users are not completed separated from the real environment, it is also considered as the precursor to the Augmented Reality technology.

This device called "The Sword of Damocles," replaced the video camera in the old head mounted display system with computer machine to generate images. It was primitive both in terms of the user interface and its ability to depict a real-looking computer graphics environment dynamically. In this system the image displayed on the retina is in perspective and changes as the user moves his head.[7] Wearing the HMD the user could see the output from the computer program using a binocular display system. Even though the virtual environment consisted of simple, wireframe rooms at that time, the three-dimension illusion in the virtual environment was real.[8] In addition, the power of VR was evident when users wearing head-mounted device remarked on the realism of the resulting stereotype images.[9]

Although this idea was then highly advanced, there was no chance of realizing the initial usage of this head-mounted display among the general public.[10] Southerland's

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[7] Sutherland, Ivan E. *A Head-Mounted Three Dimensional Display*. The University of Utah, Salt Lake City, Utah: Fall Joint Computer Conference, p. 757, 1968.
[8] Ibid., pp. 757-764.
[9] Ibid.
[10] Sutherland, Ivan E. *Virtual Reality Before It Had That Name.* Videotaped lecture before the Bay Area Computer History Association. March 19, 1996.

outline of computer displays nevertheless motivated many researchers to work on this idea and perfect the technology.

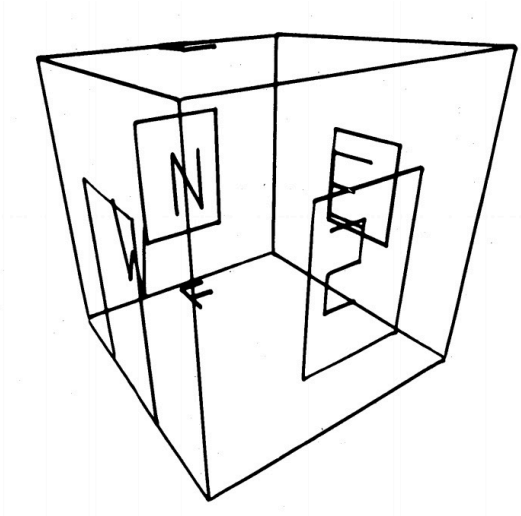

Figure 1.3: A computer-displayed perspective view of the "room" as seen from outside. Source: Sutherland, Ivan E. *A Head-Mounted Three Dimensional Display*. The University of Utah Salt Lake City, Utah: Fall Joint Computer Conference, 1968.

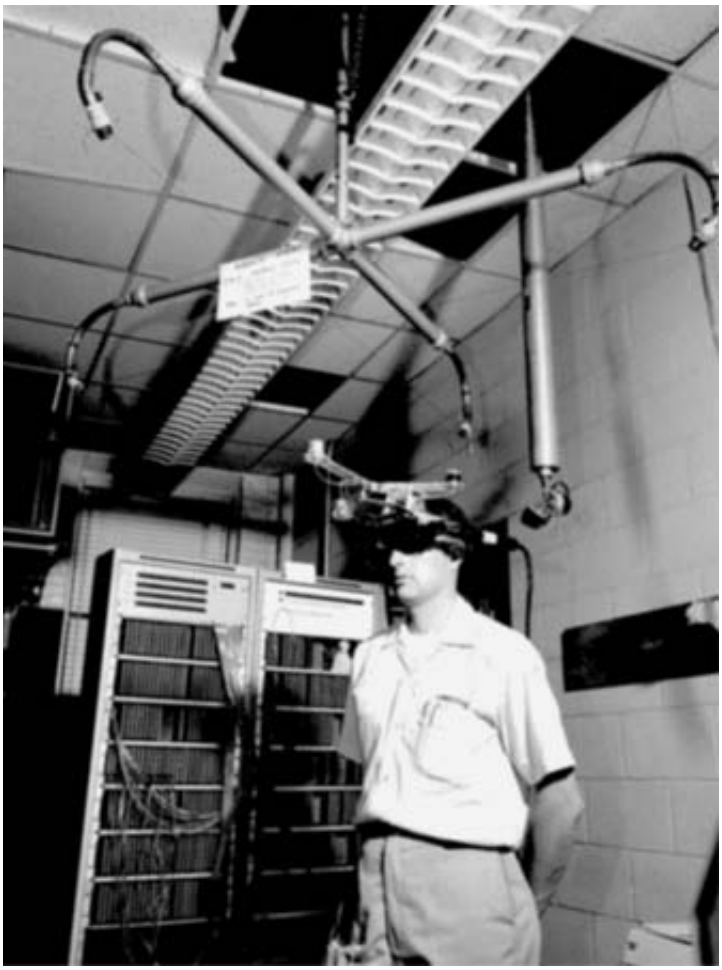

Figure 1.4: The mechanical head position sensor in use
Source: Sutherland, Ivan E. *A Head-Mounted Three Dimensional Display*. The University of Utah Salt Lake City, Utah: Fall Joint Computer Conference, 1968.

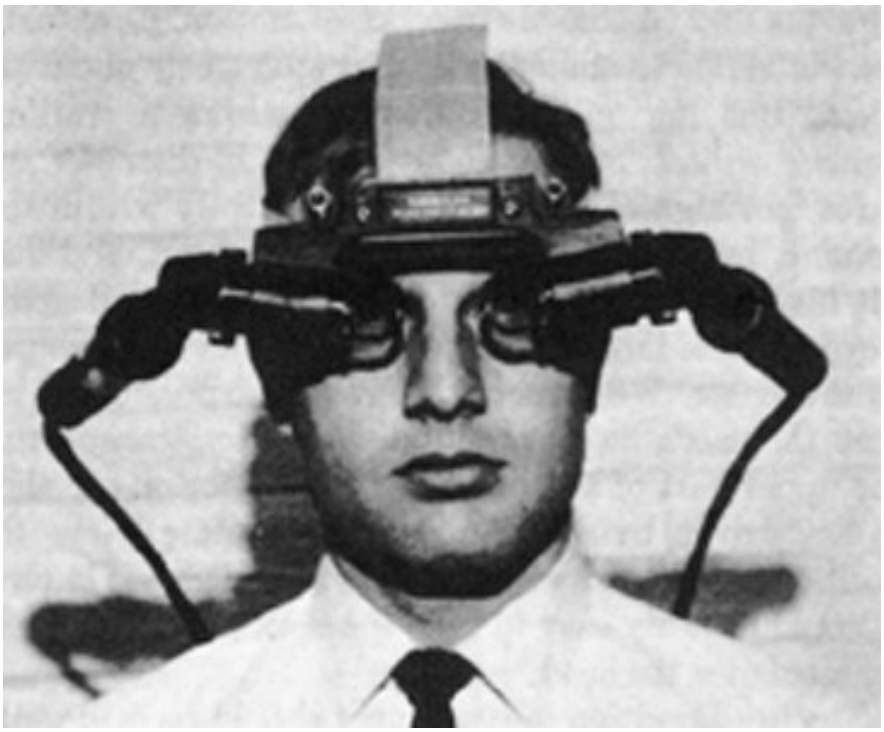

Figure 1.5: HMD optic with miniature CRTs
Source: Sutherland, Ivan E. *A Head-Mounted Three Dimensional Display*. The University of Utah Salt Lake City, Utah: Fall Joint Computer Conference, 1968.

2.2.3 The Wide Angle View Concept

Before the wide field of view concept was proposed in the late 1970s, the stereo window view was as narrow as 90 degrees, the angle that a normal eye could observe when looking straight ahead. If eye swiveling was allowed, the capability of human eyes view could cover 270 degrees of the vision field without head motion, wider than what the stereo window is able to present. This meant that the viewer could not only see the content displayed on the HDM screen, but also sense the stereo window frame and the objects that are outside the screen, whether the images is computer generated or by product of remote camera. Such a system fails in a critical way to qualify as an immersive virtual reality.

Attempts were made to gain a greater angle of view to fill the region of optical axis of the eyes, in order to support the illusion of being immersed in another space. In 1979, inventor Eric Howlett designed the LEEP (Large Expanse Extra Perspective) optic system,[11] a wide angle stereoscopic optic system. It provided a panorama stereo angle to include the entire region over which the normal eyes can swivel, and that also eliminates the stereo window inherent in systems with a narrower field of view.[12] This wide-angle optic system set up the basis for most of today's VR headsets.

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[11] Howlett, Eric M. Wide Angle Color Photography Method and System. US Patent US4406532 A. Sep 27, 1983.

[12] Howlett, Eric M. "Wide Angle Orthostereo." John O. Merritt and Scott S. Fisher, ed.. *Proc. SPIE,* Vol 1256. Santa Clara, CA, US: Stereoscopic Displays and Applications, Sep 1, 1990, 210.

2.2.4 Multi-sensory system in Virtual Reality concept

In 1986 in the NASA Ames Research Center, Virtual Reality technology was further developed, given that it extended the base VR visual display with multiple sensors, including the auditory and tactile. The primary objective of this study was to facilitate astronaut training. The virtual environment simulated the outer space, which allowed the astronauts to interact with complex operational tasks through telepresence.[13]

For tactile interaction in this virtual reality system, a light-weight glove like device was introduced to transmit the arms, hand and finger gestures to the host computer, so that user could operate the virtual objects appearing in the virtual environment.[14] This multisensory, interactive display device combined many of the previous advanced human machine interaction study results of the previous two decades. It provided an alternative path for the advancement of human-computer interaction (HCI), based on which many related study topics began to evolve, including fields in psychology, communication, and information science. As the hardware technology matured, it allowed the media to spread the idea of commercial VR a few years later.

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[13] Fisher, S.S., M.McGreevy, J. Humphries, and W.Robinett. *"Virtual Environment Display System."* Edited by Frank Crow and Stephen M. Pizer. 1986 Workshop on Internactive 3D Graphics. Chapel Hill, North Carolina: ACM SIGGRAPH; NSF in cooperation with ACM SIGCHI; the IEEE Computer Society, 1986.
[14] Ibid.

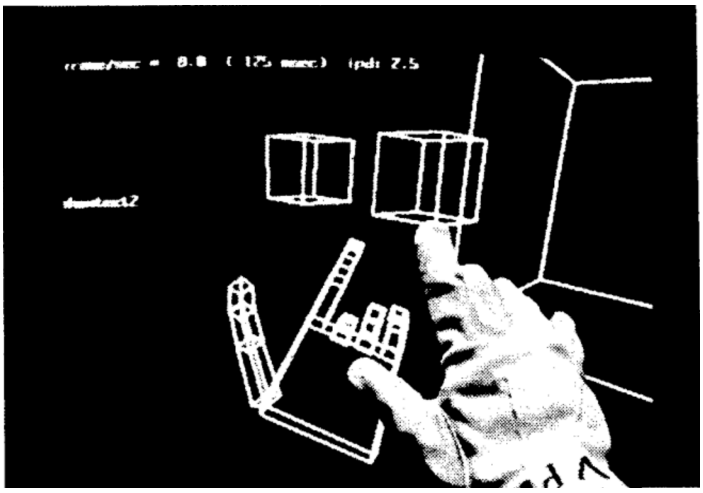

Figure 1.6: 3D graphic virtual objects and articulated hand directly controlled by Data Glove.
Source: Fisher, S. S., M. McGreevy, J. Humphries, and W. Robinett. *"Virtual Environment Display System."* Edited by Frank Crow and Stephen M. Pizer. 1986 Workshop on Internactive 3D Graphics. Chapel Hill, North Carolina: ACM SIGGRAPH; NSF in cooperation with ACM SIGCHI; the IEEE Computer Society, 1986.

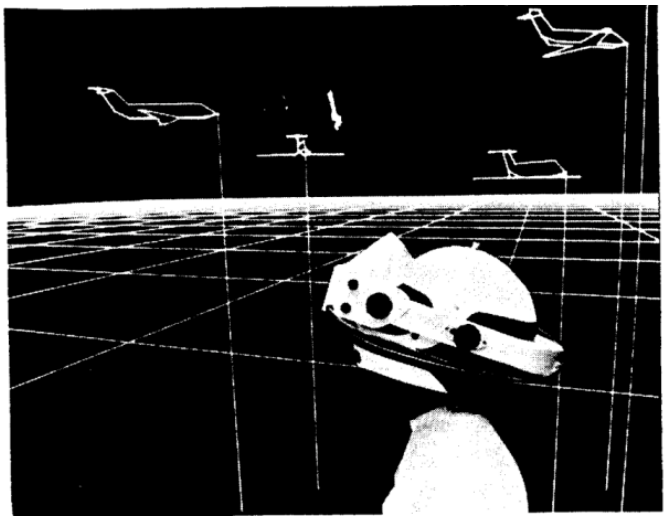

Figure 1.7: Virtual Reality Concept. Imagery displayed in the virtual environment appears to completely surround the user in 3D-space and enable the operator to explore virtual objects and environments in real-time and from multiple viewpoints.
Source: Fisher, S. S., M. McGreevy, J. Humphries, and W. Robinett. *"Virtual Environment Display System."* Edited by Frank Crow and Stephen M. Pizer. 1986 Workshop on Internactive 3D Graphics. Chapel Hill, North Carolina: ACM SIGGRAPH; NSF in cooperation with ACM SIGCHI; the IEEE Computer Society, 1986.

2.2.5 Cave Automatic Virtual Environment (CAVE)

During the same period researchers started to develop another virtual reality concept, one in which computer graphics were projected onto an enclosed space, which was called a Cave Automatic Virtual Environment (CAVE). The CAVE system was developed by the Electronic Visualization Lab (EVL) at the University of Illinois Chicago Circle in 1991.[15] The main characteristic of this system was that it allows users to step into an environment with virtual graphics projected onto the walls of a room. This system enabled users to have a complete vision of a VR image without wearing a helmet.

The CAVE is a surround-screen, surround-sound, projection-based virtual reality (VR) system. By putting on lightweight stereo glasses, users could walk around inside the CAVE as they interacted with virtual objects. From the beginning the CAVE was designed to be useful for scientific visualization. It was made to help scientists make discoveries within a high-tech workstation. The station gave multiple users a space to share the virtual environment simultaneously. By doing this, scientists could carry on a discussion, make discoveries, and exchange ideas efficiently. The concept has been developed further since it was invented. Today, types of CAVE-like environments appear all over the world. They are mostly applied in product development at engineering companies, medical training, architecture and industrial design, scientific research, museums, and education.[16]

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[15] *The CAVE Virtual Reality System.* July 28, 2001. https://www.evl.uic.edu/pape/CAVE/ (accessed July 4, 2017).
[16] Blascovich, Jim, and Jeremy Bailenson. *Infinite Reality.* p. 9-191. HarperCollins Publishers, 2011.

2.3 Post-1980's to 1990's: VR Market Switches from Military to Commercial

Throughout the history of the development of VR, many pioneering companies and individuals have encouraged the transfer of the technology into commercial use. During the 1970s-1980s, while Polhemus was developing the motion tracking technology in military applications, two employees, Emie Blood, an engineer, and Jack Scully, a salesman, came up with the idea of exploring the commercial uses of VR in fields such as entertainment, training situations, and medicine after they gained feedback from customers about their interest in commercial use of tracking technology. After being fired by Polhemus in 1986, due to inappropriately proposing this spinoff company to the superiors at McDonnell-Douglas (the then-owners of Polhemus), they registered a new company called Ascension. [17] Ascension played a part in the 1990's during the rise of VR by developing motion trackers for high-priced games.[18]

Another attempt was made by VPL Research in 1980s, whose founders are computer scientists Jaron Lanier and his colleague Thomas G. Zimmerman. Their Data Glove built for NASA, a sensor-equipped device that tracks the movement and position of the wearer's hand, was applied in virtual reality systems. At the time of its development, this wearable device was thought to have possible applications in computer control, gaming, and remote surgery. The device was improved later into the commercial entertainment version, called PowerGlove for video game industry. Yet the entire wearable system still need improvement at that time to function precisely and provide the

[17] Gresham, Tom. *They Do the Locomotion. Business People-Vermont*, March 2003. Interview with Ernie Blood and Jack Scully, http://www.vermontguides.com/2003/3-mar/ascension.htm (accessed 03 16, 2017).
[18] Ibid.

real tactile feeling. It promoted the concept of a VR relatively accessible to public, who began to gain a better understanding about it.

Although VPL Research made an effort to explore the market value of VR technology and communicating with the public, the market in1980s was not well prepared for a sustained industry push in VR. It was still limited in use of government laboratories, military training, and academic researches.

In 1991, *Virtuality*, a virtual reality gaming machine, was introduced in video arcades. The product company, Virtuality Group, was first founded in 1985 under the name W Industries by Jonathan Waldern, a Ph.D. graduate at Loughborough University of Technology, one of the few companies working exclusively on commercial application of VR technology.[19] This virtual reality video game machine consisted of a stereoscopic visor, joysticks, and networked units for multi-player gaming. Two unit types were introduced: one in which the player stands up (SU), the other in which the player sits down (SD). Both systems utilized head-mounted displays.

[19] Horsman, Mathew. *Virtuality ties up Atari deal.* March 17, 1995. http://www.independent.co.uk/news/business/virtuality-ties-up-atari-deal-1611632.html. (accessed July 4, 2017).

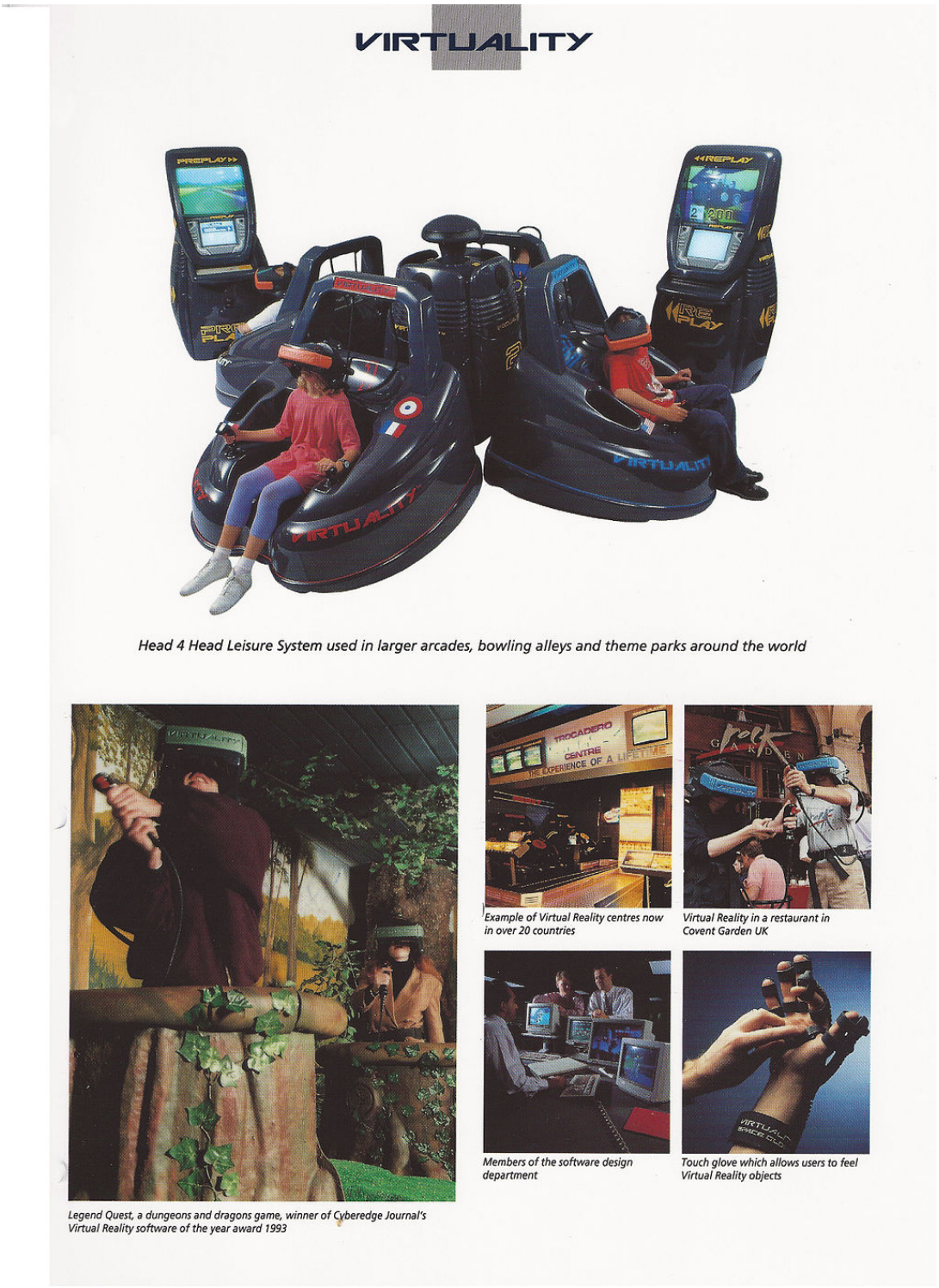

Figure 1.8: A page introducing the Virtual Reality game system in the early 1990's VR campaign.
Source: https://commons.wikimedia.org/wiki/File:Virtuality_Marketing_Page.jpg (Accessed by Nov 15th, 2017). Author: Dr. Jonathan D. Waldern, April, 1 1994.

Afterwards, commercial VR experienced a small peak in the mid-1990's and then declined. At that time people leveraged the potential of VR in the entertainment industry with video games but seldom explored the possible applications in other fields. In part this was due to the high cost of developing a VR product. Development costs prevented companies from selling to low-level markets and restricted them to doings business with the government, labs, and the military. For example, it cost $75,000 to buy a multi-pod Virtuality game machine. The head-mounted tracking systems were likewise expensive, at $15,000, and a pair of hand tracking gloves cost five to ten thousand dollars. In reality VR was still too advanced to be accepted as a "bare necessary in life" when computer devices in general were not accessible to most of the public.

In addition, a few years later the development of internet and personal computers gradually changed the game entertainment industry. Although videogames in the 1970's-1980's existed in the world of video arcades, this phenomenon decreased with the rise of the internet and 3D games in the late 1990's, which kept most customers home. Home consoles and handheld game consoles began to dominate the market.

2.4 Post 2000's to present: The rise again of VR

Through the late 1990's to the early 2000's, VR companies continued to operate with a low and more pragmatic profile. The military was still the biggest advocate for VR's utility.[20] Since the 2000's, PCs have become much more advanced, cutting down the

[20] Compiled by Adi Robertson and Michael Zelenko with additional reporting and interviews by Katie Drummond, Casey Newton, and Melissa Smith, *Voices From a Virtual Past—An Oral History of a Technology Whose Time Has Come Again.* http://www.theverge.com/a/virtual-reality/oral_history (accessed July 24, 2016).

cost of VR development. Then, in 2012, a young entrepreneur named Palmer Luckey revealed a $300 virtual reality headset called the Oculus, which brought the VR in public view again.

Recently several companies including Google and HTC have released their virtual reality products, such as Google Cardboard, which is a DIY headset that uses a smartphone to drive it, and HTC Vive, which allows users to walk around in the virtual world with a handheld controller to manipulate objects. Several Virtual Reality Platforms have been launched in 2016, most in entertainment game industry.

Today Virtual Reality has become once again a novelty topic in public debate. Just like many other things in this world that always come back at some point in favor, so is Virtual Reality.

Figure 1.9: Google Cardboard VR headset with a smart phone in the visor slot
Source: Google Official Website https://vr.google.com/cardboard/ (Accessed by July 25th 2017)

Figure 1.10: HTC VIVE VR. The two handheld controllers enable user to manipulate the object in VR environment.
Source: Photo by James Bareham / The Verge, https://www.theverge.com/2017/4/5/15191326/htc-vive-anniversary-state-of-vr (Accessed by May 15th, 2017)

3 The Implementation of VR in the Digital Heritage Movement

The process of digitizing heritage information, including information about the documentation, reconstruction, and presentation of historic objects and sites, began in the 1990's when computers became more accessible to the public. During the "Imagina Conference" in Monte Carlo in 1993, a real-time guided tour of a digital reconstruction of the Cluny Abbey, demolished centuries ago, was displayed.[21] This was an early showcase of how digital heritage technology could be applied for heritage representation. Following that, many digital heritage applications were released, such as Virtual Pompeii, Virtual Lowry, the Caves of Lascaux, and the Palace of Ashur-nasir-pal II. The first Virtual Heritage conference was held at the Assembly Rooms of Bath, UK. Many virtual heritage applications had been developed at the Virtual Systems and Multimedia (VSMM) Society Conference, starting with the one held in 1995 in Gifu Japan.[22] Discussions about the use of virtual reality have been held at international conferences, such as Europe's VAST (International Symposium on Virtual Reality, Archaeology and Cultural Heritage), IEEE VR, ACM Siggraph to the CAA, ISPRS, CIPA, ICOMOS, ForumUNESCO, Virtual Retrospect, Museums and the Web.

In the 1990s, the common problems digital heritage projects had were that they usually lacked visual realism and detailed historical information, which failed to meet the need for documentation and interpretation. For example Virutal Pompeii, whose first version was developed at Carnegie Mellon's Studio for Creative Inquiry in 1995-1996

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[21] Thwaites, Harold. "Chapter 17 Digital Heritage: What Happens When We Digitize Everything?" *Visual Heritage in the Digital Age*, Eugene Ch'ng, Vincent Gaffney and Henry Chapman, ed., p. 330. London: Springer, 2013.
[22] Ibid., p. 331.

sponsored by Silicon Graphics and many other sponsors did not have enough supporting materials, including historic descriptions of that area and its detailed artsworks. [23] [24]

After 2000, virtual technology began to be accepted as people began to see the potential of using virtual and multimedia technology to preserve, protect and undetstanding the invaluable heritage. The emerging trend of using VR technology in this generation can be grouped into three domains: 3D documentation, 3D representation, and 3D dissemination.[25] The use of long-range 3D scanners could overcome the traditional methods by documenting the data of existing conditions precisely and rapidly for virtual construction work. The development of website and multimedia environment provide a platform where virtual histories work can be portrayed lively. The immersive technology such as Computer-Aided Virtual Environments (CAVEs) and Virtual Reality helps to represent the historic sites in a virtual realistic way.[26]

4 Conclusion

The demand for virtual 3D environments and for more real and natural human interaction with those environments has led to advances in virtual reality technology in the past century, making products available to the consumer at a constantly decreasing price. It also demonstrates that this progress benefits from multiple interactions in

[23] Jacobson, Jeffrey, and Jane Vadnal. "*The Virtual Pompeii Project."* School of Information Sciences, School of Art History, University of Pittsburgh, USA, 2005.
[24] *Virtual Theater District of Pompeii.* 2012. http://publicvr.org/html/pro_pompeii.html (accessed July 4, 2017).
[25] Alonzo C. Addison, University of California, Berkeley. "Emerging Trends in Virtual Heritage." *IEEE*, April-June 2000: pp. 22-25.
[26] Ibid.

industry, universities, and government. The fusion of ideas arises from various research areas, such as computer graphics, engineering and computer architecture.

In the end, the advantages of virtual reality in heritage applications have already been recognized by many innovative, pioneering preservationists and computer scientists. That the proponents of virtual reality in historic preservation come from diverse fields of study indicates that a virtual heritage project is a mulidisciplinary work, which can involve experts from archaeology, history, computer science, and data curation.

CHAPTER 2

"ARMCHAIR" COMMUNICATION

FROM TELEGRAPHY TO TELEVISION

Today VR pioneer companies such as Facebook Oculus, Sumsung, Google, and HTC have devoted considerable resources and time to address the challenges of virtual reality technology, anticipating that humans will be able to interact with the world in a virtual cyber space. Understanding the world as if one is in a real environment requires the nervous system in the brain receive and process the perception information in the virtual world in way similar to that in the real physical world. In the physical world, the immediate way to relate and understand the environment is through perceiving the signals from the physical or chemical stimulations of the sense organs. Hence, an ideal virtual reality system is able to stimulate eyes, ears, nose, mouth, and tongue, the basic five elements a healthy human. It also means that human could gain spatial communication via electronic device without leaving their seat any more. The interest in developing a virtual presence in an increasing number of applications begins with several small increments in the past two hundred years' communication history, involving the culture, education and economy.

1. Wire age: Electronic ears

The initial approach began with the understanding of electronic theory in the 17th and 18th centuries when scientists found electrical currents could flow through certain materials to transmit simple signals.

In 1843 American inventor Samuel Finley Breese Morse developed a telegraph machine.[27] Morse's single-circuit telegraph converts letters of the alphabet into electrical signals that are sent via wires placed between two stations. The electrical signals are received in the form of code (Morse Code) transcribed by trained operators and often written on paper. In this fashion people became to relate to the world through text message interpreted by the telegraph in some ways virtually. Due to its fast transmission speed, the telegraph was adopted for point-to-point communication almost immediately.

Soon after the invention of telegraph, experiments with electromagnetic variations accelerated. In 1876 a telephone conversation was conducted by Alexander Graham Bell between him and Thomas A. Watson.[28] Electronic machinery was thus given the function of transmitting sound. It was quickly realized that the telephone could serve as a convenient tool for personal conversations. In May 1877, the first payment of $20 for a year's lease of two telephones was received at the Boston office of the Bell Telephone Company, opened in July 9, 1877 with 5,000 shares of stock being issued.[29] Next, the idea of broad scale commercial telephone communication was developed, supplementing news by the telegraph. A telephone newspaper *"the Telefon Hirmondó"* was created in 1893 in Budapest, Hungary, to provide news and entertainment to subscribers over telephone lines.

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[27] "Chapter Two: Invention of Electronic Telegraph," *History of Radio to 1926*, by Gleason L. Archer (1880-1966), p. 22-29. New York: The American Historical Society, 1938.
[28] Ibid., p. 49-50.
[29] Ibid., p. 51.

2. Wireless age: Electronic mouth

With the development of telegraph and telephone, networks of wires were built under and above ground. Perhaps the annoying phenomenon was the interference caused by the telephone and telegraph lines arranged close together.[30] The early attempt towards the wireless communication began with the discovery of electromagnetic waves by Heinrich Hertz, young German scientist in 1886. After him, wireless transmission was further developed by Eduoard Branly in France and then by another young scientist Guglielmo Marconi in Britain from 1892 to 1899.

In late 1890s Morse Code message transmission via wireless waves was successfully demonstrated in Britain and United States. It stimulated public's interest and imagination of this new communication invention. At that time wireless telegraphy was found especially useful by ocean going vessels, when laying wires was impossible in the water but instant communication was required for for ship to ship and ship to shore communication. Gradually wireless telegraphy business evolved into two different types, one for commercial purposes and the other for national defense. Companies such as British Marconi Company with a branch American Marconi in US and National Electric Signaling Company (NESCO) in US provided services to customers like Navy, shipping companies or weather forecasting departments to facilitate their instant long distance operation through wireless telegraphy communication.

The world events like Russo-Japanese War in 1904 induced many national governments to realize the military importance of setting up wireless telegraphy stations

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[30] "Chapter Five: Wireless Telegraphy," *History of Radio to 1926*, by Gleason L. Archer (1880-1966), p. 53. New York: The American Historical Society, 1938.

along their seashores. Wireless telegraphy technology was soon adopted for national defense purposes and inevitably became a monopoly during the wartime.

By 1906, the "armchair" civilization was able to send Morse code in all directions and made it accessible to any receivers as long as it is in the same wave length. Inventors moved forward with the dazzling idea to superimpose continuous sound into the waves to be picked up audibly by receivers that would recognize the human voice. An early attempt by Reginald Fessenden who believed and then proved that a smooth and continuous high frequency vibration could carry sound information just as Bell did in electric circuit in the telephone. Fessenden together with the other two investors, Given and Walker, organized the National Electric Signaling Company to develop Fessenden's idea and provide inventors unlimited opportunity for research.[31]

The idea was further demonstrated by the young inventor Ernst Alexanderson in General Electric Company, in Brant Rock, Massachusetts, under the direction of Fessenden. Through an experimental transmitter, human voice and music were successfully received by wireless operator on ships over the North Atlantic in 1906.

With the improvement in detector techniques, such as the invention of vacuum tube and crystal diode in 1906 and the invention of electronic amplifier in 1912, human voice could be broadcast in at a considerable distance wirelessly. The advance in radio technology brought the concerns about patent infringements, as was the case with the telephone and telegraph. For example, the American Marconi Company became involved with a number of court cases. The lawsuit against the United Wireless Company led it to

[31] Ibid., p. 72.

be sold to American Marconi because it was forbidden to produce similar equipment by using Marconi's patents.

According to David Sarnoff, who later became the president of Radio Corporation Company (RCA), prior to 1912 American Marconi was relatively an unimportant concern. Their five stations were mainly involved with shipping company communication and wireless manufacturing business. After purchasing United Wireless Company, American Marconi controlled the stations along east coast from Maine to Texas and west coast from Oregon to California, a total of approximately fifty shore stations.

In the early days, radio was used by shipping companies, department stores and big corporations. Manufacturers were reluctant to deal with publicly accessible communication and often used codes to keep information confidential. Yet several world events occurring in the early twentieth century accelerated the technological progress.

In 1912 the loss of the Titanic increased the public awareness of the benefits of wireless communication. American Marconi employee David Sarnoff, together with his two assistants spent three days sitting in the wireless station installed in Wanamaker's store in Philadelphia, broadcasting the latest news of Titanic to the public, including the survivors' information.

The value of radio communication was further demonstrated in World War I. Due to the speed by which the information traveled over ground and water, radio stations were gradually taken over by federal government and used in military service, mainly led by the Navy. In 1918, President Woodrow Wilson's world peace speech was transmitted through the wireless to the public in the United States and abroad.

After World War I, each of the wireless stations were returned to their original owners and the development on radio's commercial value began anew. Apart from its basic uses, experts and inventors began to see the possibility of radio as a medium of public education and entertainment as the first practical radio was created. Unaware of this technology's potential, young boys and men were still enjoying the Morse code produced by wireless telegraph and even started learning this code, but the radio industry enjoyed a considerable number of advocates. Experiments in playing music were carried on in 1915-1916 in which David Sarnoff noticed the value of amusement by wireless telegraphy to the sailors at sea. He envisioned a wireless telegraphy could become a "household utility" for family entertainment. In 1916 Sarnoff sent a "Radio Music Box" proposal to the Marconi Company General Manager Edward J. Nally. Sarnoff planned to bring music into the home by wireless.[32] As a Russian immigrant, young Sanroff understood how entertainment programs with music could amuse the working class and relieve their daily heavy work, at a time when similar tunes were only available in theaters. In his proposal Sarnoff considered the affordable sales price of the radio, and the need for improvements in the technology, before the "market research" concept emerged in the mid 20th century. In his plan, the sale of Music Box within three years would bring a gross business of $75,000. According to RCA's annual revenue report between 1924-1926 the total revenue from Music Box was $85,000,000.

Through the success of the experimental music program, investors came to realize the distinction between premium programming and mass communication through a

[32] "No Small Potatoes", *Television in the Antenna Age*, David Marc; Robert J. Thompson, p. 15. Blackwell Publishing, 2005.

technical means of distribution. This line of thought was embraced and demonstrated by CBS president William S. Paley in 1938, who thought that good quality programs was essential for radio stations to attract and hold the mass audience.[33]

In the United States, the broadcasting business was demonstrated with the start of radio station KDKA by Westinghouse in 1919. The inauguration service was broadcasting the National Election returns on Nov 2, 1920. In 1926 and 1927, the Radio Corporation of America formed the National Broadcasting Company (NBC) with two networks: NBC Red, and NBC Blue, later called American Broadcasting Company (ABC) in 1943, due to antitrust pressure. In the mean time, other broadcasting companies such as Columbia Broadcasting System (CBS), Zenith Radio, DuMont, and Philco grew and together shaped the radio industry in the country. The Federal Radio Commission (FRC) was established to regulate radio broadcasting market in 1927.

The success of radio programs during 1930 to 1940's golden age made "broadcasting" a household term for every family. The demographic of radio audience gradually shifted from male amateurs to females, especially with the emerging of "soap operas." The radio advertising became more directed to a female audience, often concerned with beauty.[34] Radio networks began to sell their air time to merchants. Companies continue to pay millions of dollars to deliver their messages to the public via radio every year.

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[33] "Programming the System for Quality," *Television in the Age of Radio*, Philip W. Sewell, p. 113. NJ: Rutgers University Press, 2014.
[34] "New Sets Called Musical Marvels," *The New York Times*, September 22, 1929, Page R1.

In addition to advertising support, radio received financial help in other fashions. For example, in the United Kingdom, many broadcasting companies, including the British Broadcasting Company (BBC) were state-supported. A dedicated tax or license fee imposed by the government allows the revenue to be directly transferred to broadcasting companies to support their programming costs. The key reason for this approach is the government's concern on the unfettered commercial influence of the national culture via radio programs. BBC's system has become an example adopted by many other countries.

3. Post-wireless age: Electronic Eyes

The attempt to transmit images emerged in 1840s. Scientist Alexander Bain in 1842 London found that electrical currents could flow through metal plates to transmit simple letter signals and produced a discoloration at the sending terminal.[35] In 1847, F. C. Bakewell of England invented a two-cylinder electronic system to trace handwriting drawing.[36] In 1855 Giovanni Caselli developed the Pantelegraph, which laid the two of the foundations of the later image transmission system: it used sequential scanning of the pictures and the means to synchronize the transmitter with receiver. This system is known as "Copy-telegraph" and developed into a "Facsimile" (FAX) today.[37]

In 1873, Willoughby Smith and Joseph May, electrical workers in one of the Atlantic cable stations in Ireland, discovered that selenium's resistance decreased with the intensity of the light falling upon it. Since then, more experiments were conducted to test

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[35] "Chapter One: A Long Road Inventors Trod," *The Outlook of Television*, by Orrin E. Dunlap, Jr., p. 6. New York and London: Harper & Brothers Publishers, 1932.
[36] "The Copying Electronic Telegraph," *The Spectator*, Nov 16, 1850, p. 20.
[37] "The Invention of Television." *Television: An International History*, Anthony Smith, ed., p.14. Oxford: Oxford University Press, 1995.

other metal's reaction to the changes of light intensity for devices that could transmit pictures.[38] Before the first practical solution appeared, many visual communication gadgets were invented, including the telephonograph, a combination of Bell's telegraphy and Edison's phonograph in 1877, and Maurice LeBlanc's systematic scanning of objects to transmit images over distance.[39]

During 1881-1885, Paul Nikpow invented the scanning disc. This system transmitted still pictures for a distance through a series of sequential measurements, transmissions and displays, breaking down the still image into picture elements. The term "*photo-telegraphy*" and "*televising*" was created to describe this process.

Based on this fundamental idea, the first generation of "television" was created. John Logie Baird of Scotland demonstrated his television system in front of the Royal Institution members in London in January 1926. The light of an object hit on the photoelectric cell through the pinholes of a spinning Nipkow disc. The photoelectric cell converted the light into electricity that varied according to the light intensity. The varied electricity was sent out and received by a device that caused a neon light bulb to flicker accordingly. The receiving Nipkow disc, spinning at the same speed as the first, put the light together to replicate the entire picture. Though the system was cumbersome with images "faint and often blurred," this was the first public demonstration of generating virtual motion images via electronic machine. These televisions occupied the market through 1920s to 1930s.

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[38] "Chapter One: A Long Road Inventors Trod," *The Outlook of Television*, by Orrin E. Dunlap, Jr., p. 6. New York and London: Harper & Brothers Publishers, 1932.
[39] "The Invention of Television," *Television: An International History*, Anthony Smith, ed., p. 14-15. Oxford: Oxford University Press , 1995.

In addition, scientists began to explore a new way to transmit pictures through cathode rays in tubes. This began with Karl Ferdinand Braun's cold cathode ray tube in 1897. The idea arose from the previous discovery that when a certain voltage was applied to electrodes attached on the two ends of a sealed tube, the gas inside get ionized, currents flowed and glowed with a certain color.

In 1906, Lee DeForest invented three vacuum tube, Audion, which amplify the weak electricity flows. It allowed electric waves to be powerful to transmit signals. In 1907, Boris Rozing in the United States, and his student Vladimir Zworykin in Russia developed a receiver by using a cathode ray tube, replacing the movable parts in the television.

In 1925-1929, scientists were overcoming the barrier of combining motion pictures with sound records. These pioneers realized that television would become more commonplace. In 1926, Dr. Alexanderson predicted that television would eventually come into every family's home, broadcasting comedy shows, just as the "radio enriched the live of thousands of lonely farmers with music that was once heard in large cities."[40]

From 1927 to 1930, San Francisco inventor Philo T. Farnsworth demonstrated the first all-electronic television system.[41] It applied new principles by removing the mechanical disc parts that had been used to break up or "scan" and receive the image, and installing an image dissector and an all-electronic scanning and sync generator. An

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[40] "Chapter Four: Experts Analyze the Road," *The Outlook of Television*, by Orrin E. Dunlap, Jr., p. 62. New York and London: Harper & Brothers Publishers, 1932.
[41] Brigham Young Academy & Brigham Young University High School Alumni Association. "Philo Taylor Farnsworth Mathematician, Inventor, Father of Electronic Television." *Brigham Young Academy & Brigham Young University High School.* Salt Lake City, UT., 2006. http://www.byhigh.org/History/Farnsworth/PhiloT1924.html (accessed July 12, 2017).

electronic television was considered superior to the mechanical one because there were no moving parts, reducing noise and size.

In 1930 one of the earliest television receivers was installed by Baird Lab at the Prime Minister of the United Kingdom's residence in London. Ramsay MacDonald, Mr. MacDonald's daughter and other members of his family watched the "vaudeville" performance by twin broadcasters. This television program was operated on two different wave lengths with one handling the image and the other the sound.

Having invested millions of dollars on visual transmission technology, it was expected that television would one day prove its practical value and the manufactured units would generate profits. The structure of broadcasting industry was modelled on radio. In the United States, experimental television stations were built as early as 1928 when NBC (W2XBS) was opened in New York City. Amateur stations were also created by enthusiasts. Filmmaker C. F. Jenkins' experimental station (W3XK) was opened by Jenkins Television Corp. As a motion picture maker, Jenkins was very interested in how images were transformed through invisible waves. He predicted that some day motion pictures would connect to radios and be delivered to every household. In 1932, Jenkins introduced a "lantern-slide" scanning system and invited government officials to watch the blades of his windmill-like machine casting images.[42] In the first year, visual broadcasting including television broadcasting and picture broadcasting were permitted

[42] "Chapter Fourteen: Television's Commercial Destiny," *The Outlook of Television*, Orrin E. Dunlap, Jr., pp. 51-54. New York and London: Harper & Brothers Publishers, 1932.

by FRC, but they were barred from 6:00 to 11:00 p.m. so as not interfere in any way with other radio programs.[43]

In 1928, WGY station (W2XAD) broadcasted the first television drama in the United States, *The Queen's Message*, which was J. Hartley Manner's one-act play, under the direction by Dr. Alexanderson in General Electric lab in Schenectady.[44] The sound was picked up by microphone and received by radio. The actions were captured by camera and received by a three-by-three inch screen receiver. There existed two different voices in this television performance. Some newspaper critics, such as that in *New York Herald Tribune* thought that due to the unstable imaging signals, the marketing future for the sound and voice was questionable. Other reviewers, such as that writing for *The New York Times* predicted that radio-television broadcasting would benefit the public. The 1930 annual report of the FRC declared that "since visual broadcasting still haven't developed to the point where it has real entertainment value, all the licenses issued are on a experimental basis and quarterly reports covering experimental development of this service is required."[45]

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[43] *Third Annual Reports of the Federal Radio Commission 1928-1929*, FRC, 1929, https://apps.fcc.gov/edocs_public/attachmatch/DOC-338387A1.pdf (Accessed by July 21, 2017)

[44] "Television used as vehicle of drama-one act play with cast of two characters is broadcasted," *The Wilkes-Barre Record*, Sept. 12, 1928, p. 1.

[45] Fourth Annual Reports of the Federal Radio Commission 1929-1930, FRC, 1929, https://apps.fcc.gov/edocs_public/attachmatch/DOC-338392A1.pdf (Accessed by July 21, 2017)

In the following year's FRC annual report[46] the "increasing public entertainment value" of visual broadcasting was pointed out. "There has been a large amount of public interest shown in the development of visual broadcasting (television) and its possibilities for public entertainment and use." In the same year, articles in *The New York Times* discussed the future of television at home, indicating that some radio audiences were undecided in between whether to wait patiently to acquire a new television set, or upgrade their old 1925 radio set with a new one with better tone.[47] "Public interest" television went beyond entertainment to become a main factor stimulating laboratories to increase their improvements.

Radio retailers were expecting television would stimulate their trade. In 1931 Haynes Griffin said "Television [is] an immediate savior of the radio industry. Development will be rapid when people become interested in the hobby of seeing by radio."[48] The questions remained of how television would sell itself to the public and build up an audience.[49] Compared to more than 500 radio broadcasting stations in existence in the United States, there were only a few television stations operating in 1930.

In 1931, the number of amateur television receivers in Chicago area was 3,000, which made some people have the vision that television is "around the corner" on a

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[46] Fifth Annual Reports of the Federal Radio Commission 1930-1931, FRC, 1931, https://apps.fcc.gov/edocs_public/attachmatch/DOC-338393A1.pdf (Accessed by July 21, 2017)
[47] Microphone is Still King, by *The New York Times,* Sunday, June 1, 1930.
[48] "Radio Dealers Foresee Harvest in Television", *The New York Times*, March 22, 1931.
[49]"A Look Back and Then Ahead; International Broadcasts Called 1930's Outstanding Contribution In Radio--Some Expect New Year Will See More of Television." Orrin E. Dunlap Jr, *The New York Times,* December 28, 1930. P. XX8

commercial basis.[50] Yet, the pictures received were as small as a handkerchief and a darkened environment was required. Walter Gifford, the president of American Telephone & Telegraphy Company in 1930 said that the commercial value for television was still uncertain, given that the equipment though with great improvements and simplification, still required expert attention and large units of apparatus.[51] In a *QST* poll on the attitude towards television, people expressed two opinions, one with great interest and the second with great avoidance.[52]

In spite of these concerns, the English Derby horserace was televised by Baird Lab at Epsom Downs in 1931 in London, demonstrating that outdoor events could be televised under sunlight without artificial lamps. According to *New York Evening Post*, "English men watched the Derby in peace and quiet." This inspired the later experimenters who sought a new way of transmitting world-wide news events and actions.

From 1930-1932, interlace scanning for cathode ray tube was developed in US and Germany. It gained several improvements afterwards to scan higher line counts and achieve higher resolution pictures.

By 1932, the two different views on the future of television continued to be expressed. Dr. Lee Deforest stated that the expensive cost and complexity of making a television would mean that it would remain in the laboratory indefinitely. The public's

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[50] "Chapter Thirteen: A Flying Spot of Magic," *The Outlook of Television*, Orrin E. Dunlap, Jr., p. 193. New York and London: Harper & Brothers Publishers, 1932.
[51] "Chapter Eight: Faces on Wires-Faces in Space," *The Outlook of Television*, Orrin E. Dunlap, Jr., p. 113. New York and London: Harper & Brothers Publishers, 1932.
[52] "Chapter Thirteen: A Flying Spot of Magic," *The Outlook of Television*, Orrin E. Dunlap, Jr., p.197. New York and London: Harper & Brothers Publishers, 1932.

concern for privacy would work against the widespread use of the technology. Hollywood worried about the side effects that television would have on the radio, film and theater industries. By contrast, David Sarnoff, an active advocate, believed that the far-reaching possibilities of television guaranteed its influence in education, business enterprise, religion, literature, and entertainment.[53]

In 1933, Dr. Vladimir K. Zworykin introduced his new invention, the iconoscope. This camera tube could produce a stronger picture signal than earlier elements. Instead of the earlier cameras which required a single very brightly lit spot, this camera tube could be operated under a well-lit condition. What remained was the need for regulatory oversight and financial backing to put the units in production.[54]

In view of the technical developments, in 1934 a federal regulatory agency—the Federal Communication Commission (FCC)—was created to oversee and regulate all wireless communication. Since its establishment, FCC has been charged with executive and quasi-judicial power to regulate interstate and international communications by radio and television in the public's interest. Early regulations included broadcast spectrum allocation, including the debate on VHF and UHF in 1939,[55] image quality, and the color

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[53] "Chapter Fourteen: Television's Commercial Destiny." *The Outlook of Television*, Orrin E. Dunlap, Jr., p. 221-250. New York and London: Harper & Brothers Publishers, 1932.
[54] "Outlook for Radio-Sight", *The New York Times*, July 2, 1933, P. X6
[55] "The Arrival of TV." *One Nation under Television-The rise and decline of Network TV*, J. Fred MacDonald, p. 39. New York: Pantheon Books, 1990.

versus monochrome discussion. The race between NBC and CBS during 1948 to 1953[56] is typical of what is seen in the television industry today.[57]

The discussion of the pros and cons of television continued. Media commentator Gilbert Seldes compared television with radio from a cognitive perspective. He concluded that since the spoken words by radio stimulate the rational part of the brain, and images impact the sensual system which deals with more basic human nature, combining television with a radio program actually decreased the intellectual value of radio. He also indicated that television expects a near-total attention from viewers, which would have a disruptive effect on American life.[58] Radio was believed by many to be more flexible and superior to television, and thus would never be replaced. Television could be applied as a supplement, with a more specialized application. By contrast Willem Van Hoogstraten, a orchestra conductor in New York City, did not see television as a threat: "My answer is no. Television may revolutionize other forms of radio entertainment but it cannot be expected to create a devoted interest in the higher forms of musical composition."[59]

By 1939 there were already twenty-two licensed non-commercial experimental TV stations in the United States.[60] According to the Gallup poll, four million American families showed an interest in having a receiver at home someday, however, one

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[56] Ibid., p. 40.
[57] "The Beginnings of American Television." *Television-An International History*, edited by Anthony Smith, p. 35. Oxford: Oxford University Press , 1995.
[58] "The 'Error' of Television," Gilbert Seldes, *The Atlantic*, May 1937 Issue, https://www.theatlantic.com/magazine/toc/1937/05/ (Accessed by July 20, 2017)
[59] "Chapter Fourteen: Television's Commercial Destiny," *The Outlook of Television*, Orin E. Dunlap, Jr., p. 221-250. New York and London: Harper & Brothers Publishers, 1932.
[60] "Struggle for an Industry." *One Nation under Television-The rise and decline of Network TV*, J. Fred MacDonald, p. 12. New York: Pantheon Books, 1990.

thirteenth percent of the polled number indicated that they wished to purchase a receiver at that time.[61] The opening of New York World Fair in the spring of 1939 allowed public to see for themselves what they were missing. At the Fair, the latest television receivers were displayed in the pavilions of RCA, Westhinghouse, and GE. RCA-NBC also telecast President Roosevelt's speeches for the first time.

To increase the public in purchasing a television, during 1939-40 companies such as the Farnthworth Television Company, Philco and RCA conducted tours promoting their receivers to retailers and potential customers. According to the Farnthworth Television Company, it visited eighty-eight retailer stores introducing the new medium.[62] By 1940, experimental programs had gained a modest audience, including amateurs and enthusiasts from radio, engineers, production staff, critics and regulators. In front of the growing public's anticipation on television in US, FCC approved semi-commercialization of television in 1940.

RCA became the first to launch a great sale of television sets with reduced prices, programs and a network all together to the customer. RCA's action stimulated the other television programmers and manufacturers (DuMont, Philco, and Zenith) to follow a similar path. As RCA anticipated, the more customers purchased its televisions, the more difficult it was for the FCC to regulate the transmission and reception standards. To avoid the monopolization, National Television System Committee (NTSC) was founded in July 1940 along with the promulgation of a one set universal television standard in July

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[61] Ibid., p.17

[62] Bud Gamble, "The Television Tour of 88 Department Stores," *Televiser*, Winter 1945, p. 48. (As cited by MacDonald, J. Fred. "Struggle for an Industry." *One Nation under Television-The rise and decline of Network TV*, p. 19. New York: Pantheon Books, 1990.)

1941 approved by FCC for all the receivers to get the same pictures at the permitted spectrum bands. The regulation of black-and-white transmission included the new 525-lines standard and the use of FM for audio station, as a compromise of the existing standards in the market: 441-lines with 30 frames and AM radio sound (RCA), 605-lines with 24 frames (Philo), 625-lines with 15 frames (DuMont) in the market.[63] The comprehensive commercial TV program was also approved and allowed to begin on July 1st in 1941. Television set sales began to increase with the growing of individual television stations.

In a Gallup poll from *Public Opinion* in 1945,[64] the survey indicated that the majority of the population were uncertain about whether or not to purchase a television for use at home. In response to the question "Do you know what television is?" 84% responded "Yes." Then, of the 84% who knew what television was, when asked "Have you ever seen a television set in operation?" only 22% said "Yes." Again, these 84% were asked about their plan to purchase a television, and 24.6% thought it might happen in two or three years, 36% think it would be longer than that and 25.2 % think they would never have a television. The public's ambivalent attitudes demonstrated that most people did not think television necessary to their daily life.

Another survey by *Television Factbook (1949-1979),*[65] indicated that from 1946 to 1954 the percentage of household who owned television sets has rapidly increased from 0.06% to 59.4%. The total television set production in 1947 is 178,571. This number

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[63] "Struggle for an Industry." *One Nation under Television. The Rise and Decline of Network TV*, J. Fred MacDonald, p. 17. New York: Pantheon Books, 1990.
[64] (US Dec 29'45), Strunk, Mildred, and Hadley Cantrail. *Public Opinion 1935-1946.* Princeton, p.857. NJ: Princeton University Press, 1951.
[65] Washington, Television Digest, 1945-. *Television Factbook*, 1945-1979.

boomed to 7,261,109 in 1953. By 1979, near 98% of the households in the United States had at least one television at home.

One direct reason for this change is the improvements on the television apparatus. Images were no longer as fuzzy as in 1920. The advancing in image resolution provided opportunity for television's extra value.

The second reason was the relationship between the decreasing price of the television market and the increasing annual income. When commercial television was introduced to the public in 1940s, it was those with discretionary income and an inclination for what later was called "*New Technology*" that became the first buyers. According to the electronic advertising,[66] a black-and-white television produced by DuMont cost from $329.50 to $695 in 1951 when the average income was $3,210. In 1960, the average income increased to $6,690 while the price of a color television set by RCA was $495.

The third drive for the increasing demand for television was the exploration of numerous programs, adding extra value. Television programs started with drama and event broadcasting. These grew fast after 1945, led by comedy and drama in late 1940s, sitcom and game shows in 1950s and quiz shows in the 1960s. The audience gender gradually shifted from men to women.

These changes influenced the film industry. To attract customers to the movie theaters, Stereoscopy, 3D view and Sensorama were introduced to create enhanced sensory effects. This was considered the start of virtual reality a decade later.

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[66] *Electronics/ TV of the 1950s.* http://www.vintageadbrowser.com/electronics-ads-1950s (Accessed by July 18, 2017).

4. Conclusion

The launch of any electronic communication device was a collaboration of many prominent scientists and researchers in different labs from various countries. The move from telegraph and telephone to radio and television was possible as individuals because more entrepreneurial and companies sponsored specific developments. In the twentieth century, the growing use of all forms of electronic communication led the federal government to become involved in regulation.

Virtual Reality is a further development of previous inventions, following a similar path. Some commentators suggest that a cheap wireless VR headset will be released in later 2018.[67] The advancement of Virtual Reality is that it allows viewer enter into an immersed virtual space. The highest form could correlate to all the sensory systems of a human being, including auditory, vision, tactile, olfactory and gustation, and even movement in the form of gestures. Technical difficulties remain, but going beyond providing entertainment it is clear that medicine and specialized military training are already proving very useful. These will be explored further in the next chapters.

[67] Facebook to Unveil Wireless VR Headset for the Masses, *Fortune*, July 13, 2017, Tech. http://fortune.com/2017/07/13/facebook-vr-wireless/ (Accessed July 24 2017)

CHAPTER 3

ILLUSION AND TRUTH IN THE VISUAL WORLD

If virtual reality is considered as a tool to create the visual illusion of being immersed in an environment, the earliest attempt to this field is the study of the vision imaging, including the interaction of light with matter and the construction of instruments that use or detect them. This chapter begins by tracing the origins of perspective in Renaissance Italian drawings and paintings, continuing with an examination of the French "fool the eye" perspectives that imitated reality with more emphasis on light, shadow and darkened areas in pictorial representations. The second section of the chapter explains how the understanding of light "rays" led to the exploration of optics, producing equipment of several kinds, including the camera. The importance of photography as a creative medium and a documentation method cannot be overstated. This leads to the final section of the chapter dealing with film animation, another important step closer to the development of what is now known as virtual reality.

1. Virtual Reality in Visual Arts

1.1 From imagination to perspective paintings

The illusion of reality in drawing and painting depends on the difference in perception between two-dimensional and three-dimensional representation. In the early 3rd century this topic was approached by the Greek mathematician Euclid in his work *Optics*. It established a relationship between geometry and visual perception. This interest continued through the Middle Ages, particularly in regards to astronomy and

surveying. The principles of perspective were only occasionally used by artists and painters before the Renaissance, however, as the illustrators were still struggling to convey the missing third dimension with sufficient consistency.

One of the earliest experiments of this is the "Jesus Before the Caïf," a ceiling painting by the medieval Italian painter, Giotto di Bondone. Although Giotto's work attempted to suggest the reality, his use of perspective was still imperfect, given that only a few of the vanishing points are on the painting and they inconsistent applied.

Figure 3.1: Cristo davanti a Caifa (1305)
Sources: https://www.wikiart.org/en/giotto/christ-before-caiaphas
(Accessed by Feb 25, 2017)

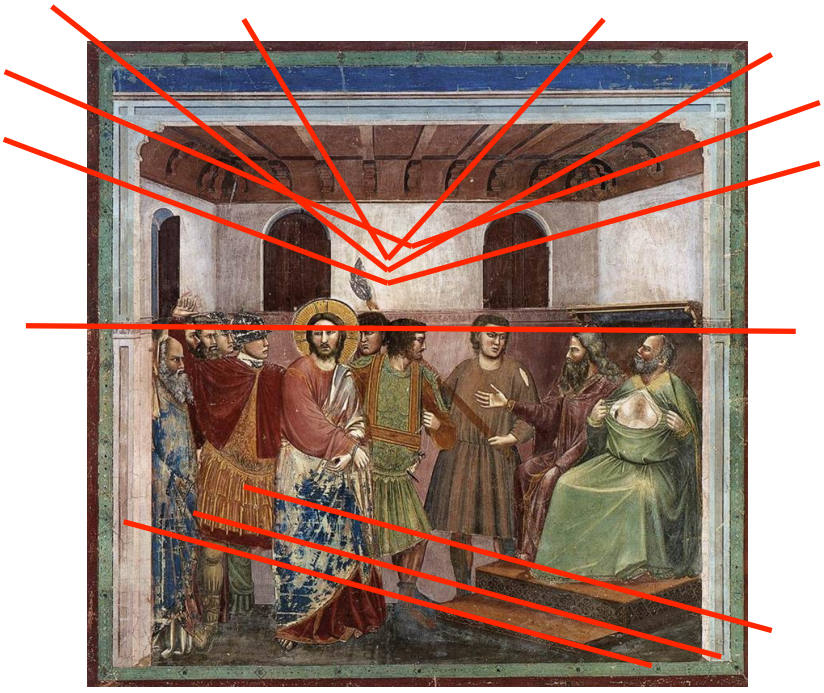

Figure 3.2: Author's analysis
Sources: https://www.wikiart.org/en/giotto/christ-before-caiaphas
(Accessed by Feb 25, 2017)

Since the 14th century, the search intensified for a unified theory about how objects are represented and how they are actually seen. The theory behind realistic perspective theory began with the discovery of the vanish point by Filippo Brunelleschi, best known as Renaissance Italian architect.[68] A more completed basis mathematical principles of perspective were laid out by architectural theoretician Leon Battista Alberti in his treatise *Della Pittura* in 1435, which proved a systematic and clear discussion of the use of geometric principles for the creation of perspective.[69]

Following the publication of *Della Pittura*, the discussion of the laws of perspective has spanned centuries with the explorations of one point perspective, two-point perspective, and three-point perspective, to name a few of the common types. The study of perspective was reinforced by algebraic geometry and analysis geometry. Later still, the development of electrical engineering and electronography provided the basic formula of mathematic perspective and advanced projective representation, computer-generated imaging and computer graphics.

1.2 The Perspective Illusion in Arts: Trompe l'oeil

One of the good examples of the use of perspective to create an illusory reality is *trompe l'oeil*, a technique of painting that trick the viewer's eye into seeing painted

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[68] Dauben, Dr. Joseph. *Renaissance & Reformation in Europe-early Renaissance in Italy: 1400—A beginner's guide to Renaissance Florence. Early Applications of Linear Perspective.* 2016. https://www.khanacademy.org/humanities/renaissance-reformation/early-renaissance1/beginners-renaissance-florence/a/early-applications-of-linear-perspective (Accessed by Feb 4, 2017).

[69] Bertol, Daniela. *Designing digital space: An architect's guide to virtual reality*. John Wiley & Sons, Inc. p. 6, 1996.

objects as if they exist in three dimensions. The term *trompe l'oeil* is French for "deceive the eye" and was coined during the Renaissance period. Although there are earlier examples of the use of *trompe l'oeil* techniques, only after artists started applying the laws of perspective more rigorously did *trompe l'oeil* paintings become more true-to-life.

The development of this artwork is based on the structures of human being's eyes perceiving the 3-dimensional world. The light reflected off the objects in the real world coming into the eyeball projects onto the retina screen, which lines the back of the eyes in the form of 2-dimensional image. These 2D image signals go through a series of process in our brain before being interpreted as if they are three-dimensional and in perspective.

In *trompe l'oeil* arts, by carefully depicting the scale and distance of the visual objects in relation to viewer, artists created the paintings with a real in-depth effect. During the Renaissance, artists used the *trompe l'oeil* technique in an attempt to increase visually the space of a wall or ceiling and create the illusion of 3-dimensional space on a 2-dimensional surface. One common type of *trompe l'oeil* is architectural painting, where columns, sculptures or other architectural components are shown on the wall or ceilings, creating the desired illusory effect to expand a room into imaginary space.

This technique was used when there was a lack of money to build these architectural elements. Further development of perspective theories during the Baroque period allowed for a more fully-integrated approach to architectural illusion. This more highly-developed form of architectural *trompe l'oiel* is known as *quadratura*. The Italian Jesuit painter and architect, Andrea Pozzo, was one of the practitioners of *quadratura* during the Baroque era. Pozzo's masterpiece, the frescoed ceiling of the church of Sant'Ignazio in Rome, is a prime example of the use of perspective to create an illusion.

On the ceiling of the church, Pozzo used perspective to paint scenes celebrating the works of Saint Ignatius and the Society of Jesus, depicting the life and apotheosis of St. Ignatius, and create the illusion of a dome at the church's crossing.[70]

Throughout human history, art has been based on imitation and illusion, a kind of visual duplicity, but one that viewers have observed.[71] The study of the geometry of vision was not only widespread in the arts, where it eventually led to the development of the laws of perspective, but also in the sciences, where it led to the establishment of the basic principles of optics.

[70] N/A. *Apotheosis of St Ignatius by Andrea Pozzo Explanation of High Baroque Quadratura Painting.* http://www.visual-arts-cork.com/famous-paintings/apotheosis-of-st-ignatius.htm#background (Accessed 02 13, 2017).

[71] Sharp, Kevin. *The Reality of Things Trope L'oeil in America*. Vero Bech Museum of Art, p. 11. 2007.

Figure 3.3: Interior of the Camera Picta in the Palazzo Ducale

Figure 3.4: Ceiling of the Camera Picta in the Palazzo Palace
Figure 3.3 & 3.4 Source: https://17green.wordpress.com/2014/03/14/trompe-loeil-andrea-mantegna/ (Accessed March 25, 2017)

2. The Development of Photography

As early as 4th century BC, scholars and philosophers both in the eastern and western world have demonstrated the phenomenon that lights generates an inverted image of the outside world to appear on the wall of a darkened room when light from the outside enters the room through a small hole. Inspired by this principle, inventors developed an optic device to capture images, later called the *camera obscura.*

The use of camera obscura grew in two ways. One served as a drawings tool to aid Renaissance artists in perspective. As a portable box, the camera obscura was commonly used in paintings, portraits, maps, and theater backdrops. The other path led the camera obscura to be further developed into a photographic camera in the first half of 19th century. This new use came with the introduction of daguerreotype to the industrialized Western society in 1839, the first photographic method that allowed people to permanently capture images. Since then, photography has remained viable, as it fills a cultural and sociological need that cannot be met by works created by hand.

2.1 Photography in documentation

Photographs became an important tool for documenting everything that is happening, and has happened. In the Western world, for example, people began to use camera to record the scenery of the American West in the early 19th century. By using photography to capture images of scenery, the appreciation of the magnificent landscapes

increased. It also allowed other people to envision the economic value of the land, stimulating them to explore the less developed areas of North America.[72]

The American painter Albert Bierstadt worked with his brothers using photography to publicize the scenery of the Rocky Mountains in 1859.[73] With their photographs, the brothers created stereographic views that allowed the public to view 3-dimensional landscapes of the West. The landscape photographs were even presented in albums and lantern slides to Congress and other influential people in applications for funding for scientific expeditions and for the creation of national parklands.[74]

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[72] Rosenblum, Naomi. "Chapter 3: Documentation: Landscape and Architecture 1839-1890," *A World History of Photography*, p. 128-131. New York, London: Abbeville Press Publishers, 2007.
[73] Ibid, p. 132.
[74] Ibid, p. 151.

Figure 3.5: Bierstadt Brothers, Glen Ellis Falls, White Mountains, N.H. (plate 1019), ca. 1860–62. Albumen silver print. Private collection.

Source: http://www.19thc-artworldwide.org/autumn13/jensen-on-albert-bierstadt-and-the-stereographic-landscape (Accessed March 25, 2017)

Besides being valuable for recording the exploration of unknown parts of the continent and the beauty of nature, photography was also the ideal tool for the documentation of daily life, cultural events, industrial development, scientific documents, and warfare and conflicts.

In East Asia, photography was introduced to China in the 1840's, when rebellions and wars opened the country to European imperialism. John Thomson, a Scotsman, is considered to have been one of the prolific photographers working in China during the mid to late 1800's. He spent from 1868 to 1872 based in Hong Kong.[75] During this time, he traveled throughout the country and used photography to document Chinese customs and nature. Afong Lai, who, according to Thomson, was a man with "cultivated taste,"[76] recognized photography's view-making role. In 1859, he opened his photography studio, which remained in business until the 1940's, creating a rare and large body of photographs.[77] His interest in topographical views and social life allowed his photographs to reach into peoples' lives and culture.

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[75] Ibid., p. 125-127.
[76] Ibid.
[77] Cabos, Marine. *Lai Afong,* In *Photography of China,* http://photographyofchina.com/blog/lai-afong (Accessed April 28, 2016).

Figure 3.6: Group Of Chinese Women with Fans, Canton, China [c1880], by Afong Lai
Source: https://www.flickr.com/photos/ralphrepo_photolog/4071802299
(Accessed March 25, 2017)

Although a photograph is a 2-dimensional image, a photograph encourages the viewer to apply meaning to the image. The meaning an individual applies to a particular image is based on that individual's cultural experiences and visual literacy.[78] This act of meaning-making allows a viewer to fully engage with photographic records in a way that permits the viewer to transcend time and place. When photographs are thoughtfully arranged in series by professionals, historical facts can be reframed as a narrative and can be used to transmit a historical memory to a viewer.

The very objectivity of photographic records is a controversial topic, in part because every photograph is taken from the point-of-view of the photographer. For example, Architecture was an ideal subject for the photographic processes introduced by J.L.M. Daguerre and William Talbot in 1839, since buildings were amenable to the very long exposure times required. The elevation approach was treated as an extension of architecture rendering to reflect the details of the façade. The perspective approach on the other hand was to reflect the overall structure of the building from the corner viewpoint.[79] What the photographer chooses to photograph, and the techniques he chooses to employ,

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[78] Persinger, Tom. Introduction: *Photography Beyond Technique, Essays from F295 on the Informed Use of Alternative and Historical Photographic Processes,* London, New York: CRC Press, 2014. https://proquest-safaribooksonline-com.proxy.library.cornell.edu/book/photography/9780415817561/introduction-photography-beyond-technique/h1_3_xhtml#X2ludGVybmFsX0h0bWxWaWV3P3htbGlkPTk3ODA0MTU4MTc1NjElMkYwOV9jaGFwdGVyMDFfeGh0bWwmcXVlcnk9 (Accessed by June 15, 2016)

[79] Shutter Release, History of Architectural Photography: Book Review of *Architecture Transformed: A History of the Photography of Buildings from 1839 to the Present (*Robinson, Cervin, and Joel Herschman*.)*. Cambridge, MA: MIT Press), http://www.iconicphoto.com/pdf/history_book_review_0808.pdf (Accessed by Nov 15th, 2017).

provide the image with meaning before it is shared by others. Likewise, what photographs are chosen to be part of a historical record and the way the record is presented to influence how viewers interpret what they see. This took place in the 1850's, when architectural photographs were used to influence the European and American opinion about the need for the restoration of dilapidated national monuments in France.[80] The photographers used raking light to strengthen the buildings' shadows and draw attention to the texture of the architectural components of the buildings. This created a romantic aura about the sites, focusing the viewer's attention on their uniqueness and irregularity, instead of providing an accurate record of their state. This technique is still used with two-dimensional images in architecture to arouse memories, emotions, or sensations, for example a particular theme space.[81]

3. Vision persistence theory

During the time of the popularization of photography, animation—a technology that takes advantage of an optical illusion—became fashionable. The start of the now hundreds-year-long animation industry is dated back to the time when people began to investigate human's vision perception.

One of the most popular optical toys in 19th century, the *Thaumatrope* ("wonder turner"), stimulated the discussion vision persistence. The toy is made of a disc and held by two pieces of strings on opposite sides. The both sides of the disc are painted with

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[80] Robinson, Cervin, and Joel Herschman. *Architecture Transformed. A History of the Photography of Buildings from 1839 to the Present*. P.18. Cambridge, MA: MIT Press.
[81] Lukas, Scott A. The *Immersive Worlds Handbook. Designing Theme Parks and Consumer Spaces*. p.16. Burlington, MA: Focal Press, 2013.

drawings. When the disc twirled by the strings, the two pictures appear to blend into one image.

Scientific studies were conducted British physician Peter Mark Roget, who provided the reason for the apparent curvature of the spokes of moving carriage wheels. In his paper, *Explanation of an Optical Deception in the Appearance of the Spokes of a Wheel when Seen through Vertical Apertures (1825)*,[82] he suggested that the optical illusion was due to the persistent vision of moving objects. Although later proved to be an incorrect position, he inspired further development of vision persistence theory.[83]

Several film animation devices were invented, including phenakistoscopes, zoetropes, flipbooks, and praxinoscopes. By the quick substitution of one image for another, the image appeared to be able to provide a sequence of "realistic" movements. While the sequences of drawings became the predecessor of films, they were fundamental to the understanding of movie making in the 20th century.

3.1 The start of animation in the film industry

The early use of sheets and rolls of celluloid film and the movie camera allowed the photographers to capture a rapid sequence of images. Primitive photography-based motion pictures were first made in the late 1870's, with the goal of analyzing the movement of objects in a way that was not possible observed with the naked eye. One such motion picture was made by photographer Eadweard Muybridge to analyze the motion of the hooves of a running horse in 1872. The motion camera also inspired

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[82] Herbert, Stephen, ed. *A History of Pre-Cinema.* Introduction, Vol. 1. 2 vols. P. 253 London: Routledge, 2000.
[83] Ibid.

physiologists, including Etienne-Jules Marey, to record and analyze the internal movement such as heartbeat and external body motions.

Due to the power of film's visual effect, people then turned their interest to motion pictures for story-telling, which allowed the growth of cinematography. Early actors in cinematographic history were Thomas Edison in the United States and the Lumiere Brothers in France. Thomas Edison and his assistant, Dickson, used 1½ inch wide film in the late 1890's, laying the standard for today's 35 mm. commercial film. Early motion pictures showed things like a man watering his garden or a train arriving at a station and would last 5-8 minutes, as films were restricted to the length of a film.

The significance of motion pictures became more evident as a form of entertainment welcomed by lower income classes. The Italian film *Quo Vadis*, introduced into the United States in 1913, was eight reels in length. As it was longer, it had an admission price of $1.00 but it was greeted by great public enthusiasm.[84] Gradually films were accepted by the upper class, formerly accustomed only to live theater and opera. This prompted filmmakers to begin experimenting with the feature-length film format. Early films in this format included David Griffith's *Judith of Bethulia* (1914), and, later, his *Birth of a Nation*.

3.2 Film industry influences on social life

With the emergence of the mass production of feature films, film-making shifted from individual work to a more collaborative enterprise. Huge studios and back lots were

[84] Bohn, Thomas W., Richard L. Stromgren, and Daniel H. Johnson. "Chapter 4: An industry Emerges." *In Light and Shadows. A History of Motion Pictures*, p. 310. New York: Alfred Publishing Co., 1975.

constructed in response to the needs of the industry. Meanwhile the reaction of the public to the new film varied. When first shown some productions, audiences reacted with shock and fear. Films such as *The Great Train Robbery* (1903) by Edwin Porter scared viewers. Some audience members shouted when the cowboy in the film turned his pistol on the audience and fired. *Uncle Josh at the Moving Picture Show* (1902), also by Edwin Porter, caricaturized this reaction of audience members to film by showing Uncle Josh, a country bumpkin who seriously misunderstood the nature of film, becoming confused at seeing moving pictures. This phenomenon declined as audiences became comfortable with the technology.

Despite the fact that motion pictures came to dominate a large portion of the entertainment industry in America, as in Europe, the first function of film was recording reality. The practice started with one English company in the United States that produced factual films for schools, universities, clinics, and institutions in 1911. By 1926, the number of such companies had increased to seventy-five. Several instructional films were developed for use in the St. Thomas Hospital in London, including *Microscope Magnification and Laboratory Techniques*, which gave audiences a better understanding of the realities and value of laboratory work. Universities, including Stanford and the University of Southern California were supporters of the use of educational films. Likewise, religious groups such as the Moody Bible Institute used film for demonstrating songs and as a tool for gaining converts.[85]

Motion pictures have not only been used in entertainment and the education but also by governments, including dictatorships, as an effective propaganda tool. For

[85]Ibid., p. 285-287.

instance, in 1918, films in the Soviet Union were shown to increase nationalism and pride.[86] These films, in the style of Socialist Realism, depicted the perfect communist society. The famous Soviet leader Lenin, said in his *Directives on the Film Business*, "Of all the arts, for us cinema is the most important." Film propaganda was also used by Nazi Germany in World War II. One such film, *Triumph of the Will* (1936) by Leni Riefenstahl, documented the massive Nazi Rally organized at Nuremberg in 1934.[87] These films were government-financed in order to spread ideologies to a greater number of people and instill fear in the enemies.[88]

4. Conclusion

The retina acts as a screen that captures a 2-dimensional image of what is seen. When the brain receives the same image from both eyes, it converts the 2-dimensional image into a 3-dimensional image. In the same fashion, a flat picture, false front, or theatrical flat can be successfully substituted for a 3-dimensional scene if the same image can be provided to each eye.[89] This unique feature of our eyes makes *trompe l'oeil* possible. This physiological feature also becomes the prerequisite condition for the development of virtual reality technologies.

As the "New Medium" in the 19th century, the practical development of photography and motion pictures reflects the desire of humans to create and engage

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[86] Ibid., p. 108.
[87] Ibid., p. 108.
[88] "Chapter 8: The Stories told by Film." *In Film, Form, And Culture,* 3rd Edition, Robert Kolker, p. 225-226. New York: McGraw-Hill, 2006.
[89] Hochberg, Julian. "Visual Perception in Architecture." *Journal of the Graduate School of Fine Arts*. P. 26-45. Philadelphia, PA: University of Pennsylvania and MIT Press, 1983.

alternate realities, whether past, present, or fictional. This has prompted its use in fields such as historical and cultural documentation, arts, and entertainment. The powerful visual stimulus provided by film has a persuasive psychological effect on human subjects, allowing it to be used for indoctrination or re-education.[90]

Given all of this, virtual reality can be considered as an upgraded optical tool, using similar visual principles to present the world in a more interactive way. New applications for virtual reality will be developed to facilitate peoples' daily lives and fill their need for education and entertainment. Virtual reality will likely also play a role in meeting other, as-yet-unforeseen, needs of humanity.

[90] Garth S. Jowett, Victoria O'Donnell. "Chapter 3: Propaganda Institutionalized." *Propaganda & Persuasion, Sixth Edition*, by Victoria O'Donnell Garth S. Jowett, p.114-125. CA: Sage Publications, Inc., 2015.

CHAPTER 4

THE DUNHUANG VIRTUAL REALITY THEATER

After riding on a bus from downtown for 20 minutes, passing the dunes and blinding sands of the Gobi Desert, tourists are delivered to the Dunhuang Digitization Center. It is 15 miles away from the protected Mogao grottoes, which were constructed over the course of ten centuries and contain the world's largest treasury of Buddhist art. At the center tourists watch two movies introducing the Mogao grottoes before visiting the real ones. The movies are shown in the newly launched Omnimax dome theater in the Digitization Center, built in 2006, providing tourists with an immersive visual experience while sitting in an auditorium. In the movie "Dreamy Temples," seven grotto scenes are portrayed. This includes caves No. 45 and No. 285, which are representatives of the high arts of the Tang era. The real caves are kept closed for protection. Using seamless splicing technology, the 20-minute movie is a 3D, virtual reconstruction of the grottoes' elegant artistic works. The movie opens a channel for tourists to appreciate, learn, and understand the works of art and history of Mogao in an immersive environment. The 340 million Yuan[91] digital theater in the Digitalization Center was opened in August 2014, and is the first and biggest virtual cave system of grottoes in the heritage field.

This chapter reviews the history of the caves and the developing interest in their exploration, followed by a description of the need to accommodate a growing number of visitors in a center, and digitalization process that led to the current interpretation.

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[91] Liu, Yutao. *China News*. January 24, 2015. http://www.chinanews.com/cul/2015/01-24/7001918.shtml (Accessed 07 15, 2016).

1. The History of Mogao Caves

Duhuang is located at the western end of the Hexi Corridor in Gansu province. In the Han Dynasty, when the famous Silk Road opened, Dunhuang served as one of the most prestigious sites on the trade route. Dunhuang connects on the east to the ancient capitals of Chang'an and Luoyang in the east. To the west of Dunhuang, the Silk Road splits into two routes, one to the south passing Kunlun Mountains and reaching to Dayueshi and Anxi, and the other to the north towards Urumuqi and extending along the foot of the Tian Mountains. Traffic flow coming from either route eventually intersected at Dunhuang before entering Central China. Serving as the hub of trading from the east and the west, Dunhuang not only initiated trade and commerce, but also absorbed multiple cultures, joining and melting them together. The culture of Central China is considered taking root in Dunhuang. Additionally, by virtue of Dunhuang's location in the western region, Buddhist culture from India and Western and Central Asia gradually imported here.

Figure 4.1: Ancient China SilkRoad Route Outline Map.
Source: https://silkroadtoronto.files.wordpress.com/2009/10/silkroad-outline-map.gif.
(Accessed April 15, 2016)

Against this historical backdrop, the Mogao grottoes originated and eventually became representative of the largest and most richly decorated treasury of Buddhist art in the world. They are renowned for their wall paintings, painted sculptures, and ancient architecture.[92] In China, Mogao, together with the Yungang, Longmen, and Maijishan caves, are regarded as the Four Cave-Wonders. The Mogao Grottoes became included on the list of World Heritage Sites in 1987. Today the Mogao caves comprise a system of 492 temples, 16 miles southeast of Dunhuang, west to the Hexi Corridor.

The construction of the caves took place over the course of 16 dynasty periods, from the pre-Qin (Sixteen Kingdoms) to the Yuan Dynasty. During the period of the Sixteen Kingdoms, when wars were frequent, many people from central China and the Hexi Corridor fled to Dunhuang, which was relatively peaceful and prosperous at the time. Traveling Buddhist monks from the west came to China to teach Buddhist law, and they established a Buddhist community in Dunhuang that grew quickly.[93] Many temples and stupas can be found in the area.

The first Mogao caves were dug in 366 CE as places for Buddhist meditation and worship.[94] According to the book Fokan ji,[95] on a trip to Minsha Mountain, the monk Le Zun had a vision of thousands of Buddhas showered in golden light. This inspired Le Zun to build a Buddha cave on that site. The construction work was continued by a

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[92] UNESCO. World Heritage List. 1987. http://whc.unesco.org/en/list/440. (Accessed by April 20, 2016).
[93] Wei Shou, 魏收. *Book of Wei- a history of Buddism and Taoism* 魏书-释老志. North Qi 北齐, 554 AD.
[94] UNESCO. World Heritage List. 1987. http://whc.unesco.org/en/list/440. (Accessed April 20, 2016).
[95] Li Kerang, 李克让. *Fokan Ji* 佛龛记-修莫高窟佛龛碑. Tang Dynasty， 唐圣历元年, 698 AD.

monk, Fa Liang, who built a second cave next to the earlier one.[96] The grottoes increased in number over the subsequent 16 dynasties, particularly as Buddhism became accepted as the predominant religion in the country. This was with the support of North Wei, West Wei and North Zhou. During the Sui and Tang Dynasty, with further expansion of the Silk Road in western China, Dunhuang became even more prosperous with additional trading markets and commerce activities. Benefiting from this, the Mogao caves were continuously enlarged and reached the scale of the Thousand-Buddha caves, known during the reign of Empress Wu Zetian. The An Lushan rebellion, which occurred circa 755 AD, caused the decline of the Tang Dynasty. Afterwards, Tibet, the strongest supporter of Buddhist culture, controlled the Hexi corridor. Tibetans' endeavors in Buddhist culture and arts continuously extended the Mogao caves.

Later, Dunhuang was occupied by Mongolia and Dangxiangqiang. Then the Mogao Grottoes were regarded as important Buddhist sanctuaries that should be protected. Few new caves were added. When Islam conquered central Asia in the 13th century, and as the sea-routes increased during the Min dynasty, the Silk Road was abandoned, and Dunhuang became depopulated and largely forgotten. All construction of the Mogao caves ceased. Most of the caves were buried under the sand, only attracting the attention of local people who worshipped there.

Until the late 19th and early 20th centuries that exploration of the ancient Silk Road and the lost cities of Central Asia was limited to a few Western adventurers: Aurel Stein (Hungarian), Paul Pelliot (French), and Langdon Warner (American). A Chinese Taoist,

[96] Li Kerang, 李克让. *Fokan Ji* 佛龛记-修莫高窟佛龛碑. Tang Dynasty. 唐圣历元年, 698 AD.

Wang Yuanlu, was a guardian of some the Mogao temples, and first discovered the Library Cave within which was stored an enormous hoard of manuscripts. The interest in discovering the Mogao caves was largely due to Westerners who feared that the many valuable manuscripts, mural paintings and status would be lost or shipped overseas.

Chinese research increased in the 1940s, when the Research Institute of Dunhuang was founded by the Kuomindang. The Institute became the Dunhuang Academy in 1944. After the establishment of the Republic of China, Premier Zhou Enlai visited Mogao Caves in 1956 and sanctioned a grant to repair and protect the site. In 1961, Mogao was declared a specially protected historic monument by the Chinese Council and large-scale renovation work began soon afterwards. This included systematic protection and improved security of the caves through the construction of a concrete façade during the 1950's and 1960's.[97] After having survived the Cultural Revolution, exploration restarted and, from 1988 to 1995, another 248 caves were discovered to the north of the original site, so that a total of 487 caves have been identified since the early 1990s.[98]

In the Tang dynasty, there were more than a thousand caves. Today there are 812 caves surviving in the Dunhuang area, among which 735 are in the Mogao Grottoes, 22 in the Western Caves of the Thousand Buddhas, 42 in the Yulin Grottoes, 7 in the Eastern

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[97] Sun, Rujian. "Review of stabilization projects at the Mogao Grottoes." *Conservation of Ancient Sites on the Silk Road* (proceedings of an International Conference on the Conservation of Grotto Sites, Mogao Grottoes at Dunhuang, October 1993), Neville Agnew, editor, pp. 159-169. Los Angeles: The Getty Conservation Institute, 1997.
[98] Muramatsu, Takako, Makiko Onishi, and Asanobu Kitamoto. *Narratives on Cultural Heritage along Silk Road with figures and photographs from rare books*. Edited by Translator Suijun Ra and English adaptation by Leanne Ogasawara, April 14, 2010, Digital Silk Road Project, National Institute of Informatics. http://dsr.nii.ac.jp/rarebook/05/index.html.en. (Accessed July 14, 2016).

Caves of the Thousand Buddhas, and 6 in the Five-Temple Grottoes.[99] The Mogao Grottoes contain the most magnificent Buddhist artwork and consist of 45,000 m^2 of wall paintings and 2,415 statues.[100] The 735 Mogao caves can be divided into two groups: those in the south area, which consist of 492 caves used for religious practices, and those in the north area, which consist of 243 caves used for living quarters by the monks. Most of the caves are fully painted with murals on the walls and ceilings. The characters depicted vary according to the different time periods. The features of Tang art, for example, express the people's strong desire for the paradise of the Pure Land represented by Mahayana Buddhism, which was increasingly popular during that time. Over 2,400 statues and sculptures inside the caves vary in size and style, reflecting the different aesthetic standards of the time periods in which they were made.

[99] Yunhe, Pan, and Fan Jinshi. *Dunhuang Real and Virtual*. P.9 Zhejiang University, 2003.
[100] UNESCO. World Heritage List. 1987. http://whc.unesco.org/en/list/440. (Accessed by April 20, 2016).

Figure 4.2: Statues in the main niche, west wall in Cave 45

Figure 4.3: Bodhisattva and devaraja, niche in Cave 45
Source: Dunhuang Research Academy-Mogao Cave 45, http://public.dha.ac.cn/content.aspx?id=091738783053 (Accessed by April 10, 2017)

2. Background Behind the Mogao Digital Project

While many elements of the grottoes are strong enough to have survived thousands of years, many of the pigments, made of wheat straw and wood elements, are very fragile. They are suffering from oxidation due to long exposure to air and light. The 492 caves in the southern area of the Mogao Grottoes were originally constructed as family temples for worshipping Buddha, not as a public cultural center. Now the site is open to the public as a museum.[101]

Among the 492 caves containing murals and painted sculptures, there are only 18 caves whose surface area is more than 100 $m.^2$ Meanwhile, 21 caves are between 50-100 $m.^2$, 41 between 25-50 $m.^2$, and 123 are between 10-25 $m.^2$, but as many as 289 caves are below 10 $m.^2$ The fact that 80% of them are no more than 25 $m.^2$ suggests that the dark and damp environment is working against their preservation. Additionally, this means that the space inside most of the caves is extremely limited, creating difficulties for thousands of visitors to come in and view the artwork. The increasing numbers of visitors in such a restricted space inevitably causes degradation of the artwork.

Since 2001, with the support of the Chinese Administration of Cultural Heritage and in cooperation with the Getty Conservation Institute in the United States, the Dunhuang Academy carried out a research study entitled "Mogao Visitors Carrying

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[101] Fan Jinshi, Dunhuang Academy China. "Tourism to the Mogao Grottoes: Overview of Conservation Challenges and Countermeasures." *Extended Abstracts of the International Colloquium: Visitor Management and Carrying Capacity at World Heritage Sites in China*, 17-19 May 2013, Mogao Grottoes, Dunhuang. Neville Agnew and Martha Demas, ed. Los Angeles, CA: Getty Conservation Institute, 2014.

Capacity."[102] The results of this research led to the drafting of policies about the appropriate usage of the Mogao Caves, including the number of visitors they can accommodate, the minimum area needed per capita, the minimum size of the caves open to the public, the minimum time each visitor can spend in a single cave, and the maximum concentration of carbon dioxide permitted in a single cave.[103] Based on a series of analyses on the then open 112 caves, evaluation of visitors' learning experiences, laboratory experiments, and studies of the cave environments both inside and outside, guidelines for the optimum management and preservation of the Mogao Caves were created.[104]

According to the assessment, the safe visiting distance is 1 m. from the mural.[105] For those caves sensitive to humidity (RH) and/or threatened by increases in CO_2 concentration, the time they are open to the public is controlled with greater attention. An analysis of the cave conditions, including a test of the air exchange rate, a simulation of the inside environment, and a microenvironment test, concluded that most of the heat and

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[102] Wu Na, Song Xiqun, Guangming Daily, 光明日报 吴娜 宋喜群. 敦煌莫高窟游客承载量公布 游客与文化遗产能否双赢. Tourists Carrying Capacity of Dunhuang, June 5, 2013. http://tour.dha.ac.cn/content.aspx?id=647435001607. (Accessed July 20, 2016).
[103] Fan Jinshi, Dunhuang Academy China. "Tourism to the Mogao Grottoes: Overview of Conservation Challenges and Countermeasures." *Extended Abstracts of the International Colloquium: Visitor Management and Carrying Capacity at World Heritage Sites in China*, 17-19 May 2013, Mogao Grottoes, Dunhuang, Neville Agnew and Martha Demas. ed. Los Angeles, CA: Getty Conservation Institute, 2014.
[104] Demas, Martha, Neville Agnew, and Fan Jinshi. "Chapter 4: The Mogao Visitor Study." *Strategies for Sustainable Tourism at the Mogao Grottoes of Dunhuang, China*, p. 84. Los Angeles: Springer, The J. Paul Getty Trust 2015.
[105] Ibid., p. 83.

moisture in the caves is generated by visitors breathing and by the opening and closing of each cave gate[106].

After the six year research project (2005-2011), Dunhuang Academy issued tourist management guidelines and finally set the maximum daily capacity of Mogao Grottoes at 3,000 persons and the maximum number of people per visiting group at 25 persons/group.[107] According to these regulations, only caves exceeding 13 m.^{2} will be open to the public, thus half of the caves were sealed up for safekeeping.[108] This means that unfortunately many visitors would lost the chance to appreciate the beautiful artwork inside those caves. In addition, since many of the visitors to Mogao are international, Dunhuang lost some of the opportunity to disseminate valuable cultural information to the world and the ability to profit from tourists.

The goal of the policy decision was to preserve the murals and sculptures from further damage, while still ensuring tourists' satisfaction. In reality, there is a huge gap between what the site can provide and what satisfies tourists during their visit. Every day, thousands of tourists from all over the world come to admire the inspired artwork. Since Mogao first opened to the public in 1979, the number of tourists has steadily increased, starting with 20,000 persons/yr in 1979 and reaching 1,000,000 persons/yr in 2015[109].

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[106] Ibid., p. 42-83.
[107] Demas, Martha, Neville Agnew, and Fan Jinshi. "Chapter 5 Strategies for Sustainable Tourism." *In Strategies for Sustainable Tourism at the Mogao Grottoes of Dunhuang, China, by Martha Demas, Neville Agnew and Fan Jinshi,* p. 87. Los Angeles: Springer, The J. Paul Getty Trust 2015.
[108] Demas, Martha, Neville Agnew, and Fan Jinshi. "Chapter 4: The Mogao Visitor Study." *In Strategies for Sustainable Tourism at the Mogao Grottoes of Dunhuang, China*, by Martha Demas, Neville Agnew and Fan Jinshi, p. 91. Los Angeles: Springer, The J. Paul Getty Trust 2015.
[109] Lei Zhengguang, 雷政广. 莫高窟年度游客接待量首次突破百万人次. Dunhuang

This number of visitors is not spread out evenly across the year, but instead is heavily seasonal.

Tourists Carrying Capacity reached one million, Oct 8, 2015. http://public.dha.ac.cn/content.aspx?id=162848249720 (accessed 07 15, 2016).

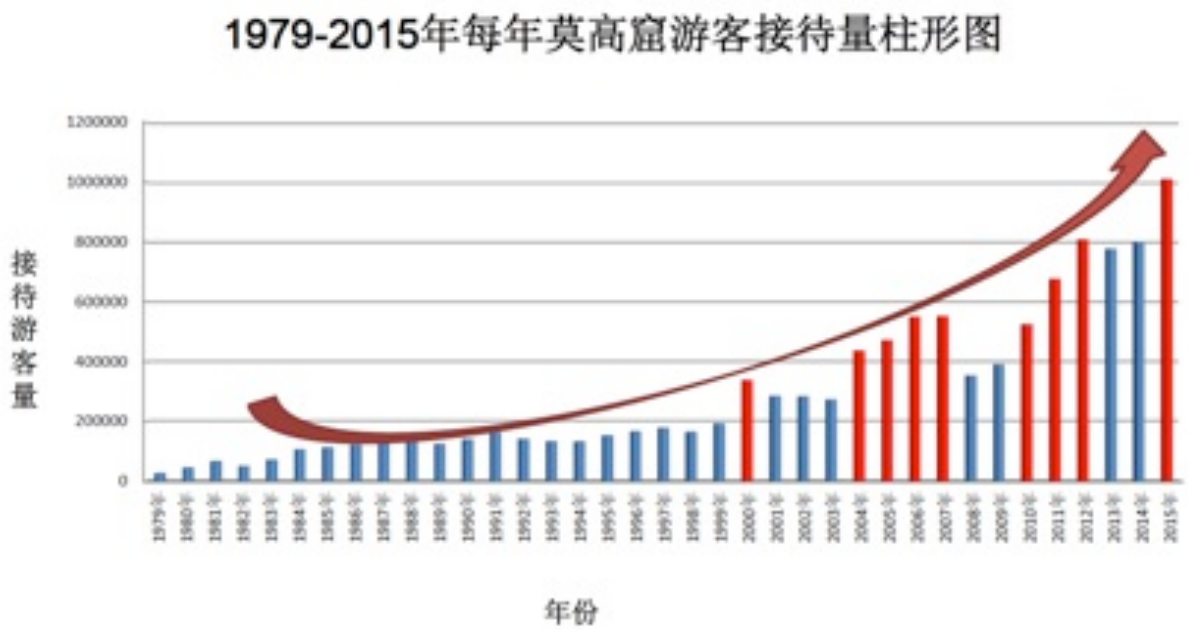

Figure 4.4: Bar chart of annual visitor numbers to Mogao from 1979 to 2015; visitors rose to over 1,000,000 in 2015.
Source: http://public.dha.ac.cn/content.aspx?id=162848249720 (Accessed by July 23, 2016)

If 2012 is taken as an example, by the end of November, the total number of tourists that had visited by that point in the year was 794,000, but from May to October there were as many as 726,000 visitors, accounting for 91.39% of the year's total. During May to October, there were more than 100 days on which the daily count of visitors exceeded 3,000. On October 3rd, 2012, a national holiday, the number of visitors reached 18,000, a record-breaking number that is five times greater than the maximum allowable capacity.[110]

Before the new regulations were set in place visitors entered the caves and observed the murals while guides explained the history behind them. The process took about two hours. The number of tourists was limited to 10-15 people per cave. In the caves, in order to protect the murals, flashlights were prohibited. Holding a lamp that did not generate heat, the tour guide gave a 3-5 minute presentation about each cave and then moved on to the next one, leaving space for the next tourist group.

The crowds of visitors not only threatened the murals' preservation but also undermined the ability of the guides to interpret to them. This is the situation that led Dunhuang Academy to consider alternative strategies for tourism. One approach was to use new technologies to both preserve and present the caves.

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[110] Demas, Martha, Neville Agnew, and Fan Jinshi. "Chapter 4: The Mogao Visitor Study." *Strategies for Sustainable Tourism at the Mogao Grottoes of Dunhuang, China*, p. 87. Los Angeles: Springer, The J. Paul Getty Trust, 2015.

3. Digital Recording and Presentation of the Mogao Caves.

In 1944, the Dunhuang Research Institute was upgraded as Dunhuang Academy, and it initiated a long term conservation program. Scholars and preservationists from the ancient architecture and archaeology institutes of Tsinghua and Peking Universities performed a study of the Mogao Grottoes and suggested a series of protection strategies, including restoration of five endangered wooden structures dating back to the Tang and Song eras.

In 1962, the Ministry of Culture applied to the State Council of PRC for financial support to preserve the frescos and structures of Mogao. That year, one million yuan was granted for the purpose. The project started in 1963 and continued for three construction seasons. In 1966, 354 caves were reinforced, totaling 576 m. of caves. In 1984, another 26 caves in the southern section were taken into protection.

The idea of getting the Mogao Caves listed as a World Heritage site was proposed in the mid-1980's. After being listed as a World Heritage site by UNESCO in 1987, the property gained more attention. Dunhuang Academy established a series of international agreements with organizations such as the Tokyo Research Institute for Cultural Properties, the Canadian Conservation Institute, and The Getty Conservation Center Institute.

In the 1980's, Dunhuang Academy tried to introduce the use of digital technology to store images of the numerous Mogao murals. Fan Jinshi, the former president of Dunhuang Academy, promoted this idea. More was done in the following decades.

In 1993, the No. 45 cave was chosen as the subject in the "Dunhuang Fresco Computational Storage and Management" project, which lasted for three years. Close-

range photogrammetry and digital scanning technology was used to obtain high-resolution images. Images were saved as electronic files with attribute data, such as archival references and interpretive data.

From 1996 to 1998, further computerization was attempted and digital media added with the assistance of Zhejiang University, while Dunhuang Academy worked on the ideas for a Mural virtual tour. In the same year, Dunhuang Academy started a joint project with Northwestern University in the United States called the "Dunhuang Fresco Digitalization" collaboration. From 1998 to 2006, with Northwestern University and funds from the Andrew W. Mellon Foundation, Dunhuang Academy digitized all of the frescoes in 22 caves with 2D images, although the paintings are not flat. Most of them have undulating surfaces, which prevent the camera from getting accurate images. In addition, the inability of the traditional camera to get everything in focus in one picture restricted its use in recording 3D objects, such as statues in niches.

In June 2009, a "Ditigal Heritage Seminar" was hosted by Dunhuang Academy and Microsoft Research Asia. At that gathering, Moshe Ben-Ezra introduced the GigalPixel Digital Camera "Apsaras" System, named after Dunhuang's famous "Flying Fairy" fresco paintings. As a part of Microsoft's eHeritage program, Asparas was created to provide the opportunity for photography of non-2D subjects by capturing many different focus points and stacking them.

4. Digitization of Dunhuang Cave Art

The goal of Digital Dunhuang is to build digital models of Dunhuang Cave Art in computer systems in order to provide accurate and detailed digital materials for

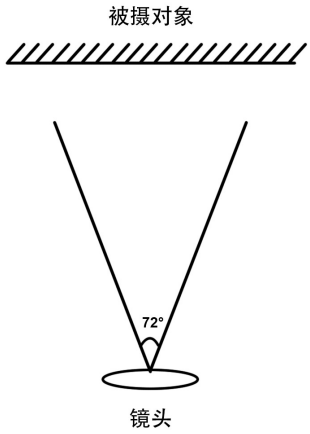
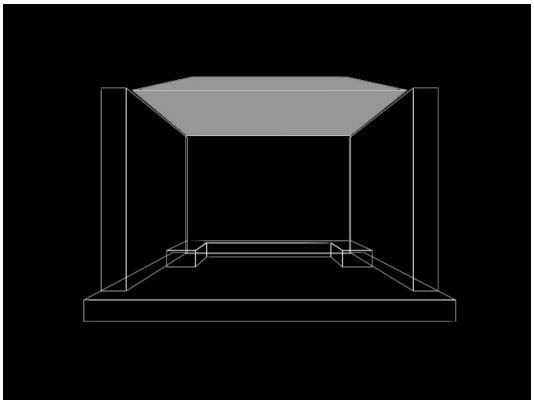
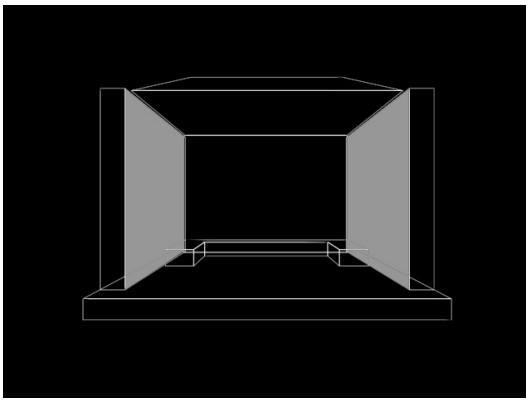
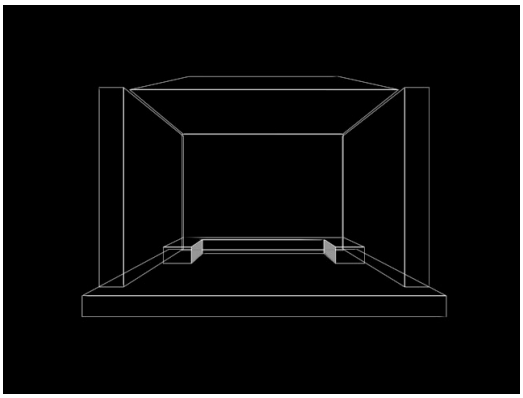
information sharing, protection, restoration, archaeology, tourism, appreciation, and development of Dunhuang cultural relics.[111] The work is comprised of two main parts: (1) mural arts and (2) 3D statues.

The acquisition of mural information relies on digital photography. As part of the digital camera equipment, a lighting system is erected on a track that has been laid parallel to the fresco wall inside the cave. Manually, photographs are shot, one by one, at equal spacing along the fresco wall. To meet the requirements for optimum resolution and minimum deformation, each image must have 50% of its area overlapping with adjacent photographs. It generally takes about three days to record a 15 $m.^2$ cave. For example, the area of cave No. 57 is 12.61 $m.^2$ In total, it would take 567 photos to document the entire cave. This process would last about three days, excluding the time it would take to set-up and prepare for the work.[112]

[111] Yunhe, Pan, and Fan Jinshi. *Dunhuang Real and Virtual*. P.1-8. Zhejiang University, 2003.
[112] Zhijun, Sun, et al. *The Experiment of Gigapixel Camera on Digital Dunhuang Project*. National Research Center for Conservation of Ancient Wall Paintings, Digitization Center, Dunhuang Academy, Microsoft Research Asia, Beijing: Microsoft Research Asia, n d, Microsoft Research Asia document.

Figure 4.5: Caisson Ceiling and Thousand Buddha in Cave 57
Source: Dunhuang Academy Center-Mogao Cave 57
http://public.dha.ac.cn/content.aspx?id=453980748254 (Accessed by April 10, 2017)

Table 4.1: Cave 45 shooting process by using Microsoft Gigapixel Camera (Apsaras)[113]

	
Schneider 300mm with camera angle at 72 degree	Shooting the ceiling
	
Shooting the north and south walls	Shooting details within the cave

[113] Zhijun, Sun, et al. *The Experiment of Gigapixel Camera on Digital Dunhuang Project*. National Research Center for Conservation of Ancient Wall Paintings, Digitization Center, Dunhuang Academy, Microsoft Research Asia, Beijing: Microsoft Research Asia, n d, Microsoft Research Asia document.

When shooting objects with complicated depth variations, such as painted sculptures, two types of technologies have been adopted. One is the use of a 3D scanner to record information about the statue. After scanning, several partial models are merged to produce an integrated 3D, geometric model of the statue. This allows the model produced by the scan to be viewed from multiple points.

The other method is to take multi-viewpoint photos using equipment such as the Apsaras 360 camera. Apsaras captures multiple pictures of the same object under conditions of equal distance and height cross angle with uniform illumination using different "focal lengths", so that by a process called "focus-stacking" software can compile the images to bring everything in the final picture into focus.[114] By providing high resolution ratios, even 300 times better than the naked eye, the images are displayed in great detail.

5. The Mogao 3D Theater

The enormous amount of image data that has been collected provides the opportunity for it to be used in multiple ways. Apart from being analyzed by researchers, the data is being used for making virtual presentations of the caves available to the public. A 340 million yuan[115] digital center opened in August, 2014, and was the first virtual cave system in the grottoes heritage field. Using seamless splicing technology, the theater show a twenty minute long movie virtually rebuilding the elegant grotto works in a three

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[114] 1 Billion Pixel Digital Camera System Used in Mogao Grottoes at Dunhuang. n.d. http://english.ccitimes.com/research/2011-11-12/27741321060716.shtml. (Accessed April 20, 2016).

[115] Liu, Yutao. *China News*. January 24, 2015. http://www.chinanews.com/cul/2015/01-24/7001918.shtml (Accessed July 15, 2016).

dimensional perspective, allowing tourists to understand the works of art and history of Mogao in an immersive environment. For visitors, the 3D virtual reality movie they watch in the dome theater provides more detailed images of the grotto than they would be able to see at the original sites. Seven grotto scenes are rendered and interpreted with background music in the movie "Dreamy Temples." This includes caves No. 45 and No. 285, which are representatives of high arts in the Tang era while the real caves are kept closed for protection.

Through artistic interpretation of the cave images and the use of background music, tourists are provided with the sense that they are in a solemn, sacred environment. They gain a spiritual feeling for the Buddhist artwork, likely in line with the objectives of the original artist who created the work a thousand years ago.

Figure 4.6: The digital dome projection in the Dunhuang Visitors' Centre. Courtesy of the Dunhuang Academy. Photographer: Sun Zhijun.
Source: http://idp.bl.uk/archives/news44/idpnews_44.a4d (Accessed by July 05, 2016)

According to the deputy director of the Mogao Digitization Center, Li Ping, tourists have the opportunity to fully appreciate 360 degree views of Cave No. 285, Cave No. 45 and Cave No. 220 in the Digital Center. For example, the story of the enlightenment of 500 blind robbers in Cave No. 285 is fully explicated in a 20-minute movie. After watching the 3D movies in the Digital Center, tourists enter the protected area of Mogao to experience the real caves with their guides. As a result, visitors tour 15 caves, seven of which they tour virtually. This relieves the pressure caused by high tourist flow on the environment surrounding the relics, protecting them from further damage. According to Dunhuang Academy, it is estimated that with the 3D VR theater the Mogao Caves will be able to accommodate 6,000 tourists per day, twice as many as can currently be accommodated.

6. Conclusion

Through careful testing and analysis and the use of digital technologies, the Mogao Grottoes have become a model for how to conserve cultural heritage sites while still supporting tourism and presenting cultural information to the public. Virtual reality technology creates an immersive environment that enhances the experience of visitors to the site. The virtual presentation makes use of a variety of crafts, images, writings, and music, each contributing to the overall experience. The Mogao cultural heritage site, just like many other cultural heritage sites in China, is concerned both with preservation and cultural transmission. These are conventionally limited by the site conditions and by the character of the culture, which can be difficult to communicate. The animation and storytelling components of virtual reality arouse a psychological reaction to historic

objects in people, allowing visitors to be better able to catch the implicit cultural information being presented to them. The beauty of the physical artifacts and the heritage they connote are both conveyed through a well-executed show.

As urbanization and tourism increase, the impact of large numbers of visitors to heritage sites has emerged in recent decades as a global threat.[116] Tourism, as a growing economic activity, has created more pressure than expected on heritage sites, which are particularly vulnerable to a heavy flow of visitors. Overcrowding, traffic congestion, physical degradation of monuments, and many other negative effects of tourism challenge heritage site conservation and management.[117] The introduction of virtual reality use into heritage sites provides a new opportunity for balancing development and conservation concerns.

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[116] Demas, Martha, and Thomas Roby. *"Conservation and Management of Archaeological Sites."* Edited by Jefferey Levin. *The GCI Newletter* (J. Paul Getty Trust) 30, no. 2 (Fall 2015).

[117] Harry Coccossis, University of Thessaly, Greece. "Carrying Capacity as a Tool for the Management of Tourism Pressure on Heritage Sites." *Extended Abstracts of the International Colloquium: visitor management and carrying capacity at World heritage sites in China*, edited by Neville Agnew and Martha Demas, p. 47. Los Angeles: Getty Conservation Institute, 2013.

CHAPTER 5

THE CARDBOARD SHIKUMEN PROJECT IN SHANGHAI

The "Cardboard Shikumen" project is a digital replica of a historic neighborhood in Shanghai. A demonstration version was first launched in November, 2015 by Lewei Huang, a junior undergraduate at Shanghai New York University (NYU). Having grown up in Shanghai, Shikumen is the seat of Huang's memories. The neighborhood he lived in for more than 20 years was to be replaced by high-rise buildings as part of urban development in Shanghai. In an interview, Huang said that he treats his work as a historic preservation project. He took the project up in response to the demolition taking place in urban China today, with a mission to document memories of the neighborhood common to the residents. This chapter begins with the historical development of this neighborhood, and describes the housing type that is the focus of attention. The next topic is the rising interest in preserving these properties, which gives rise to the last section that describes the Cardboard Shikumen Project and its implications.

1. Brief History of Shikumen

Shikumen neighborhoods consisted of residential buildings with a unique architectural style that emerged in the mid-nineteenth century in South China from a blending of Chinese and Western forms. The invention of Shikumen-style housing is relevant to the history of the development of Shanghai. The establishment of the city dates back at least to the Song Dynasty (1277AD) when it was identified as an ancient

town.[118] Before the seafaring industry came to dominate the economics of the area, Shanghai was a normal-sized county in old China, ranking in size behind many larger cities of the time, including Hangzhou, Suzhou, and Nanjing, each of which had populations of more than 300,000 people. The modern development of Shanghai began during the China-Britain Opium war in 1840. After losing the war, the Qin government was compelled to sign the Nanjing Treaty with Britain. This included opening Shanghai as a treaty port, which initiated modernization of the town.

Through a series of treaties, made during the colonial period from the 1840's to the 1940's, the old city of Shanghai was dominated by four principal countries, including Britain, the United States, France, and Japan. Each country established its concession and settlement there. After that foreign governments allowed capitalists to own and lease property and enjoy territorial rights on their land. With more investments being made in the concessions, Shanghai began to develop rapidly. New buildings were constructed for offices, financial institutions, and banks along the river waterfront (the Bund). Today, these edifices still remain as landmarks that indicate the past presence of foreign powers.

The increase in foreign investment was coupled to the arrival of both domestic and international immigrants. The dwellings within the old city were constructed during two main periods. Before the Taiping Rebellion in the 1850's, Chinese people and foreigners lived in separate parts of Shanghai, with foreigners residing in their own concessions along the Bund and Chinese people residing on the inner side of the Bund. The separation between the Chinese people and the foreigner residents limited information

[118] Johnson, Linda Cooke. Cities of Jiangnan in Late Imperial China. p. 155. SUNY Press, 1993

exchange between the communities until the Taiping Rebellion and, later, the Revolution of 1911, when many Chinese people became destitute and homeless. With an increasing number of Chinese people coming into the concessions looking for safe shelter, food, and job opportunities, the foreign concessions became prosperous. Shops, restaurants, and businesses of various sorts were opened. New streets were planned for commercial and recreational activities. Shanghai, with a mixture of indigenous and exotic cultures, gradually became the dominant economic hub of South China.

Expansion of urban development and growth of the downtown challenged the housing situation in this area. The conflict caused by a rapidly growing population, which included many former villagers with specialized skills and rich families from Southern China. The rising cost of housing meant that real estate became expensive, and stimulated the appearance of a new innovative collective housing type: Shikumen Lilong housing.

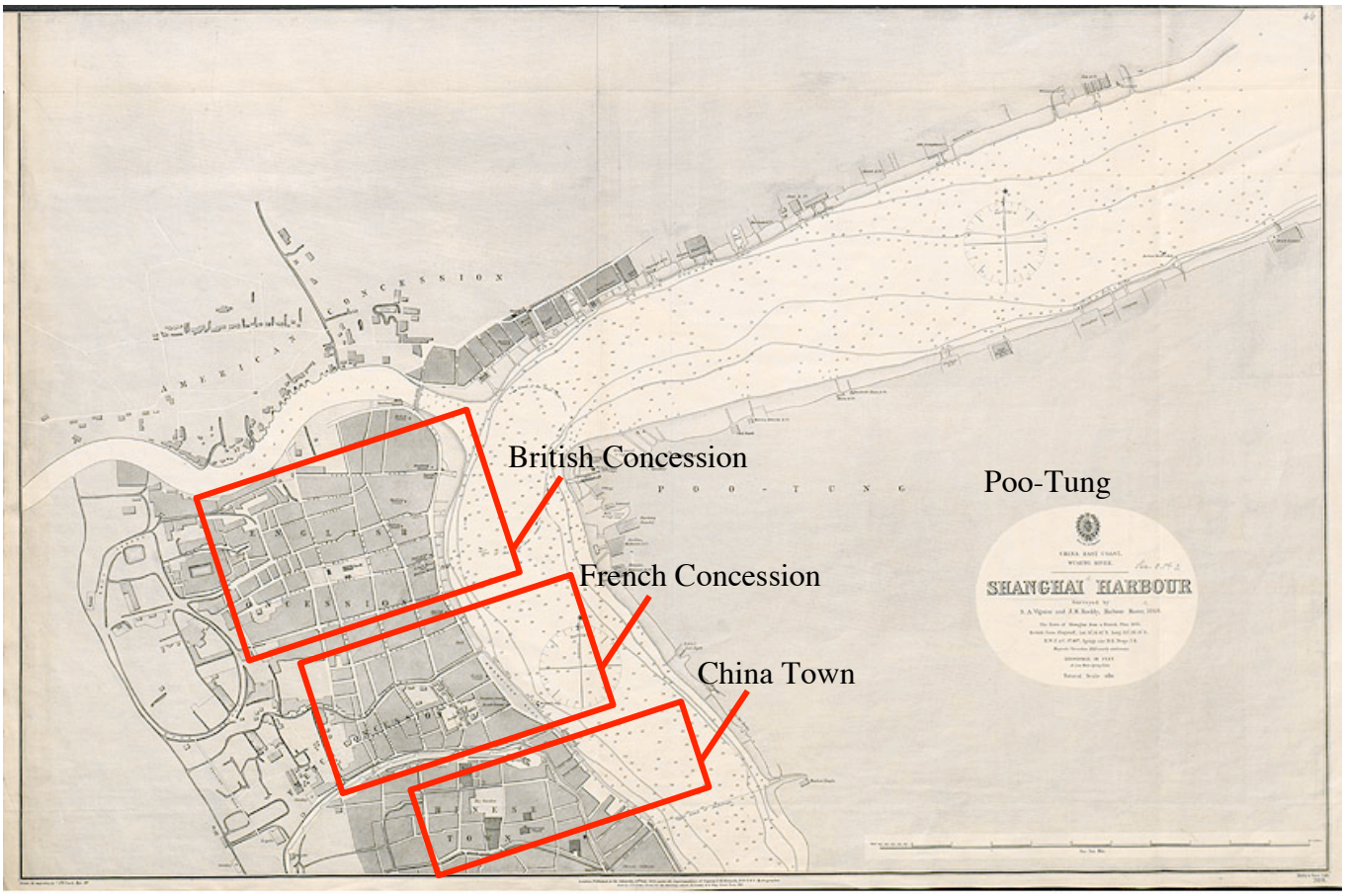

Figure 5.1: Shanghai Harbour. Surveyed by S.A. Viguier and J.M. Hockly… 1866. The Town of Shanghai from a French Plan 1861. Publisher: London
Source: Online Gallery, British Library,
http://www.oldmapsonline.org/map/britishlibrary/4931155 (Accessed by July 23, 2017)

2. Shikumen Housing and Lilong

The name Shikumen originates from the pronunciation of "stone gate" in the Shanghai dialect. The major feature of this housing type is how it combines Western row housing with traditional Chinese courtyards. Due to the assortment of groups that resided in the housing, varying from rich to poor, Shikumen houses were built with a range of options to meet the requirements of each group and to adapt to different contexts. There are at least three types of housing that have been recognized as typical Shikumen housing. They are the Old-Shikumen (1869-1910), New Shikumen (1919-1930), and Garden Shikumen (post-1930's).

The pattern of the neighborhoods formed by these housing types is called "lilong" in Chinese. The basic layout of Shikumen housing consists of rows of one- or two-story houses with long, alley-like courtyards between the rows. The width of the courtyards varies from 11 to 13 feet. Gateways to the courtyards have stone frames, sometimes with decoratively carved capitals and cornices. In order to meet high housing demand, most of the Shikumen housing units, except those of the Garden Lilong type, are built attached to one another, separated only by partition walls. Viewed from the outside, the long line of stone-framed doors creates a rhythm, with the sides of the alley echoing each other.

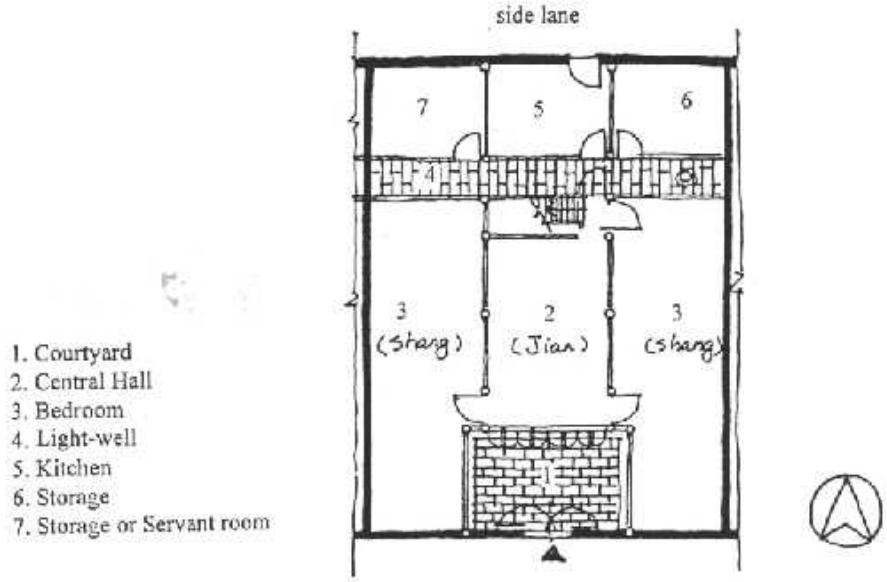

Fig. 3.1b Plan of an Old Shi-ku-men Lilong House (in one-jian and two-shang pattern)
Source: Sheng, Hua, *Shanghai Lilong Housing*, p. 33, 1987.

Figure 5.2: Old Shikumen Housing Layout

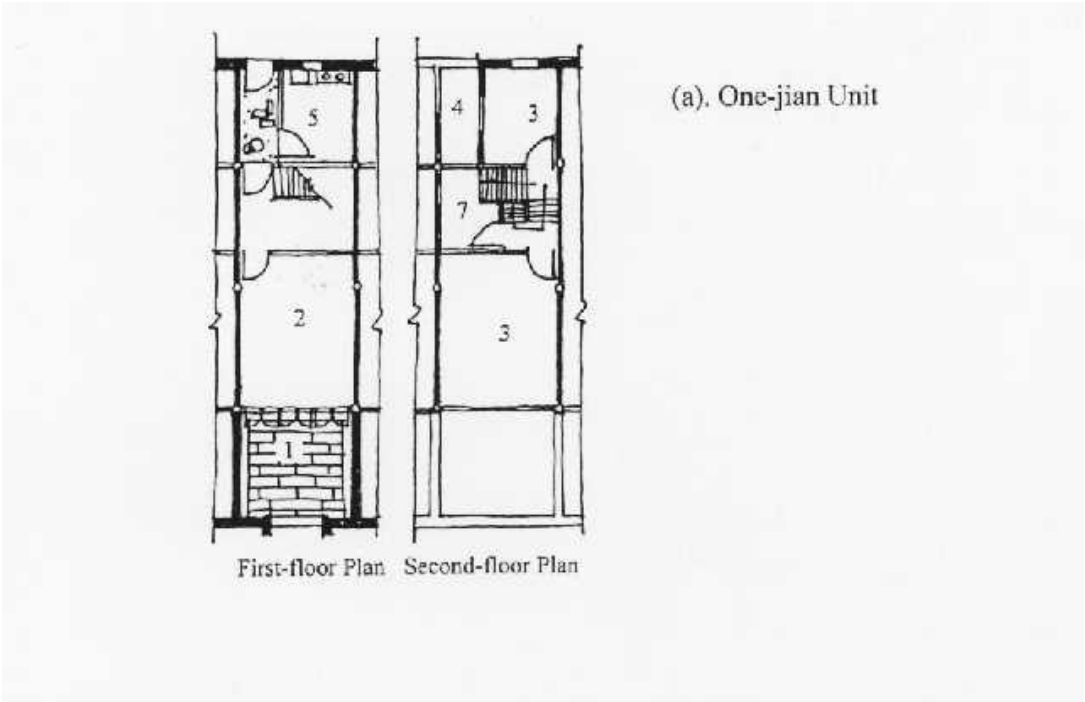

Figure 5.3: New Shikumen Housing layout
Sources (Fig. 5.2-5.3): *China's Vernacular Architecture*, G. Knapp, Ronald, 1989

Figure 5.4: Shikumen Lilong in Shanghai
Sources: http://shanghaistreetstories.com/?page_id=1288 (Accessed by Feb 20, 2017)

Before the Liberation in 1949, the Lilong was the main housing model in Shanghai and these buildings dominated the urban space. They were built chiefly in the International Concessions, particularly in the French Concession, which is where Shanghai city center is located today. At the end of 1941, when Shanghai was controlled by Japanese conquerors, and during the Sino-Japanese War, the construction of the Lilong was suspended. Shanghai's economy entered a great depression during the postwar era, limiting the construction of new real estate. After the Liberation in 1949, the Lilong housing was considered less efficient in construction technology and delivery method compared to that of modern apartment buildings. As the Lilong housing was not able believed to meet the requirements of the growing, working-class society, this unique type of housing has not been built in new China since.

3. Shikumen as Part of Shanghai's Historic Heritage

Today, it is accepted that Shikumen is a special housing type that reflects the presence of Western thinking in old Shanghai. The one-hundred-year-long evolution of Shikumen has made it a housing symbol of old Shanghai today. In 1949, when the communist regime took over Shanghai, there were about 9,000 Shikumen housing sites, accounting for 64 percent of the total built area of the city.[119] It continued to serve as the major residential form in Shanghai until the late 1980's and early 1990's[120] when

[119] Xuefei Ren, Department of Sociology and Global Urban Studies Program. "Shanghai, Forward to the Past: Historical Preservation in Globalizing." City & Community (Michigan State University) Mar 7, 2008.
[120] Ibid.

Comrade Deng Xiaoping made his Development Speech while visiting South China. It was during this time that the most rapid urban development in Shanghai's history began.

Admittedly, Shikumen houses were built with earth, and were not maintained for years, so that they have become so called "decrepit houses." In 1992, the Shanghai government announced its "365 plan," declaring that by the end of the 20th century 365 (vaguely-defined) hectares of decrepit houses would be demolished in the city. Since then, land and housing reforms have become more important than decrepit houses in the urban renewal of Shanghai.

On the one hand this has improved the problem of poor housing conditions in the old city, relocating many residents to better living conditions. Statistics indicate that by 2000 the government had achieved its goal of demolishing buildings covering an area of 40 million square meters. This was approximately 4.5 million square meters per year. On the other hand, the demolition triggered a series of social problems, such as conflicts between developers and grassroots residents' groups about housing rights that led to conflicts between development and preservation. In order to accomplish the urban renewal plan, municipal and district governments set up policies that transferred urban land to private foreign and domestic developers, in return for substantial leasing fees. With the first lot of land leased to a Japanese company in 1988, the commodification of land began, gradually shifting land use from public housing to commercial housing development. Urban renewal of Shanghai became a profit-driven real estate market.

Promoted by the government and driven by developers, this model has since become one of the most powerful engines of China's phenomenal economic growth.[121]

During the 1990's, 27 million square meters of old housing were demolished, 640,000 households were relocated—mainly from inner city districts to suburbs—and one billion square meters of new housing was constructed. This inevitably brought disaster to many historic buildings and neighborhoods, many of them failing to survive.

4. Historic Preservation of Shikumen Housing in Shanghai

The Shanghai government started to work on historic preservation in the late 1980's. The first list of historically significant sites was issued in 1989 by the local Shanghai government. Since then, the list has expanded from an initial 50 sites to include more than 700 sites today. In 2002, municipal government policy changes allowed residents' some involvement in preservation. Owners and users could identify and recommend their buildings for listing and preservation subject to review and approval by experts and officials.[122] Even though these actions were helpful, the number of historical structures that have been saved is disappointing. Lacking money to conserve the old buildings, the local government would rather simply replace them with new projects that would yield immediate profit. The comparatively few so-called historic preservation projects maintained the original exteriors of the Shikumen, but turned them into a profitable tourist attractions.

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[121] Shao, Qin. *Shanghai Gone: Domicide and Defiance in a Chinese Megacity*. Rowman & Littlefield Publishers Inc., 2013.
[122] Ibid.

The Xintiandi project has become an example of combining preservation with commercial development. Xintiandi is the site of the first congress of the Communist Party of China. A private developer, the Shui On Group, started to invest in the district in 1999. Most of the Shikumen structures in this development district are preserved and have been renovated for real estate income but the original residents were replaced by businesses that operate from within the houses. Walking along these mid-19th century narrow alleys a sequence of book stores, cafes, restaurants, and shops is evident. The lifestyle here today is no longer the same as it originally was. It is fortunate that these old buildings have survived thanks to profit-driven intentions, but the cultural memory of the neighborhood died with the evacuation of the original residents. This change led to a project that attempts to re-capture some of the ideas that occupied this part of the city.

5. Cardboard Shikumen Project

Although some Shikumen neighborhoods with designated historic significance, such as Xintiandi, have been preserved and reused for various reasons, many ordinary neighborhoods failed to escape. Most have already been bulldozed to be replaced with high-rise towers by the city as part of the urban development program. Liewei Huang sought to preserve his neighborhood by creating a digital replica of it in his "Cardboard Shikumen" project.

5.1 Background

Having grown up in a Shanghai lilong, Leiwei Huang considered himself an authentic Shikumen native, a characteristic which is part of his identity. For his

Shikumen project, he focused on his own neighborhood, which was located in the Jing'an District, a normal Shanghai neighborhood. After hearing the news that his hometown of more than 20 years was to be demolished in 2015 by the Shanghai government, Lewei started to think about what he could do to save his personal memories, as well as preserve a piece of Shanghai history.

In 2014, Google Cardboard was introduced to the public. Leiwei was inspired to combine his idea with this VR technology device. Funding for the project came mainly from an undergraduate research award at NYU and $20,000 Leiwei was able to raise in the summer of 2015 to start his research study. His mission was to build an inexpensive and user-friendly experience, accessible from any reasonably modern device.

The three-month project lasted from May to July and covered an area of seven Lilong alleys. Cardboard Shikumen provides a panoramic view of the neighborhood, including the architecture, residents, and snapshots of the residents' daily activities. A user clicks an arrow on the screen with his mouse to navigate the virtual neighborhood. In these virtual scenes, the audience encounters the architecture of Shikumen and the quotidian life of the residents: neighbors sitting together chatting, playing Mahjong, and an old man resting in a wicker chair under the sun. The acoustic effects are presented along with the motion, and the noises of the bustling streets enhance the viewing experience.

Figure 5.5: Shikumen neighborhood presented in Virtual Reality device
Source: https://shanghai.nyu.edu/is/around-shikumen-80-clicks (Accessed by April 15, 2016)

5.2 Work Procedure

Creation of the beta version of Cardboard Shikumen started with the capturing of footage of the Shikumen neighborhood. In order to obtain 360 degree images of the area, Lewei assembled a camera rig, comprised of 6 Xiaoyi Action cameras facing in 6 different directions. Then, he walked along his Lilong neighborhood, step by step, with his camera rig. He was able to record panoramic footage which he later converted for display on a VR device. He shot the elevations at an equal distance of every 2-3 steps. It took him 4-5 days in total to capture all the imagery of his neighborhood.

After he completed the photography, Lewei spent 2 weeks working on a web app that mainly uses A-Frame, a virtual reality framework by Mozilla, a free software community. Meanwhile, other open-source libraries were built to present the panoramic footage in WebVR, a web-based virtual reality interface. In an interview, Leiwei mentioned that the technology of WebVR is still in the process of being developed, which means that there are no precedents or examples one can follow.

Cardboard Shikumen looks very similar to Google Street View, but Leiwei further explained that instead of providing accurate guidance for navigation of streets like Google Street View, the Shikumen project is focused on documenting the space of a historic site through virtual reality, as well as on educating the audience about the history of Shikumen. In addition, the project is of an open-source design so that people from anywhere and anytime can upload information. Users can even modify the street view based on their own perspective of the site. Leiwei's next step is to add historic narratives relevant to the neighborhood history for users to read while navigating through the scenes.

During his work at the site, many neighbors were curious to see him with his device walking back and forth in the streets. Some of them were quite alert at the very beginning. After explaining to them that what he was doing was for historic preservation, many became supportive, although some people over 60 may not have fully grasped the ideas and concepts of virtual reality.

6. Conclusion

The Cardboard Shikumen Project was designed by a junior college student, Leiwei Huang. It has already aroused some discussion among the public about whether VR can preserve our heritage. With the development of VR, digital heritage is moving towards people being able to interact with digital heritage presentations. These immersive experiences enable audiences to view the past in a more realistic way. Web-based VR programs give the public access to view and participate in historic sites, which are otherwise inaccessible in reality. This brings the possibility for the understanding the many endangered heritage sites.

Another value of this project is that not only imagery but also auditory information is recorded and presented to the audience. The sound of the marketplace in an area is another source of information about local residents' lives and is an essential memory worth keeping. VR expands the concept of restoration of historic sites. Additionally, less funding is involved in VR recreation of historic sites as opposed to many of us thought even though high technology was involved in this project. VR offers many possibilities since the best technology is not always necessary for preservation work. The biggest challenge for the Shikumen project today is to find a way to

permanently store the digital data. When everyone is looking for ways to obtain real and accurate models, documentation of heritage is more than just 3D scanning of site information.

7. Comparison and Discussion

Table 5.1 Dunhuang Grott project and Shikumen Cardboard project

	Mogao Grotto	Shikumen Cardboard
Funding	- 1 billion yuan	- $20,000
Project Scale	- 400 caves	- Grid street plan with three streets running one way and four streets running another way
Duration	- 5 years	- 3 months
People	- Dunhuang study experts - Digital technology experts	- 1 undergraduate student - 2 university instructors: 1 from New Media and 1 from Shanghai History
Method	- Photographs of fresco paintings and statues using a 1 billion pixel camera riding parallel to the wall	- 360 degree photographs of a street view using sports cameras
Characteristics of the Project	- On-site virtual cave - Pre-edited film narratives, providing only a viewing experience to the audience.	- Files can be accessed by people regardless of time and location, - Open-source code allows users to create site information based on their own preference
Accuracy	- Very high resolution images of the artwork	- Real-time snapshots of the street view
Purpose	- To record the highest possible resolution photographs of the artwork for preservation of the endangered original objects - To provide a better experience for visitors, especially during the peak tourist season.	- To record the history of Shikumen neighborhoods before they are demolished - To show the public the history of the area
Characteristics of the Site	- Internationally well-known heritage site,	- Less popular to the public - Common residential

	- Top-priority government investment	neighborhood - Mainly significant to local residents
Influence	- Virtual cave theater provides better image quality of Dunhuang fresco view to the visitors, - VR film program resolves the contradiction between the increasing visitor number and the fragile environment of the Dunhuang heritage caves	- Imagery of common Shikumen neighborhood is successfully recorded.

Chapters four the five of this thesis discuss two cases of the use of virtual reality technology for preservation of heritage sites in China. The two projects have different scales. As a major asset at the national level, Mogao Grotto contains time-honored unique artistic values. The work of digitalizing the fresco and presenting the images via VR cave are supported by national and authorized power. Compared to this point, Shikumen project is done by an amateur local young resident and it is quite smaller in scale. It is because of its historic value at a local level, its preservation significance reaches out to the group limited in certain neighborhood. It is also because VR was still a new invention to many people. Individuals with interest in new media attempted to explore its application in various directions. The aspiration of Shikumen project indicates that virtual reality could provide an equal opportunity for members of the public to demonstrate their own cultural and historic memory via open-access publisher, such as web platform. Virtual Reality as a time machine is able to allow a passenger to enter the past regardless of whether permitted by an authority or non-expert. Based on this point, the two projects are inspiring to future preservation work.

In each case, the goal of the project was specific. In the case of the Mogao Grottoes the aim was to provide an archival collection of images for use by a wider portion of the population and to resolve the conflict between preservation and tourism in specific tourist sites. It also demonstrates how virtual reality offers an alternative solution for presenting the objects while supporting their physical conservation. Virtual reality additionally provides as a useful tool for the analysis of these objects, through making high-resolution images available for study. From a social perspective, another advantage of VR is that it provides an immersive experience of the space. The experience provided by a VR tour is competitive with an on-site visit in terms of accuracy, environment, experience, and education. Meanwhile, the realistic VR images provide a buffer between the flood of visitors and the endangered heritage sites.

For the Cardboard Shikumen project the focus is on the notion of preservation through recordation. A high resolution recording of a historic neighborhood was completed and displayed using virtual reality devices before it was demolished. In addition, this is a web-based project, which enables people across space and time to experience the structure virtually as long as a VR device is available. Lastly, the Shikumen project's recording of a normal historic neighborhood brings attention to the problem of how to preserve the collective memory of common people. Because Mogao is a renowned and authentic heritage site that has gained considerable attention and funding, investment in the Mogao virtual project was greater than average. Other official heritage sites receive much attention. The preservation activity on these sites is "normal," and centers on the depiction of designed and authoritatively presented narratives that convey

carefully chosen details about the sites.[123] The Shikumen neighborhood project features a common residential area with stylistic architecture and daily activities. The work of Lewei Huang provides an example of a way to engage a community in its own heritage in an inexpensive yet effective way. In this case, the need for recording an unofficial heritage site arises from a private initiative and is basically a community-based activity. VR technology provides an opportunity for groups and individuals, such as Lewei, to use their creativity to provide personal interpretations of historic places in an innovative way. This enriches the public interpretation of heritage itself and is driven by technology.

[123] Silberman, Neil, and Margaret Purser. "Collective Memory as Affirmation." Heritage and Social Media. Understanding Heritage in a Participatory Culture, Elisa Giaccardi, ed., p. 14. Routledge, 2012.

CHAPTER 6

A VIRTUAL REALITY EXPERIMENT IN CROSS-CULTURAL UNDERSTANDING

As discussed in previous chapters, the growth of virtual reality technology has gradually shaped how we manage and interpret our cultural heritage. The variety of potential uses, such as the reconstruction of an ancient place that no longer exists, the exhibition of a place that is closed off to the public, or that comprehensive documentation of a historical site in images so that it can be remembered after it is gone shows that VR has many possible uses in heritage preservation.

By providing the experience of a virtual "walk-through," virtual reality enables visitors to place themselves in historic sites as if they have been teleported there through space and time. This technology is applied in heritage sites with the vision of using visitors' immersive sensory experiences to stimulate their emotion and imagination, allowing them to build a stronger connection with the place they are visiting.

Even though researchers have documented the advantages of using VR as a medium, there are still many uncertainties about whether the implementation of VR can impact users' cognition, especially in regards to culturally related content. The reason to study cultural cognition in virtual reality is that historic preservation work is a social movement directed at saving and caring for our cultural heritage. An artifact or work of art has been chosen for preservation suggests that that item holds social and cultural value to the group preserving it. Often that group interacts with the world through its behavior, language, and organizational structures. Language, in particular, is a powerful tool for transmitting culture, in part because it conveys and defines the way in which the group

view the world, including attitudes, values, beliefs, and behaviors that relate to one another.[124]

There are numerous different cultures and subcultures with various self-identities. The fact that how social group members view themselves, and, more importantly, what their attitudes are towards the values of other groups is likely to bring conflicts between values and attitudes of these groups. This requires historic preservationists to be more sensitive than usual to the cultures and their artifacts in order to maintain suitable humility in a process.[125]

For example, museums and heritage sites attract thousands of visitors from different backgrounds. These cultural centers become sensitive places containing various attitudes and values. Although the use of VR in museums and heritage sites will enhance peoples' learning about what is exhibited and described, does an immersive environment motivate visitors' interest in different cultures? How can we test user experiences of VR technology to ensure that the cultural interaction is meaningful, educational, and enjoyable? How do we know that meaningful learning has been achieved?[126] To test these questions, a social experiment on learning Japanese language and behavior was conducted in a virtual reality environment and its results are analyzed in this chapter.

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[124] "Chapter 7: Advocacy and Ethics." *Historic Preservation-Caring for Our Expanding Legacy*, Michael A. Tomlan, p. 266. Springer, 2014.
[125] Ibid., p. 277.
[126] Champion, Erik. "Part III Culture and Society: History and Cultural Heritage in Virtual Environment." *The Oxford Handbook of Virtual Reality*, Mark Grimshaw, ed., p. 269-278. Oxford University Press, 2014.

1. Literature review

1.1 Cross-Cultural Communication

For anthropologists and other social scientists, culture was first defined by Edward Tylor in 1871 as the full range of learned human behaviors, which include knowledge, belief, art, law, morals, customs, and any other capabilities and habits acquired by man in order to function as a member of society.[127] Hence, understanding a different culture is to enter the mind with different perceptions, behaviors, communications and beliefs, through sensing and feeling it, inevitably at the cost of separating oneself from a previous culture and letting oneself become involved in a new one.

On one hand, this transmission process is influenced by both internal and external factors of oneself. The contemporary study of cross-cultural communication looks at both external factors, such as social structure defined by nation or organizations, and internal factors, such as individual personalities and psychology cognitions. Research has shown that the cultural differences existing between different groups result in frictions between the forces of acculturation and self-preservation.[128] For example, when a minority culture encounters a majority culture, it is very likely that the minority culture members will acculturate to the culture of the dominant majority, while still maintaining their own original cultural identities.[129] From a cross-cultural management perspective, the culture barriers can generate biases because of the opposing values in different groups, which

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[127] Tomasello, Michael, Ann Cale Kruger, and Hillary Horn Ratner. "Cultural Learning." *Behavioral and Brain Science* (Cambridge University Press) 16 (1993): p. 495-552.
[128] Leung, Kwok. "Methods and Management in Cross-cultural Research." *The Handbook of Cross-cultural Management Research*, Mark F. Peterson, David C. Thomas, Peter B. Smith, ed., Sage Publications, 2008.
[129] Ibid.

then lead to conflict and potentially create obstacles to the realization of the benefits of integration.[130]

On the other hand, some studies also confirm that cultural learning can be explained and taught to some extent. Culture has been defined by some researchers, as being composed of two main types of elements: physical elements, including buildings, materials, and structures, and subjective elements, such as values, beliefs, language, and norms that have worked in the past and are worth transmitting to the next generation.[131] [132]

Learning culture is subject to the process of learning knowledge, which consists of learning both explicit and implicit knowledge. Neuropsychological studies of brain-damaged individuals have demonstrated that there is a clear separation between the areas of the brain that specialize in explicit learning and memory, and those that specialize in implicit learning and memory.[133] Thus culture learning, or culture transmission process should also include both the explicit and implicit parts of a group's way of thinking. One obvious explicit culture element is language. As a cultural item, language has been demonstrated by social scientists and philosophers to contain the power to influence thought and cognition.[134]

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[130] Stahl, Günter K. "Cultural Dynamics and impact of Culture Distance within Mergers and Acquisitions." *The Handbook of Cross-cultural Management Research*, Mark F. Peterson, David C. Thomas Peter B. Smith. eds. Sage Publication, 2008.
[131] Triandis, Harry C. *The Analysis of Subjective Culture*. NewYork: Wiley, 1972.
[132] Triandis, Harry C. "Subjective Culture." *Online Readings in Psychology and Culture*. 2002. http://dx.doi.org/10.9707/2307-0919.1021. (Accessed by July 20, 2016)
[133] Ellis, A. W., and A. W. Young. *Human Cognitive Neuropsychology*. Hove, East Sussex: Lawrence Erlbaum Associates, 1988.
[134] Prinz, Jesse. "Culture and Cognitive Science." *The Stanford Encyclopedia of Philosophy*, edited by Edward N. Zalta. Spring, 2016.

In terms of implicit cultural elements, custom norms are usually hard to be explained explicitly by words, but can be perceived through observation and participation. Norms are ideas about the expected behavior of group members. People in a culture are expected to behave as specified by norms. The degree to which they can vary from these norms is dependent on how strict or permissive a culture is. For example, Japanese culture is governed by many subtle norms that are based on respect, authority, and self-discipline, with an emphasis on manners and interpersonal relations. In Japanese culture, the bowing norm, which communicates gratitude, is commonly found in social communication activities such as greeting, expressing humility, or apologizing, each with different bowing degrees. It is difficult to describe these clearly to a learner through words. The recognition of this simple social custom, which is tightly associated with culture, is necessary for understanding Japanese culture.

In addition, a study of social interactions in a virtual world by Blascovich et. al. indicates the potential of immersive virtual environments benefitting learners and instructors.[135] Other researchers, such as Moreno,[136] have noted the potential of VR for promoting students learning. Bailenson et al. have conducted a series of research studies exploring how virtual reality impacts the psychology of cognition. Other work has

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[135] Blascovich, Jim and Andrew C. Beall. "Digital Immersive Virtual Environments and Instructional Computing", *Educational Psychology Review*. Springer, Mar 2010. p. 57-69.
[136] Moreno, Roxana. "Learning in High-Tech and Multimedia Environments." *Current Directions in Psychological Science,* Mar 15, 2006, p. 63-67.

indicated that virtual reality could have an influence on many outcomes, including innovation, social cognation,[137] and empathy.[138]

1.2 Presence Theory

In the 1990's, in the field of human-computer interaction (HCI) Byron Reeves and Clifford Nass proposed the media equation theory, which describes the interaction between humans and computers.[139] It has been widely accepted that media experiences are equal to human experiences.[140] Humans respond to media in a way that is relatively similar to how they respond to other humans in terms of politeness, personality, emotion, and social factors. The discovery of an interpersonal distance between computers and humans laid the basic foundation for future studies of human-computer interactions and the development of user experiences.[141] In the virtual communication environment (VE), researchers have noted the importance of measuring a subject's sense of presence. Presence is the sense of "being there," which is the objective of the virtual environment. Additionally, the purpose of a VE is to give the subject the illusion that what they are experiencing in the virtual environment is real. A sense of presence is the defining

[137] Lee, M., K. Kim, S. Daher, A. Raij, J. Bailenson, and G. Welch. "The Wobbly Table: Increasing Social Presence via Physical-Virtual Object-Mediated Interaction." *IEEE*. IEEE, 2016. p. 11-17.
[138] Ahn, S. J., J. Bostick, E. Ogle, and J. N. Bailenson. "Embodying nature's experiences: Taking the perspective of nature with immersive virtual environments to promote connectedness with nature." Paper presented at the Annual Association for Education in Journalism and Mass Communication (AEJMC) Conference. San Francisco, CA., 2015.
[139] Reeves, Byron and Clifford Nass. *The Media Equation-How people treat computers, television, and new media like real people and places*. Cambridge University, 1996.
[140] Ibid.
[141] Ibid.

experience of virtual reality.[142] Usoh[143] and his colleagues have introduced the main factors thought to influence presence:

1. High-resolution information displayed to the participants in a manner that does not indicate the existence of the display device.

2. Consistency of the displayed environment across all sensory modalities.

3. The possibility of the individual being able to navigate through—and interact with— objects in the environment, including interaction with other actors who may spontaneously react to the individual.

4. The individual's virtual body, their self-representation within the environment, should be similar in appearance or functionality to the individual's own body, and respond appropriately to the movement of their head, eyes, and limbs. The connection between an individual's actions and the effects of those actions should be simple enough for the individual to quickly learn.

As it is widely accepted that presence is a term attributed to a psychological phenomenon, researchers such as Sheridan have suggested that the fundamental way to measure presence is through self-reporting, since presence is a mental manifestation.[144] Participants' feelings towards the virtual space can be scored through simple questions using a rating scale. It has been argued that immersion and involvement are also both necessary for experiencing presence and that an increase in the sense of presence will increase learning and performance.[145] Although a number of studies have been conducted

[142] Steuer, J.S. "Defining virtual reality: Dimensions determining telepresence. ." Journal of Communication 42 (1992): p. 73-93.
[143] Usoh, Martin, Ernest Catena, Sima Arman, and Mel Slater. "Using Presence Questionnaires in Reality." *Presence* Vol 9, no. 5, MIT Press, Octobor 2000. p.497-503
[144] Sheridan, T. B. "Musings on telepresence and virtual presence." *Presence: Teleoperators and Virtual Environments* Vol. 1, 1992. p. 120-125.
[145] Witmer, Bob G., and Michael J. Singer. "Measuring presence in virtual environments: A presence questionnaire." *Presence*, Vol. 7, no. 3, MIT, June 1998. p. 225-240.

on the experience of presence, there is not enough research that specifically focuses on culture and virtual reality environments.

2 Virtual Reality Study

2.1 Purpose

This study was designed to test the impact of experiencing a virtual reality environment on the transformation of participants' attitudes towards another culture and on their learning of cultural information. Since virtual reality provides participants an opportunity to immerse themselves in a virtual world, it was possible that the participants would interact with the content in the same way as real inhabitants. The first research question was: how does a VR environment influence peoples' perception of cross-cultural content? The second question was: can cultural content presented via VR stimulate a positive attitude about and interest towards a foreign culture?

Since the goal was to test how immersion in different types of cultural environments affects the transformation of cultural perspectives, it was necessary to measure multiple outcomes: (1) learning of cultural knowledge, including language and behavior; (2) feelings of presence in the immersive cultural virtual environment; (3) experience of the virtual environment by participants from various cultural backgrounds; and (4) piquing of peoples' interest in cross-cultural content by the virtual environment.

2.2 Hypothesis

Compared with other media formats, such as a those that use 2D screens and lack the qualities of an immersive environment, the hypotheses are that: (1) virtual reality

environments have a greater impact on cross-cultural understanding, specifically on motivation, interest, and knowledge-learning, because they produce a realistic, interactive, and immersive experience; and (2) that this effect applies to participants from both Eastern and Western backgrounds.

To test this, an experiment was conducted to compare participants' reactions to two different media experiences, with the experimental group taking part in a virtual reality environment and the control group experiencing a non-virtual reality environment. The content, including text and 3D graphics, was presented via desktop display (D) or head-mounted display (HMD). The experiment was intended to examine whether use of a HMD leads to higher participant retention scores and higher ratings on interest, presence, and motivation.

2.3 Methodology

2.3.1 Participants

The study involved 60 people in total. Data were collected on a full range of demographic characteristics, including gender, race, college major, and ethnicity. It was anticipated that these variables would be used as controls in multivariate analysis of the results of the two study components. The participants were all volunteers who were recruited from fliers, e-mails, Facebook postings, and face-to-face meetings on the Cornell Campus. Thirty of the participants were Chinese Asians (49.2%), representing Eastern schools of thought for the study; 18 were white Americans (29.5%), representing Western schools of thought for the study; and 13 came from other cultural backgrounds (28.7%) and included African Americans (2), other Asians (6), and Hispanics (4). Their

average age was 22.8 years, and ranged from 18 to 37 years. Forty were male (65.6%) and 21 were female (34.4%). A table showing the college major of each participant is below, from which it can be seen that the participants primarily came from a computer science background.

The only requirement for participation in the study was that the participants could not have too much knowledge of Japanese culture or the Japanese language. In response to the survey question "How familiar are you with the Japanese language?" 36 of the participants chose "not at all," while 25 chose "at least know some words."

2.3.2 Experimental Design

The experiment was carried out based on a study by Usoh et al. about the factors, listed above, that provide a sense of presence in a virtual environment. In order to provide a sense of presence on our experiment, the following factors were considered in our design:

i. High resolution information was displayed through VR device.

ii. Visual and auditory senses were stimulated in the experiment for consistency of the displayed environment across all sensory modalities.

iii. Bowing movements were sensed by the VR device and computer system, allowing the virtual environment to respond appropriately and naturally to the movement of the participant's physical body.

iv. Except for collecting words, navigating the environment, and reacting to bowing movements, no other complicated actions were involved in the game.

The video game depicted a traditional Japanese housing environment, with traditional Japanese-styled elements, including a sliding door made from wood and paper,

wooden floors, a bamboo courtyard, Japanese paintings and art, and a tatami room. The purpose of this environment was to enhance participants' physical presence in an environment containing cultural content.

The game the participants played was a demo of a 3D video game for language learning, called *Crystallize*. In the game environment, players collect words by interacting with avatars. The experiment consisted of 7 dialogues with the avatars in total. For each dialogue, the participant started the conversation by using the mouse to click on the avatar. The words to be learned popped up on the screen with the standard Japanese pronunciation. Then, the participant was directed to click on each word and learn its meaning.

Concepts about cultural behavior were introduced in each dialog. Bowing was a featured Japanese cultural behavior that was added to the dialogues in the experimental group. Participants could bow to the avatar when wearing the VR device as they would in real life.

Figure 6.1: Overhead view of the Crystallize virtual reality scenario. Players navigated through a Japanese teahouse and solved language learning questions by interacting with non-player-controlled characters.
Source: Cheng, Alan, Lei Yang, and Erik Andersen. "Teaching Language and Culture with a Virtual Reality Game." *CHI 2017*. Denver, CO: ACM, 2017.

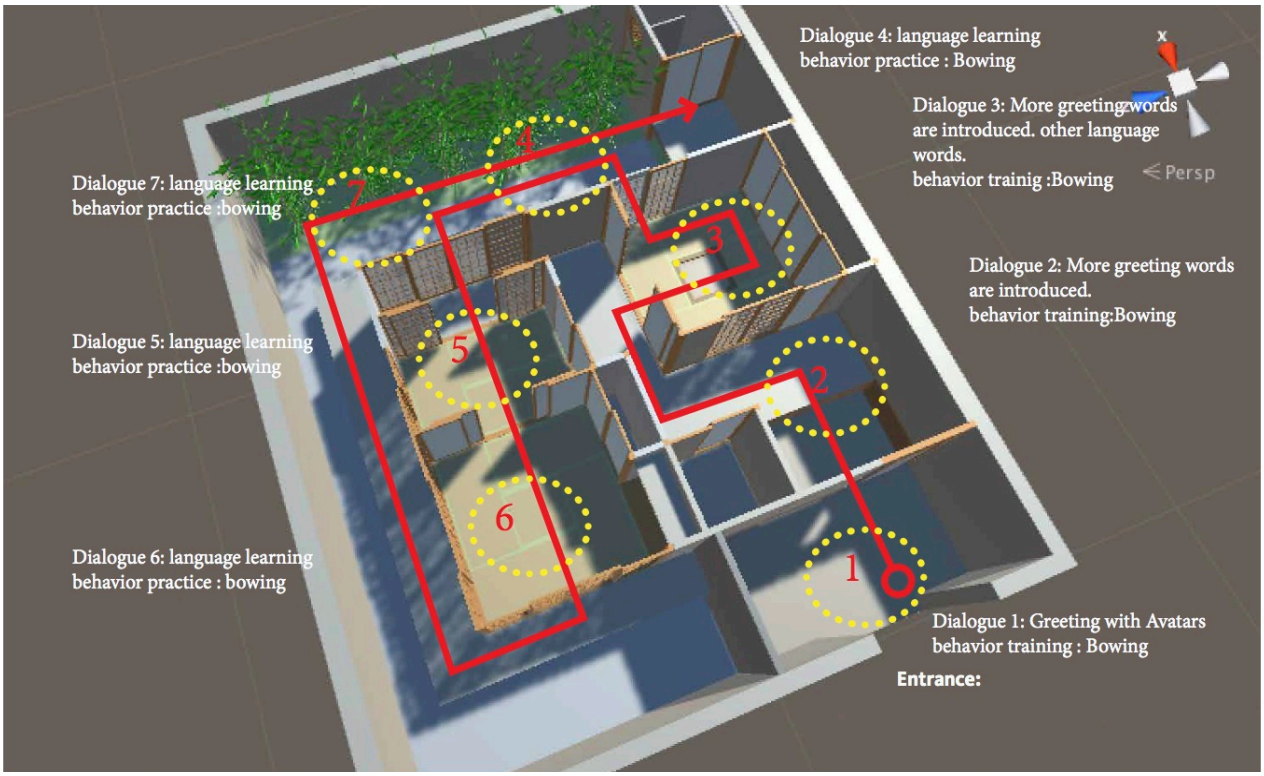

Figure 6.2: Game route layout in the experiment. Seven dialogues were included in the game demo
Source: Screen shot from Game scenario, May 13, 2016.

2.3.3 Experimental Procedure

The experimental procedure consisted of three phases: an initial, demographic questionnaire and two user studies. Before the participants started the experiment, they were asked to fill out the demographic questionnaire and rate their attitude towards and knowledge level about the Japanese culture by answering questions and taking a vocabulary quiz. Then, each participant engaged in both the virtual reality environment (VRE) and the non-VRE. The order in which the participants used these two environments was randomized for each participant. Thirty participants played the VRE game first and 30 played the non-VRE game first. Participants were asked to fill out a questionnaire after experiencing each environment. All experimental sessions took less than 30 minutes.

2.3.4 Hardware

i. Virtual reality device: Oculus Rift Development Kit Dk2

ii. Computer: in order to achieve the full Oculus Rift experience, the computer system met the following requirements: NVIDIA GTX 970/AMD 290 equivalent, Intel i5-4590 equivalent, 8GB+ RAM, Compatible HDMI 1.3 video output, 2x USB 3.0 ports, Windows 7 SP1

iii. Headset: Sony Stereo Headphone

2.4 Measurement

Data were collected through the surveys and the game log to assess cross-cultural presence, cross-cultural learning outcomes, and cross-cultural cognition in the VRE and

the non-VRE. Participants were required to fill out three survey forms: one before completing the experiment, one after completing the first round of the experiment, and one after completing the second round of the experiment. The surveys included questions from previously published questionnaires, as well as newly designed questions based on previous experience.

Table 6.1: Experiment structure

pre-1st round	-vocabulary quiz -self-evaluation of attitude, interest, and motivation towards Japanese culture.
post-1st round	-vocabulary quiz -self-evaluation on presence, attention, attitude, interest and motivation towards Japanese culture
post-2nd round	-self-report on media preference, interest, and feedback on the user experience.

2.4.1 Test of Cross-Cultural Presence

Participants were asked to give a self-evaluation about their experience with each environment. To test presence in the cross-cultural virtual environment, two components were considered[146] [147]: the sense of involvement (attention) and the sense of immersion (engagement). The questions used in the survey were based on the inventory designed by Lessiter and et al.,[148] [149] "The ITC Sense of Presence Inventory," and tested the participants' sense of involvement, engagement, immersion and attention in the VRE and

[146] Schubert, Thomas, Frank Friedmann, and Holger Regenbrecht. "The Experience of Presence: Factor Analytic Insights." *Presence,* Vol. 10, no. 3. MIT, 200. p. 266-281.
[147] Witmer, Bob G. and Michael J. Singer. "Measuring presence in virtual environments: A presence questionnaire." *Presence,* Vol. 7, no. 3, MIT, June 1998. p. 225-240.
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non-VRE. To self-report their sense of presence, participants answered four questions using a 5-point scale (1=much less, 5=much more). The means were compared between the groups using the VRE and Non-VRE.

2.4.2 Test of Cultural Learning Outcomes

There were two measurements used to assess language learning and behavioral learning outcomes. To evaluate the language learning outcomes, a vocabulary quiz was given to the participants before and after playing the game in the first-round environment. After scoring the language pre- and post-tests, the difference between the scores was calculated. To determine if the VRE impacted cultural learning outcomes, we compared the score differences between users of the VRE and non-VRE.

To evaluate behavioral learning outcomes in the VRE condition, two measurements were used. First, in the beginning dialogue of the experiment, the note "Please Bow" was displayed on the center of the screen immediately after the avatar bowed towards the screen, to remind the participant to bow in reaction to the avatar. In the following dialogues, the bowing prompt had a 4 second time-delay. This was to test if the participant would bow automatically before a prompt was provided. During each virtual encounter, the degree to which the participants bowed and how frequently they automatically bowed was recorded by the system. Secondly, after participating in the experiment, the participants were asked to respond to the question ""How comfortable do you feel bowing to a Japanese individual?" using a five-point scale (1=much less, 5=much more). This was to examine to what degree cultural behavioral learning can be processed in a VRE.

2.4.3 Test of Cultural Cognition

Three questions were asked about attitude, interest, and learning motivation towards Japanese culture in the pre-test and post-test. Participants answered each question using a 5-point scale (1=much less, 5=much more). The score differences for each question between pre-test and post-test were calculated. To examine if VRE made a difference on language learning, we compared the score differences between the VRE and non-VRE.

Additionally, participants were asked to respond in the pre- and post-test questionnaire to the question: "If you are interested in learning more about Japanese culture after this game, in what ways would you like to learn?" Four options were provided: "Read relevant books," "Watch relevant videos," "Go to a relevant museum," and "Visit a relevant site." Participants were asked to rate each option on 5-point scale (1=Do not prefer, 5=Prefer a great deal). The frequency, with which each of the points on the scale were selected for each option, was calculated. The score difference between pre- and post-test was measured. The difference between VRE and non-VRE scores was assessed to examine how VRE made a difference on culture cognition.

Finally, after participants finished the experiment, they were asked to fill out a survey, giving their own preference between the two types of media.

2.5 Results and Analysis

2.5.1 Cross-Cultural Presence

Table 6.2: Cultural Presence

Item	Label		Mean	Std. Deviation	Sig.
How interesting was the content presented in the game?	Focus	VRE	3.32	0.909	0.079
		non-VRE	2.93	0.785	
How entertaining was the content presented in the game?	Engagement	VRE	3.16	1.128	0.191
		non-VRE	2.8	0.997	
How much attention did you pay to the content presented in the game?	Involvement	VRE	3.58	0.923	0.229
		non-VRE	3.3	0.877	
How much did you feel involved in Japanese culture in the game?	Immersion	VRE	3.16	1.003	0.016
		non-VRE	2.57	0.858	

The results revealed that for every item the mean value for the VRE was higher than the non-VRE, indicating that a VRE is relatively more effective at enhancing presence in a cultural context than a non-VRE. Although the differences between the means were not all statistically significant, the difference seen for Immersion was statistically significant (Sig.=0.016, <0.05) and the difference seen for Focus was close to being significant (Sig.=0.079, >0.05). The results for Engagement (Sig.=0.191) and Involvement (Sig.=0.229), which examine entertainment and attention, could be influenced by the VR technology, such as by an interface or content problem. In the feedback from the participants, nearly 40% of the comments reported issues with the VR technology, including that it induced dizziness and that there were problems with the resolution and interface design. These factors are very likely to reduce participants' interest and entertainment.

Table 6.3 & 6.4: Cultural Presence on Different Cultural Groups

Between-Subject Factors			
	Value	Label	N
What media will you try first?	1	VR	30
	2	Non-VR	30
West_East_Culture	1.00		24
	2.00		36

Test of Between-Subject Effects					
Dependent Variable: **How much did you feel involved in Japanese culture in this video game?**					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Correct Model	12.152a	3	4.051	5.154	0.003
Intercept	469.049	1	469.049	596.793	0.000
VR_Non VR	4.139	1	4.139	5.266	0.025
West_East_Culture	4.073	1	4.073	5.182	0.027
VR_Non-VR * West_East_Culture	2.533	1	2.533	3.223	0.078
Error	44.799	57	0.786		
Total	559.000	61			
Corrected Total	56.951	60			

- a. R Squared = 0.213 (Adjusted R Squared = 0.172)

In answer to the question "How much do you feel involved in Japanese culture in this video game?" the factor of "different culture groups (West and East)" and the factor of "media environment (VR and non-VR)" showed no significant correlation to each other in influencing the sense of involvement in Japanese culture (Sig. value=0.078, >0.05). For each factor, however, there is evidence showing a significant correlation. The results showed a correlation between the level of involvement and the media environment (Sig.=0.025, <0.05) and a correlation between the level of involvement and the cultural group (Sig.=0.027, <0.05). These data indicate that the media environment has a relatively equal impact on participants both from a Western and Eastern cultural

background, meaning that people from different cultural backgrounds likely experience the same sense of presence in the VR environment.

2.5.2 Cultural Learning Outcomes

Table 6.5: Language Learning Outcomes

		Mean	Std. Deviation
Differences between the means of the Accuracy Rate	VRE	4.645	2.823
	non-VRE	4.7	3.075

The differences between the means of the accuracy rate between pre- and post-test vocabulary quizzes was used to examine language learning outcomes. The result showed that the mean D-value for the VRE is 4.645, which is lower than it is for the non-VRE (4.7). This indicates that the VRE did not effectively promote the learning outcomes of this experiment. The non-VRE had slightly more efficacy on language learning in this experiment.

The behavioral learning outcome was examined by checking two measurements: (1) whether a player learned to bow in response to an avatar bowing (i.e. the player bowed at least once during the play session before being prompted by the game), and (2) the bowing angle.

Table 6.6: Bowing Information

a. Overall:

Players that bowed before being prompted by the game	**47.9%**
Average bowing angle	45.8

b. Section break down:

	Session 1	**Session 2**	**Session 3**	**Session 4**	**Session 5**	**Session 6 (more conversation added)**
Bowed before being prompted by the game	36.4%	42.9%	15.4%	57.1%	40.0%	87.5%
Average bowing angle	48.4	44.0	49.7	52.0	41.8	44.3

These results indicated that a VRE is able to train the participants for cultural behavior, as almost 50% of the participants bowed without being prompted by the game. In addition, behavioral learning outcomes are enhanced as the time of interaction with a VRE increases.

2.5.3 Cultural Cognition

Table 6.7: Cultural Cognition

Cultural Cognition	Label		Mean	Std. Deviation	Sig.
Compared to before, how interested are you in the Japanese language now?	Interest	VRE	3.68	0.653	0.188
		Non-VRE	3.43	0.774	
Will you be interested in learning the Japanese language in the future?	Motivation	VRE	3.45	0.82	0.929
		Non-VRE	3.43	0.774	
Compared to before, how familiar are you with Japanese culture now?	Attitude	VRE	3.42	0.525	0.031
		Non-VRE	2.91	0.539	
Compared to before, how much are you interested in Japanese culture now?	Interest	VRE	3.42	0.672	0.079
		Non-VRE	3.13	0.571	
Will you be interested in getting involved in Japanese culture in the future?	Motivation	VRE	3.65	0.798	0.269
		Non-VRE	3.43	0.679	

For each item, the mean value for the VRE was higher than that for the non-VRE. The evidence shows that a VRE impacts cultural cognition more effectively than non-VRE in terms of interest, motivation, and attitude. In addition, the difference between the VRE and the non-VRE was statistically significant for Attitude (mean value = 0.031, <0.05), proving that a VRE is able to enhance the attitude of participants towards another culture. The difference between the VRE and non-VRE for generating culture interest

was nearly statistically significant at 0.079, likewise indicating the potential for VREs to promote people's interest in other cultures.

Table 6.8: Learning interest difference between pre-and post-test

Learning interest difference between pre-and post-test		VRE	Non-VRE	Sig.
If you are interested in learning Japanese culture after this game, through what ways would you like to learn?	Reading relevant books	0.04	-0.192	0.269
	Watching relevant videos	0.24	-0.2	0.011
	Going to relevant museums	0.16	0.077	0.654
	Visiting relevant sites	0.12	0.115	0.978

The mean of the D-value for the VRE was higher than for the non-VRE for every option. This shows that a VRE more effectively motivates people's interest in approaching other cultures. For the VRE, the means of the D-values were all positive, indicating that the participant's interest in learning Japanese culture was increasing for every item after being immersed in a VRE. Additionally, the means of the D-values for items 3 and 4 were much higher than for items 1 and 2. This reveals that after playing in a VRE, the participants became more interested in on-site or museum visits to learn about Japanese culture, as opposed to reading or watching relevant material. In the non-VRE condition, items 1 and 2 had negative D-values, showing that the non-VRE is not helpful in motivating people to pursue learning, especially through reading books and watching videos.

3 Conclusion

This experiment was conducted to evaluate the effect of a VR environment on cross-cultural understanding by comparing the sense of cultural context generated by VR and non-VR environments. There was some positive evidence that participants' perception of

cultural presence and cultural cognition was higher in the VR environment than in the non-VR environment. There was no obvious evidence showing that language learning outcomes can be more effectively achieved in a VRE than in a non-VRE. We speculate that language learning is relatively challenging and is more strongly correlated to other the factors than that of being immersed in a rich cultural context. In the end, no remarkable difference was found between Eastern and Western cultural groups in perceiving cross-cultural content in any of the environments, which means that the VR environments are equally effective for both Easterners and Westerners.

Due to time limits, the experiment contains some technical defects in the interface and the content. Of the comments provided in the user feedback, 45.9% were positive, showing a relatively high preference for using VR in interacting with cultural content, while the other 42.6% expressed negative feeling such as "dizziness" and "sickness" from being immersed in the VR environment. Eleven and a half percent of the comments expressed problems with the interface or the content, with the participants feeling "confused." These issues influenced the participants' responses to the questionnaires. In addition, since the length of the experiment was confined to 30 minutes, every item was measured by no more than two questions. In the future, more questions need to be added and further debriefing is needed.

CONCLUSION

The aim of this thesis is to identify the contextual factors and mechanism that are associated with Virtual Reality technology, and to analyze and explore its application in historic preservation. This has been developed and tested in six chapters, including three chapters of background research, two chapters of case studies, and one chapter of social experiment.

Virtual Reality, as a new member in this electronic device family is gradually shifting people's way of how they relate to the world. This achievement is based on human being's powerful visual system, which is actually a hundreds-years' exploration, led by engineers, computer scientist and visual artists. In fact it is the series demonstrations of the telecommunication tools indicating human being's creativity and tool making capability that direct us entering into today's virtual space-time. The electronic eyes, electronic ears, and electronic mouth that we used in a two-dimensional platform has been transferred into an immersed three-dimensional world. It is undeniable that a higher-grade of interactive art will emerge in the future based on this immersive medium, stirring the emotional part in everyone's heart. While the ambivalence attitudes to Virtual Reality today still coexisted in the society, as long as people, mainly led by advocators, figured out how to use it, and once they realize what virtual reality could do for them, they would not let it go any more.

The applications of Virtual Reality in heritage preservation have indicated the potential to document, restore and represent the historic relics. On the one hand, by using high-resolution 360-degree camera, it is possible for either professionals or amateurs to

record historic sites for various needs. On the other hand, the profound social and cultural values of the historic relics are enhanced through virtual reality, in that virtual reality tells stories of the tacit relics by providing the ultimate immersive experience.

Apart from that, using virtual reality to present heritage information provides an alternative direction for heritage management as well. Certainly the volume of visitors and some of their inappropriate behaviors create enormous challenges for conservation and site management. Where visitors are able to obtain detailed information from virtual reality experience, the pressure on the real heritage site is relieved through the combination of reduced access to the real sites with virtual tourism.

In addition, many studies, including the experiments described in this thesis, illustrate that Virtual Reality is able to influence peoples' minds. Immersion in a virtual environment enhances the formation of an empathetic relationship between the content and the participants. This character could be used to promote the understanding of cross-cultural content when the users are in such environment like museums, heritage sites and galleries.

Nevertheless, virtual reality is a new approach and there are many limitations to this thesis study. Due to the limitation of time, there are a number of questions that are only provided with general descriptions and ideas. The Virtual Reality development progress in the first chapter mainly looks at the activities in American VR history. It is undeniable that other individuals and companies outside the States also actively got involved in this development, for example Sega in Japan, whose products witnessed the first wide-spread commercial use of VR headset in the early 1990s.

In this thesis study, how virtual reality is related to human visual system is addressed from different perspectives. As an analogy as other telecommunication tools, the research in this thesis study only generally describes the development of telecommunication in the past century with a little bit more focus on the period when the then new technology "television" replaced the then widely accepted device "radio" and dominated the market in the 20th century. Less energy is spent on the television years afterwards. More studies are necessary to analyze how various television contents have been created in response to this technology and how the television models become a success. It provides a reference to today's virtual reality developers on how to design appropriate programs and develop business models.

In terms of the case studies chapters, the goal is to look at in what extent virtual reality could assist historic preservation practice, such as how, why and by whom. Although this aim is roughly demonstrated in the chapters, the scales of the two cases are inappropriately different. It is mainly because recruiting two different portfolios are limited by research time and by the technology development condition at that time. During its initial phase, virtual reality is still new to the public while institutes have more ability to gather resources and produce better programs. After recruiting the Mogao preservation case, the Shikumen project was then a new thing in the community, which was picked up with an anticipation that it may serve as a contrast to what many professional institutes work with virtual reality in historic preservation. Recruiting the case studies took place more than one year before the writing process began. In this intervening period, the complexity scales were realized as no longer ideal for the thesis. In front of the limited time, decision was made to continue with them although not ideal,

instead of seeking at a later moment to recruit alternative one. The project by history amateur provides an example that virtual reality is accessible to normal people who are interested in history and want to participate in preserving it. The interview was conducted when the project was still ongoing in 2015. According to the Shikumen project producer's latest updates, the old neighborhood he has shot by 360 camera have been renovated and a new version have been recorded and uploaded. Users are able to see both the before and the after construction phase images of the same neighborhood.

In addition, there are a number of other gaps in the knowledge around virtual reality and historic preservation that follow from the findings in this thesis and would benefit from further research. The study has discussed that virtual reality is able to document the historic site as it decays and serve as digital archives for rehabilitation work. As a part of heritage computing in Arts and Humanities, the future research of virtual reality and historic preservation is to study the relationship between the immersive visualization and human-computer interface with efficient algorithms, to explain the Past through interlinked visual digital forms. On the one hand, it needs historians, engineers, archaeologists, and innovative media designers to perform together on how to translate the historic information into interactive visual data. The work needs to carry the implications of people, objects and environment of the past and make it accessible to a wider public. On the other hand, it indicates that the work of collection, selection, and interpretation of the historic materials that convey the information related to the visual content is still the fundamental thing prior to the computing work.

Besides, with the visual technology itself develops, the virtual reality heritage work will become more complex and generate vast quantities of data with the

entanglement of forms and contents. Using visual technology to save the heritage site is a new trend in historic preservation, however researchers have noticed an urgent situation regarding digital heritage. It is disappearing faster than the actual, physical heritage. Because heritage in digital form no matter created from the existing physical relics or from the content can be accessed, replicated, intercepted easily by the individual and public, which cause the corruption of their integrity and authenticity. Thus while everything is recorded in digital form, there should be an institutionalized archival standards and a central database for recording and storing these virtual heritage information.

Table 7.1: Heritage Information Longevity[150]

Stone (e.g. historic building)	Paper (e.g. drawing)	Magnetic/Optical (e.g. CD-ROM)	Encoding (e.g. VRML)
1000's of years	100's of years	10's of years	1+ years

At last, heritage usually serve themselves as platform where people glue their emotions, feelings and expression. The content created by the immerging VR technology challenged the traditional way people engage in with each other, which will continue to stimulate the advocacies in preservation practice, politically and culturally. It will come along with more social issues and associated with many interest groups who want to control and will be controlled.

[150] Thwaites, Harold. "Chapter 17: Digital Heritage: What Happens When We Digitize Everything?" *In Visual Heritage in the Digital Age*, edited by Eugene Ch'ng, Vincent Gaffney and Henry Chapman, p. 341. Springer, 2013.

In general, Virtual reality and historic preservation is a young and new field to investigate. It provides a new dimension for heritage analysis, advocacy and representation, where there will be great chances and responsibilities in preservation community in the many years to come.

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Figure 1.1: The Sensorama Machine.
Photo Source: U.S. Patent #3050870

Figure 1.2: A user is experiencing the Sensorama.

Photo Source: http://www.mortonheilig.com/InventorVR.html (Accessed by July 04, 2017)

Figure 1.3: A computer-displayed perspective view of the "room" as seen from outside

Figure 1.4: The mechanical head position sensor in use

Figure 1.5: HMD optic with miniature CRTs

Photo Source (Fig. 1.3-1.5): Sutherland, Ivan E. A Head-Mounted Three Dimensional Display. The University of Utah Salt Lake City, Utah: Fall Joint Computer Conference, 1968.

Figure 1.6: 3D graphic virtual objects and articulated hand directly controlled by Data Glove.

Figure 1.7: Virtual Reality Concept. Imagery displayed in the virtual environment appears to completely surround the user in 3D-space and enable the operator to explore virtual objects and environments in real-time and from multiple viewpoints.

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Figure 1.8: A page introducing Virtual Reality game system in the early 1990's VR campaign.
Photo Source:
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Figure 1.9: Google Cardboard VR headset with a smart phone in the visor slot
Photo Source: Google Official Website https://vr.google.com/cardboard/ (Accessed by July 25th 2017)

Figure 1.10: HTC VIVE VR. The two handheld controllers enable user to manipulate the object in VR environment.
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Figure 3.4: Ceiling of the Camera Picta in the Palazzo Palace

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Figure 5.2: Old Shikumen Housing Layout

Figure 5.3: New Shikumen Housing layout

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Figure 6.1: Overhead view of the Crystallize virtual reality scenario. Players navigated through a Japanese teahouse and solved language learning questions by interacting with non-player-controlled characters.
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Figure 6.2: game route layout in the experiment. Seven dialogues were included in the game demo
Photo Resource: Screen shot from Game scenario

TABLES:

Table 6.1: Experiment structure
Table 6.2: Cultural Presence
Table 6.3 & 6.4: Cultural Presence on Different Cultural Groups
Table 6.5: Language Learning Outcomes
Table 6.6: Bowing Information
Table 6.7: Cultural Cognition
Table 6.8: Learning interest difference between pre-and post-test

Table Resource: Data received from VR Experiment

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APPENDIX I

Virtual Reality Experiment Survey Questionnaire

VR Experiment Questionnaire:

Default:

1. What is your gender? _Male _Female
2. What ID number did you get: _____
3. What is your school ID: _____
4. What is your age: _____
5. What is your culture background: _____
6. What is your major background: _____
7. What media do you try first? _ VR _Non-VR

Before:

8. How much do you know Japanese language?
   _Not at all _At least know some words

9. Please match the words based on what you know about Japanese.
   Items:
   Good morning
   Good afternoon
   Hello
   Nice to meet you
   Goodbye
   Am
   Please
   My name is

10. How interested are you in Japanese **language**?
    _Not at all _Some _Moderately _Quite a bit _Very much

11. How interested are you in Japanese **culture**?
    _Not at all _Some _Moderately _Quite a bit _Very much

*Please start the video game now

During:

12. Please match the words based on what you learned in the video game:
    Items:
    Good morning
    Good afternoon
    Hello
    Nice to meet you
    Goodbye
    Am
    Please
    My name is

13. Compared to before, how interested are you in Japanese **language**?
_Much less _Slightly less _About the same _Slightly More _Much more

14. Will you be interested in learning Japanese language in the future?
_Neither like or dislike _No _Maybe _Very likely _Absolutely

15. If you are interested in learning Japanese **language** after this gam, through what way would you like to learn?
_Talk to Japanese people
_Continue playing this game
_Take Japanese course

16. Compared to before, how much are you interested in Japanese **culture**?
_Much less _Slightly less _About the same _Slightly More _Much more

17. Will you be interested in getting involved in Japanese **culture** in the future?
_Neither like or dislike _No _Maybe _Very likely _Absolutely

18. If you are interested in learning Japanese culture after this game, through what way would you like to learn and to what degree?

	Do not prefer	Prefer slightly	Prefer a moderate amount	Prefer a lot	Prefer a great deal
*Prefer a great deal					
*Read relevant books					
*Watch relevant videos					
*Go to relevant museums					
*Visit the places relevant to Japanese culture					

19. After completing the game, do you feel more comfortable with bowing to a Japanese?
_Extremely comfortable
_Somewhat comfortable
_Neither comfortable, nor uncomfortable
_Somewhat uncomfortable
_Extremely uncomfortable

After:

20. How interesting was the content presented in the game?
_None at all _A little _ A moderate amount _ A lot _A great deal

21. How entertaining was the content presented in the game?
_None at all _A little _ A moderate amount _ A lot _A great deal

22. How much attention did you pay to the content presented in the game?
    _None at all _A little _ A moderate amount _ A lot _A great deal

23. How much did you feel involved in Japanese culture in this game?
    _None at all _A little _ A moderate amount _ A lot _A great deal

Please start the video game again:

24. Which media do you prefer to use in this video game?
    _VR _Non-VR _I don't care _None of them

25. Would you like to try a program via VR again to learn cultural related topic?
    _Definitely yes _Probably yes _Might or might not _Probably not _Definitely not

26. Please describe how you felt while using VR in this game:

    _____

(May 2016)