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Master's Dissertation 2022

Research on Personal Tele-Immersion System in 5G Background

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SUMMARY OF MASTER'S DISSERTATION

Student Identification Number	82034529	Name	Xuesi Xu

Title

Research on Personal Tele-Immersion System in 5G Background

Abstract

With the advent of various high-resolution hardware and 5G communication technologies, tele-immersion systems that can meet both indoor and outdoor scenes have become a new possibility. Although the concept of tele-immersion system has existed, it usually needs large-scale immersion display, high-speed lines and other large systems to send a large amount of information. The hardware requirements of these specialties obviously do not apply to the needs of ordinary people in their daily lives for tele-immersion systems.

In this paper, a tele-immersion system based on 5G background is proposed, which can meet the needs of outdoor use, and the hardware is the daily electronic equipment. It allows users to immerse themselves in a 360-degree outdoor scene and interact with field operators via voice or text. In this study, two experiments were conducted to assess the effectiveness of tele-immersion systems and to verify that users can master spatial relationships as well as those present. Finally, the performance and universality of the system are evaluated by subjective questionnaire. The results show that compared with the traditional tele-immersion system, the system can provide higher immersion in outdoor and indoor scenes, and the performance and versatility are good.

Key Word (5 words)

Tele-immersion, 5G, Remote-immersive, Sense of presence, Live streaming

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1. Introduction

1.1 Background

1.1.1 Overview of Virtual Reality (VR)

Virtual reality (VR), the technology originated in the 1960s and 1940s as a computer simulation system for creating and experiencing virtual worlds. Users will achieve a strong sense of presence in a virtual environment [1].

Unlike traditional user interfaces, participants in virtual reality are immersed in virtual environments and can interact and communicate with virtual objects and avatar representations by using different types of input devices and audio-based input devices. Display device is a kind of technical equipment for virtual reality visualization. They are classified according to the degree of immersion available, which is the physical presence in the nonphysical world. Because immersion is objective, if one system is superior to another in at least one parameter while the others remain constant, then the system is more immersive than the other. Since immersion is an objective system, it is more profound than the other when the other parameters are the same. There are three types of immersion display systems: Primary-immersion, semi-immersion and immersion.[2]

- Primary immersion systems

Primary immersion systems are simpler devices that use a single screen, such as a computer desktop, to display virtual environments. A typical desktop display system uses Web VRs to display virtual environments in Web browsers. WebVR is an API based on the JavaScript language that allows Web applications to display content in

VR. Users can interact with the virtual environment using a mouse, touch screen, or some other VR device.

Figure 1. 1 WebVR System Based on Mouse and Screen Interaction

■ Semi-immersive systems

General semi-immersed virtual reality systems have a high level of interaction. Semi-immersive use a set of large projections to display the virtual environment on walls, enveloping the viewer, such as the cave automatic virtual environment (CAVE), some semi-immersive virtual reality systems have high levels of interaction, such as touch feedback and tactile input devices with six degrees of freedom based on this.

Figure 1. 2 Cave automatic virtual environment (CAVE)

- Immersion systems

Immersive virtual reality systems not only isolate the user's senses from the real world, but also provide them with virtual information that provides the most powerful immersive experience. A typical example of an immersive virtual reality system is the virtual reality HMD, a wearable helmet with head position tracking, OLED displays and ambient audio capabilities. Common commercial devices such as Oculus Rift and HTC Vive offer a fully immersive virtual reality experience in a more portable form.

Figure 1. 3: Immersive Display Device (HTC Vive)

Table 1-1 illustrates the comparison of the resolution, immersion effects, interactions, and prices among the three types of virtual reality systems based on immersion levels.

	Primary immersion	**Semi-immersive**	**Fully immersive**
Resolution	Low - Medium	Medium - High	High
Immersion effects	Over the Low	Medium - High	High
Interactions	Low	Medium	High
Prices	Low	Average	Expensive

Table 1- 1: Comparison of common immersion systems

Compared with the above three categories of VR devices, they are portable in size and cost-effective. Most current mobile devices, including smartphones and tablets, range in screen diagonal sizes from 4.5 inches to 12 inches and in weight from a few ounces to three pounds. In terms of cost, low-and mid-range mobile devices cost between $50 and $400, which is more acceptable to the average consumer than other virtual reality devices that cost more than $500. In addition, immersive systems for mobile terminals are independent, which means they can operate independently of the computer. In terms of usability scenarios, smartphones are used more frequently than other virtual reality devices.

Mobile immersion terminals are currently the most consumer-friendly choice for virtual reality experiences. Although VR development has long focused on advanced device-based VR, the shift to mobile terminals is an important step towards reaching a wider audience. The challenge, however, is to bring the advanced VR experience to mobile devices with limited capabilities. This transformation is a process of optimization that requires full attention to the basic quality of the user experience. Virtual reality has a unique feature of user experience, which results from the fact that users are surrounded by simulated environment and carry out activities in it when consuming virtual reality content. These characteristics are often described as three key characteristics: immersion, presence and interactivity [3-4]. However, most previous studies have covered them only partially or without a clear distinction between presence and immersion. Generally, research shows that the entry-level and advanced VR systems will generate different levels of virtual state, and different levels of virtual state will determine the quality of user experience. Therefore, how to make good use of virtual presence as a virtual environment experience index, so that creators can better bring good experience to mobile devices with limited capacity. This article has carried on the corresponding design research with the help of the virtual presence theory.

1.2 Overview of Tele-immersion

1.2.1 Definition

Immersions a concept that interacts with remote places while maintaining a high degree of presence. By connecting a remote location to the Internet or a dedicated line and presenting the information on a highly immersive display, represented by CAVE, users can experience the immersive experience. Originally, it was intended to create a new dialogue system to replace the traditional video conferencing on the monitor screen.

Video conferencing systems such as Skype, which share information with remote areas, are incomplete systems that do not function in non-verbal communication, such as human eyes and detailed behavior. For example, the screen cannot make accurate eye contact, users can not accurately grasp the spatial relationship between each other. As a means of addressing these issues, the concept of remote immersion has emerged, combining VR technologies such as display and interaction with network technologies to achieve high-capacity real-time data communications (Figure 1.4).

Figure 1. 4 : Tele-immersion: Tomorrow's Teleconferencing, Jan, 2001

Similar concepts include "tele-existence" and "tele-presence." When tele-existence controls a robot remotely, user goes inside the robot like a skeleton and operates as if he were there. Refers to technology for working and communicating with a high degree of realism as if a person actually exists in a remote location (Figure 1.5).

Figure 1. 5: Tele-existence System "TELESAR V "

Tele-presence is a concept proposed at the same time as tele-existence, in which tele-existence makes oneself appear to be in a remote location by presenting oneself in a remote location. Telepresence is the concept of bringing remote areas around oneself by presenting images of remote areas here. Both are the same in that they give an immersive feeling as if she were actually in the remote real world, which is spatially separated. These three concepts differ in detail, but they all share the same "remote immersive feeling in the real world." In this study, tele-immersion is used as a "remote immersion experience".

1.2.2 Existing Tele-immersion System

As a feature of tele-immersion, information sharing with remote places and immersion to the world. As a means of sharing information with an existing distant place, there is a video chat system typified by telephone or Skype, but it is different from the point of immersion in the world. There is a tele-immersion, system using a large immersive display as a device for generating high immersion feeling. In the research using the large-scale video projection display which represented the cave, there is research which composes the real avatar of the real image in the virtual space and compromises it in the sense that it is in the place by three-dimensional display. A large screen is placed in a cube shape, and the user can see a virtual image in the virtual space with high presence. By combining this immersive display with a 3D video avatar, we realize realistic communication by combining real human character into immersive 3D virtual space [5]

Figure 1. 6: Communication using video avatars [5]

Some studies use immersion displays instead of distance learning. To achieve the effect of distance learning, two immersion displays are connected with one teacher and the other student. Teachers use images or 3D model data stored in databases to give lectures. On the monitor on the student's side, the teacher's body image, the open handout material, and the movement of the fingers are all three-dimensional images (fig. 1.7).

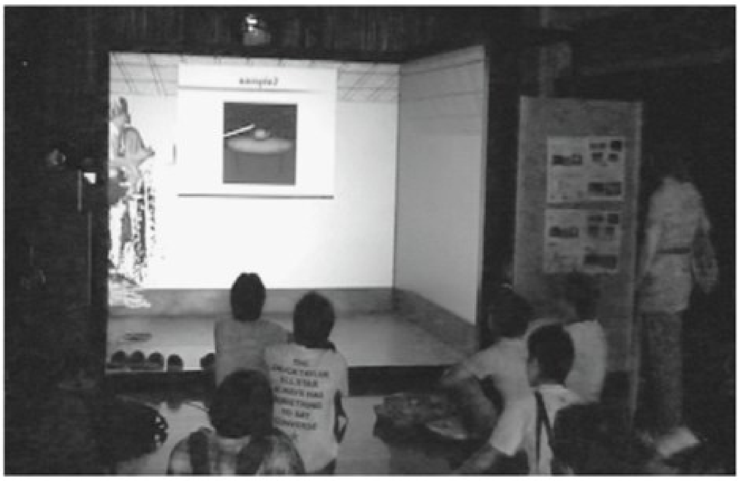


Figure 1. 7: Distance learning using CAVE

In addition, there is research on real-time projection of long-distance landscapes onto immersive displays. In TWISTER, in order to achieve 360-degree stereoscopic image of naked eye, an immersive display is constructed by high-speed rotating the track with multiple prompting units. Remotely connected images taken by multiple cameras, generating, prompting for 360-degree images, resulting in immersive remotely generated images [6] (Figure 1.8).

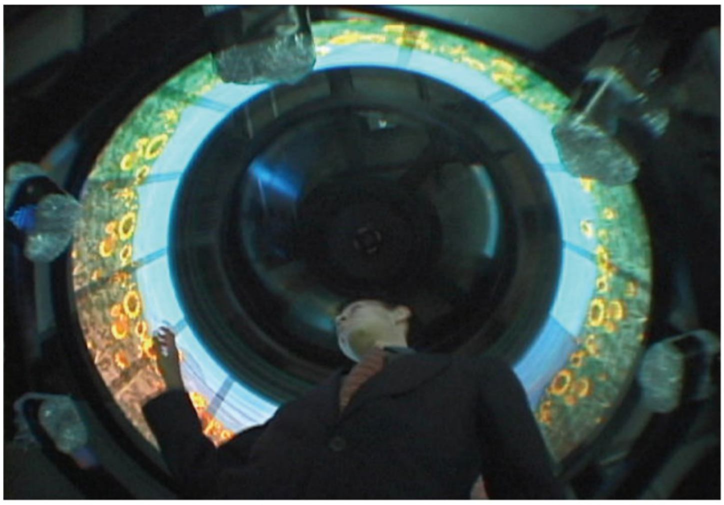


Figure 1. 8: 360-degree Panoramic Image displayed in TWISTER II

Telesar5 [6] (Fig. 1.9) is a system that combines visual information and tactile information from a stereo camera to allow for detailed manual work at remote locations.

Figure 1. 9: Demonstration of TELESAR V robot at Visioneers Summit

OmniGaze[7], a display-covered omnidirectional camera for remote presence, shows a remote user's presence with a spherical LED array on a 360-degree camera. It provides a wide field of view to a remote user, and gaze information is acquired by a gaze tracker.

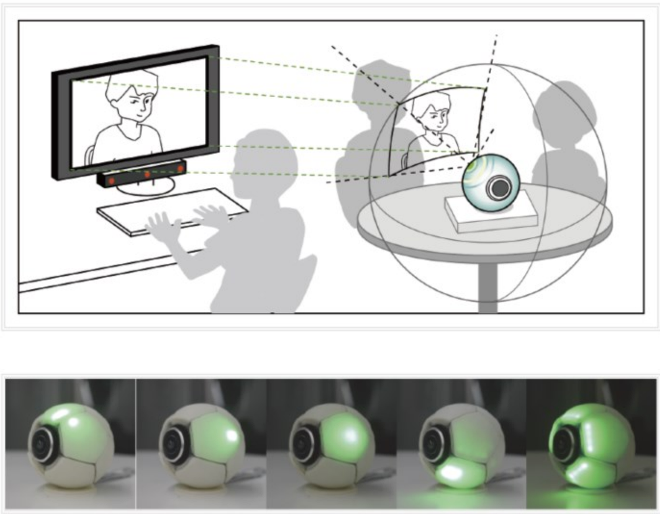


Figure 1. 10: A display-covered omnidirectional camera for remote presence

A wearable telepresence system, JackIn Neck [7], that can be worn on the neck and supports joint activities with a local user, a conversation partner who meet the local user, and a remote user of this system.

Figure 1. 11: A Neckband Wearable Telepresence

The traditional tele-immersion system has a high immersion effect, but because it requires a large screen to cover the field of view, the setting is limited. Therefore, it is not "ordinary users in daily life can use the private system," but for scientific purposes. In addition, the traditional tele-immersion communication system uses the large-scale immersion display, such as CAVE, therefore, must transmit the massive data to the distant place. New remote immersive systems such as OmniGaze, JackIn Neck, etc. that have appeared in recent years have solved the traditional shortcomings of large size and poor mobility, but viewers are still mostly confined to indoors due to network speed and immersion. At the same time, these systems make more compromises towards mobility, so most of them use ordinary cameras as remote video capture systems. As a result, the panoramic picture and the immersion of depth are lost. Therefore, there are very few remote immersion systems with both "mobility" and "free viewing" capabilities. In this paper, we design a private, long-distance immersive communication system based on 5G mobile data network, which transmits mass data through wireless communication.

1.2.3 Tele-Immersive Experience Requirement

At present, human beings have explored many ways to exchange information with remote areas. In the past, humans have tried to share real-time information with remote areas using simple, monotonous methods such as beacon fires and signal bombs. Eventually, with the development of communications technologies, the transmission of information could be explained by the presence or absence of digital signals (molar signals), and a telephone was created to convert speech into digital signals and transmit information. Later, based on the pure audio interaction, people developed a video phone which can transmit video and interact remotely. Now, with the advent of Internet communications like Skype and Zoom, people can use voice and video to communicate with anyone anywhere in the world.

Figure 1. 12: Anybots

Figure 1. 13: Double

In addition, mobile video calling systems, such as Anybots [3] (Figure 1.12) and Double [4] (Figure 1.13), have been developed to allow people to operate robots and move initiatively while viewing the PC screen. These robots are mainly developed to replace users to communicate with others remotely and have mobility. In practical applications, there are also examples of operating robots participating in remote meetings. However, due to the limitations of devices and communication signals, people's experience and sharing of content has been limited to two-dimensional plane world. Instead of immersive telecommuting services, Google's Street View, which allows users to view 360-degree images on their phones or computers, and periodically shoot and update content on their cars through installed panoramic cameras, gives panoramic virtual worlds flexibility. But the content of Google Street View lacks timeliness and interaction, people cannot experience the traditional immersion system as real-time communication and grasp the actual site location. If traditional immersive systems present content in the form of VRs like Google Street View, the flow of these services seems to satisfy not only the experiencer's need to see the landscape from afar, but also the need to move freely around the world. This was particularly important during the outbreak, when people were unable to travel freely because of environmental disturbances and needed to avoid densely populated areas. This makes people for the outdoor scene of remote immersion experience gradually increased demand. Aside from that, remote devices do not guarantee immersive and interactive spaces, so a daily immersive device for private "allowing people to go wherever they want" becomes a requirement.

1.3 Problem Statement

As can be seen from the above, due to the network and hardware equipment, most remote immersion systems are used indoors, users are often limited to the indoor experience content. These professional devices have some common flaws, most are used indoors, use expensive equipment, and rely on the wired Internet. Therefore, based on the current problem statement, we can extract system requirements: cheaper and more affordable rendering devices, high-speed wireless networks as a transmission medium, and the ability to experience outdoor scenes. At present, geospatial resources are increasingly scarce, and large remote immersion systems are not suitable for personal use. With the rise of high-resolution VR devices such as mobile head display and smart phones, it has become a new possibility for people to watch VR panoramic content through mobile phones. Mobile phone is an indispensable device in modern life. People can use it as the presentation tool of web-side VR anytime and anywhere, and at the same time break away from the bondage of wired Internet. In addition, there is a simple, low-cost virtual reality product represented by cardboard, a head display based on a smartphone. This kind of display is cheaper, can be quickly popularized among the public and has a wider range of use.

Communication speed is also an issue when a new generation of high-resolution devices is proposed. In traditional long-distance immersion systems, large amounts of data are transmitted over dedicated high-speed transmission lines. However, in personal applications, dedicated high-speed transmission lines or high-speed LANs are often limited by cost and space, and image stability and latency are often affected by communication rate. With the continuous development of information technology, the fifth generation of mobile communication technology (5G) has been born, which has the characteristics of large bandwidth, low delay and wide connection, and provides the possibility for studying the immersion system used by individuals in daily life.

1.4 Research Purpose

Considering the above situation, the ultimate goal of the research is to develop a remote immersion system which can be easily used by ordinary users in their daily life under 5G background. As the basic requirements of general consumers for products, there are five evaluation factors [8], including " Basic functions performance", "Deterioration and maintenance of functions in time", "Economy", " Expansion of functions by options", "Harmony with living environment" and " Safety and maintenance with product specifications".

Therefore, on the basis of developing a remote immersion experience system which can be easily used in daily life, it is necessary to consider the overall price, maintenance and security. As a means of developing a remote immersion experience system which can be easily used by common users in their daily life, the aim of this study is to develop a personal tele-immersion system that can be used in both indoor and outdoor. The advent of this new remote immersion system allows for a unique and customized experience, such as an immersive private tour or remote class through this system.

1.5 Structure of the thesis

This dissertation includes 5 main chapters and followed by the acknowledgment.

The first chapter describes the classification of existing VR equipment and the research purposes and significance of remote immersion system.

In the second part of this paper, the theoretical basis of virtual immersion system and the limitation of remote immersion system are explained in detail.

Then in the third chapter, Elaborated the concrete remote immersion system's architecture and the workflow as well as the system basic frame verification.

The fourth chapter evaluates the objective and subjective evaluation of the designed remote immersion system, including the user's spatial control ability, the system's operation feasibility and virtual presence.

In the fifth chapter, the summary and prospect of this paper are given. Combined with some problems found in the process, the paper puts forward some related research points and development work that can be carried out in the future.

2. VR Theoretical design and related work

2.1 Concept and composition of virtual Telepresence

Virtual Presence is one of the experiential indicators of a virtual environment. One of the first terms coined by Sheridan [9] is the sense of presence caused by virtual reality technology. Many researchers have also borrowed the word telepresence. Words derived from telepresence include product telepresence, spatial telepresence, physical telepresence, social telepresence and self-telepresence. It can be seen from the translated names and derived words that the study of telepresence has lasted for many years and involves a large number of subjects. This feature highlights the multidimensional nature of virtual reality and telepresence. Presence refers to the feeling of being present in a space, even if physically in a different location. Because "presence" is an internal state of mind and a form of internal communication, it is difficult to describe in words — one that can only be understood through experience. Trying to describe presence can be as controversial as trying to describe concepts such as consciousness or feelings of love. Nonetheless, the VR community wants an official definition of presence, because such a definition would help design the VR experience. The definition of presence was defined by the ISPR International Association for the Study of Presence in the spring of 2000 and is described on its website as follows: presence is a state of mind or subjective perception in which one's current experience, whether partially or wholly, is produced or filtered out by artificial techniques, but one's own perceptions, partly or wholly, do not play an accurate role in the experience. (International Society for the Study of Presence, 2000) [10]

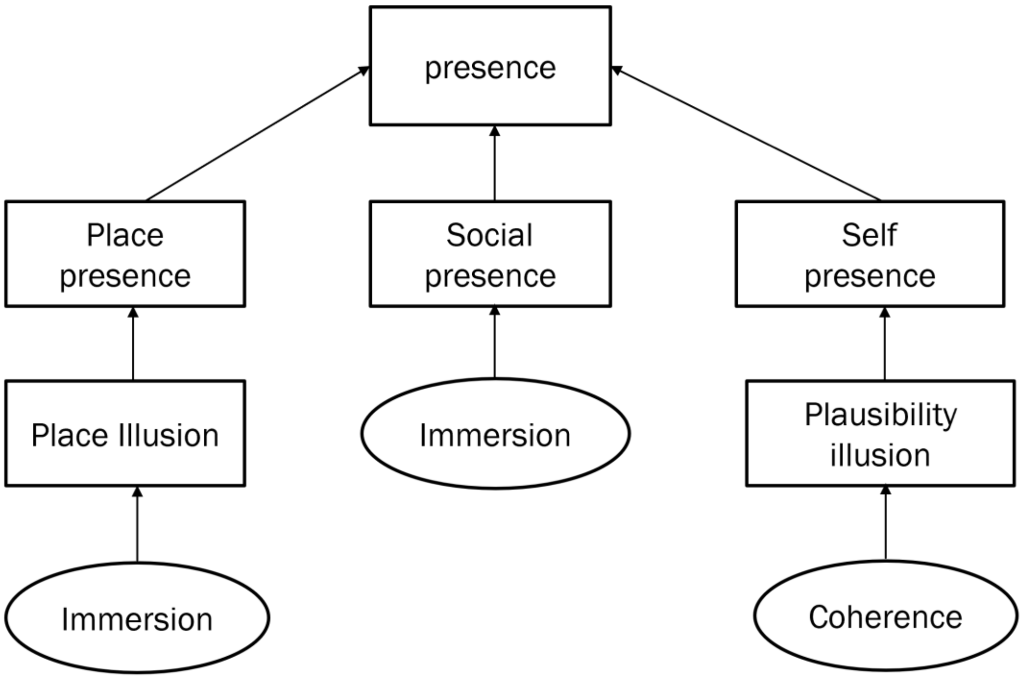


Figure 2. 1: Composition of Virtual Telepresence

2.1.1 Presence and immersion

The relationship between immersion and presence has been studied for many years. Due to the limitation of VR ability in the 1990s and the first decade of the 21st century, and the different views of different scholars on the definition and measurement of factors, the views of relevant studies are limited. First, presence is an intrinsic psychological and physical state of the user [11]. Presence is manifested by consciousness immersed in the virtual world and temporary amnesia or blindness to the real world and the technical medium. When the user produces "presence", the user does not pay attention to and perceive the technology, but pays attention to and perceives the objects, events and people that the technology represents. Users with a high presence feel that virtual reality offers an experience of participation, not simple perception.

Producing "presence" is a combination of user and immersion. Immersion produces a sense of presence, but immersion does not always induce it — users can simply close their eyes and imagine themselves elsewhere. In general, the more immersive a user feels, the more likely he or she is to feel his or her presence in the virtual world. Researchers regard immersion as a psychological state, a subjective psychological experience, and define it as the feeling of being addicted to virtual world. Immersion has also been recognized by researchers as an objective technical feature of virtual environments and a technical capability of virtual reality systems [12]. This means that virtual reality technology is more or less immersive, for example, by using more or less sensors, or by having large or small fields of view. Based on this view, we should use the technical capabilities of the VR system to objectively assess immersion, rather than to measure consumers' subjective experiences. However, this also means that different VR content types with the same VR technology have the same level of immersion. From the perspective of user behavior research, this explanation is unreasonable. Therefore, the text thinks that immersion is a psychological experience, which is based on and restricted by systematic technical ability, but it must be measured at a subjective level.

Presence	**Measurement dimension**	**Measurement description**
Place presence	Vivid and interactive	Present a high degree of real world restore and fidelity
Social presence	Social scene	can communicate in real time.
Self presence	Degree of investment Sense of reality	Maintain a high level of concentration and experience subjective visual sensations.

		Willing to believe that what you see when you experience is true.

Table 2- 1 Subjective measurement dimension of virtual presence

2.2 Related technology research

2.2.1 Three-dimensional stereo vision technology

Human beings get information from the outside world through sensory perception, of which 80% to 90% information comes from visual information. Therefore, simulating user's visual experience is the most important part of virtual reality system. In order to provide more immersion, it is necessary to provide users with enough visual information. Three-dimensional vision technology is to solve the problem of how to provide users with a realistic three-dimensional field of view. In the real world, the objects seen by human eyes are three-dimensional. People can judge the shape, size and distance of objects by vision, because the brain can calculate and perceive depth information. The human brain computes and perceives depth in four main ways. Parallax between two eyes is the most important factor of stereo vision. So, the virtual reality system simulates the parallax by using this characteristic to produce 3D stereo vision. Through the principle of binocular parallax to achieve stereo vision, first we need to obtain two binocular images for the left and right eyes to view respectively. These two images are the projection images of the same view at the left and right viewpoint shown as the figure 2.2.

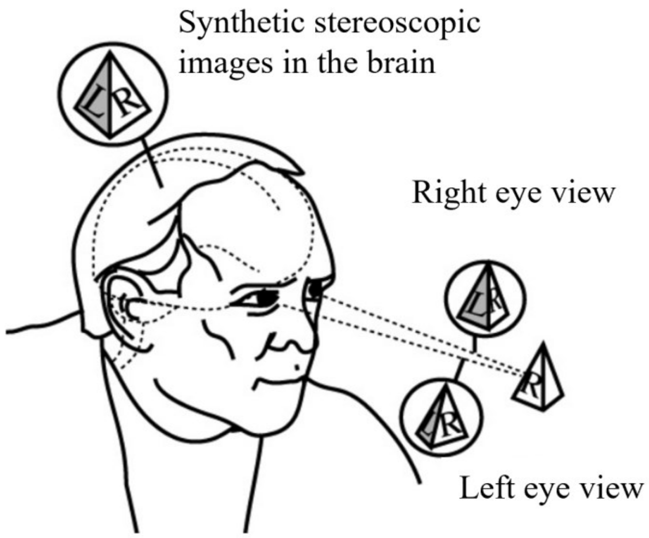


Figure 2. 2: Schematic diagram of stereo vision generated by binocular parallax

There are three common ways of obtaining binocular images [13]:

1. Dual cameras: Two cameras are used to simulate the relative position of the human eyes.
2. Software simulation: using computer vision and computer graphics principles, from the original image to calculate two binocular images. Although there is a theoretical basis, but the effect is not ideal.
3. Abstract from virtual 3D scene: The virtual artificial environment is 3D, but in the mode of single virtual camera and single display reality, it cannot directly reflect the 3D characteristics of virtual environment. Two virtual cameras are used to simulate the relative position of human's eyes, and at the same time, the image rendered by the virtual camera is displayed by a binocular image display device. In all kinds of virtual reality simulation, the application way is this way.

In this paper, the principle of simultaneous shooting with two 360-degree fisheye cameras is used for 3D real scene rendering

2.2.2 Remote immersion with different cameras

Large-scale remote immersion systems (such as caves) can achieve a high immersion feeling, but the system size and area will increase. Relatively small high-resolution display devices in VR mode include smartphones and HMD devices. By covering the user's eyes with a display, you can achieve a higher immersion within a relatively small range. The system, designed by Hiro et al. [14] (Figure 2.3), connects a stereo camera and a helmet display at a remote location through a high-speed communication line to achieve a remote immersion experience in an outdoor setting. However, due to the limitations of high-speed dedicated line and display equipment, the system is limited to use in indoor users can only observe the outdoor scene far away.

Figure 2. 3: A remote immersion experience in an outdoor setting

However, due to the physical limitations of multiple cameras, the display must be cylindrical space display, so it is difficult to generate real space. In addition, when using multiple cameras, the stepping problem of each image, the geometrical distortion of the image in the peripheral part of the camera field of view, and the difficulty of remote real-time communication will occur. Most of the above similar systems use high-speed remote communication cables for data transmission.

There is also a study of remote immersion using a 360-degree camera as a way to obtain a wide range of images without the physical camera rotation. The hyper omni vision [14] (Figure 2.4) sets a video camera on the top surface of a leaf hyperbolic mirror installed just below the lead, and acquires a mirror image of 360-degree scenery reflected in the mirror.

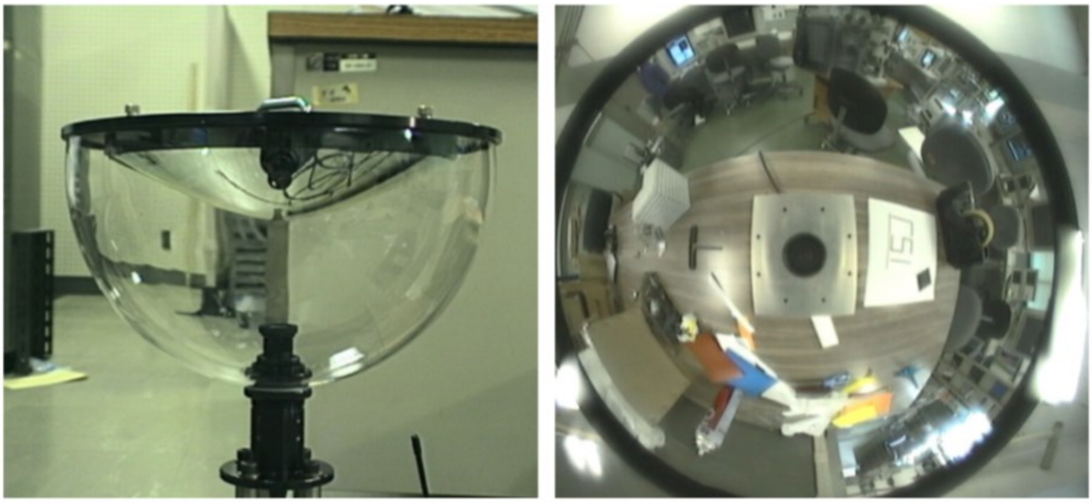


Figure 2. 4: Hyper Omni Vision [14] in an indoor setting

Although the remote immersion system using this kind of camera to capture the picture can transmit the remote real-time picture well, the low-resolution picture cannot be fidelity because of the performance limitation of single 360-degree camera. And because it cannot be used for outdoor scenes, such as video capture, cannot fully meet most of the scenes in people's daily lives, while users need to improve the immersive experience.

3. The Development of a personal tele-immersion system

3.1 The Personal System Requirements

First, as a premise, the functions that this system should satisfy are "immersion" and "movement". In other words, among the various elements that create presence, our goal is to create a higher presence by ensuring presence in visual information. In order to create a sense of presence, the first thing to ask is what a "sense of presence" is. Thus, a state of "realism" means delivering content with "fun," "power," and "dynamic sensation (activity)" through auditory and physical media, "as if you were actually experiencing it on the spot."

It turned out to be a psychological condition in which person could get a "feel". In other words, "having a high sense of presence" can be said to be a state of "as if being in the real world". In this study, the premise was to build a system that specifically targets visual features to create a sense of presence = an immersive feeling. As a basic condition of visual characteristics expected to create a high sense of presence, and the following three requirements should be satisfied:

- "High resolution" -- Reproduce videos that feel natural with detailed and realistic scenes
- "Realistic screen"-- display that realistic and highly immersive images
- "Three-dimensional"-- display that creates a realistic relationship with reproduction information

By satisfying these requirements, it is possible to create a video presentation system that gives a high sense of presence.

Then there is the interactivity of the remote immersion system, which refers to the degree of freedom the experiencer feels in the presented space without losing his or her sense of freedom. For example, if a series of actions are processed in a short period of time, when the system inputs a certain input and feeds back to the output system, these actions are embodied in the space, and the experiencer is highly interactive with the world. You can feel that movement. Here, the important point is that the motion can be processed to a close to the actual sense of time. There have been many studies on time delays when using HMDs [19] [20] to communicate with remote locations, and according to Robert S. Allison et al. [21], a threshold of delay can often be identified. It is said to be 100-200 [ms]. If this value is exceeded, the image will not change even if the head moves, the consistency between the real space and the virtual environment will be broken, and objects that should be stationary in the original space will be perceived as floating in the virtual space. Especially in the case of HMDs, video delays associated with head movement are known to cause intoxication in the experiencer, so it is necessary to build a system that does not depend on the communication environment over long distances. First, in order to create a "look around", how much range of images should be ensured? Although there are large individual differences, it can be seen that the angle of view required by the camera is sufficient as long as it can capture a range of up to 210 degrees.

Since this system aims to present the real world remotely, it can be said that the user's immersion needs are met by realizing the presentation of the world. But even if the presented world itself is already immersive, it can cause a sense of discomfort if the experiencer perceives it in an unnatural way. For example, if space is distorted, or when looking up at the sky, if there is room in the world, the experience may not be considered immersive, even if the world is immersive. Sanada [24] pointed out that immersion is the responsibility of the simulated system, which must autonomously return the same behavior as in the real world to the information obtained from the input system. Specifically responsible for the generation of target virtual space, modeling technology, simulation technology, object control technology, communication technology and other functions. Therefore, the need for immersion is how to create a virtual space that is close to the real space from the remote information obtained from the camera. In addition, in terms of presenting an immersive experience in outdoor areas, outdoor is considered as one of the requirements of this study, and the network data transmission of Internet wireless communication is also a requirement to be satisfied in this study.

In summary, the requirements for " a personal tele-immersion system that lets you see and move freely in outdoor scene" are summarized below Figure 3.1.

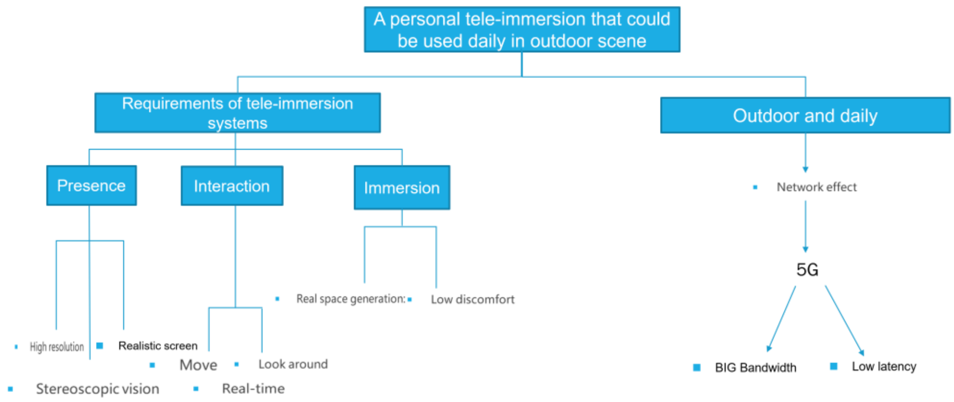


Figure 3. 1 Requirements for A personal tele-immersion system that could be used daily in Outdoor scene

According to the above-mentioned requirements that the tele-immersion system must meet, this study further summarizes and classifies its functional requirements, as shown in the following table 3.1.

Table 3.1 Functional Requirements

Presence	High resolution: VR head display screen resolution is generally 2K or 4K, so the best panoramic video resolution is more

	than three times its 8K or 12K. Realistic screen: Secure a viewing angle of 110 degrees or more Stereoscopic vision: Evaluation of appropriate sense of distance at test
Personal experience	Move: Camera operator can move on command Look around: Shooting with a viewing angle of 360 degrees Real-time Real-time mobility: Judgment by subjective evaluation Real-time look around: Delay until video generation is 200 [ms] or less
Immersion	Low discomfort: Judgment by subjective evaluation Real space generation: Real space video generation
Outdoor and daily	Network effect: Communication system via Fifth-generation communication technology

3.2 System Concept

Today, with the advent of 5G, high-performance smart phones, HMD and other high-resolution viewing devices, it is possible to develop a private, remote immersion system that can be used indoors and outdoors. Therefore, both the video capture system and the remote immersion system can be used for outdoor or indoor activities. In this way, people can choose to watch live broadcasts indoors or outdoors on different devices, or they can choose to watch them indoors or outdoors.

According to the above requirements, the system of "remote immersion experience system that can be used for indoor and outdoor viewing and moving" is constructed. The outline of the build system is shown in Figure 3.1, and the overall system composition is shown in Figure 3.2. The system consists of 3 subsystems, which are acquisition and removable subsystem, remote communication subsystem, remote video presentation subsystem. The removable collection system is usually in charge of collecting the live video and receiving the user's instruction. The collected video is then transmitted to the 5G base station through the 5G signal in the remote immersion system and then broadcasted to the server of the network live platform, and the server releases the live content to the remote video rendering subsystem used by the user, in which the user can freely choose the device and the venue to view the live content. Users can wear HMD, or take advantage of the WebVR features on their phones or computers, and get a high level of immersion by freely looking around the image sent by the camera, which is located far away. At the same time, by sending text or voice calls to communicate with the mobile terminal and give the corresponding mobile instructions to achieve remote free movement.

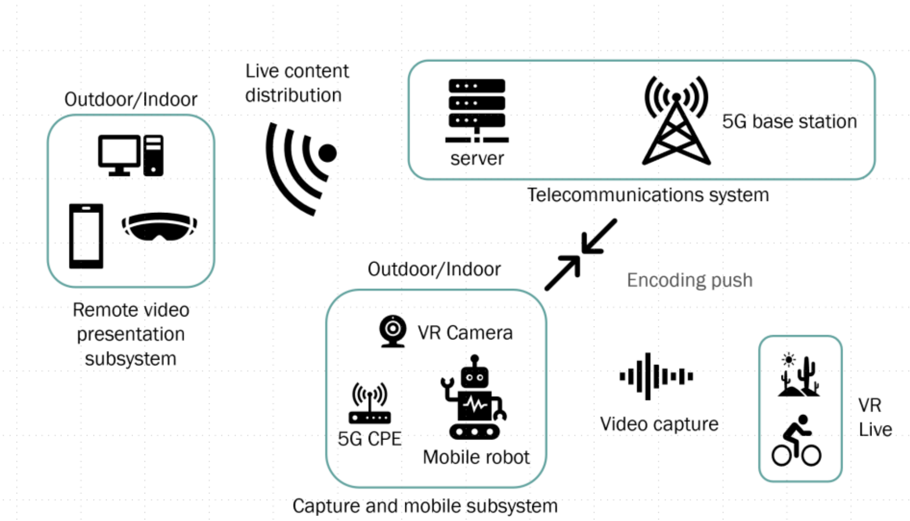


Figure 3. 2: System overview

Experimenters can wear HMD indoors or outdoors, or use computer-side or mobile WebVR to freely surround themselves with images from distant cameras for a high level of immersion. At the same time, through the real-time interactive function of the live platform to communicate with the mobile module and give instructions, so as to achieve free movement. The overall System architecture definition is shown in Figure 3.3.

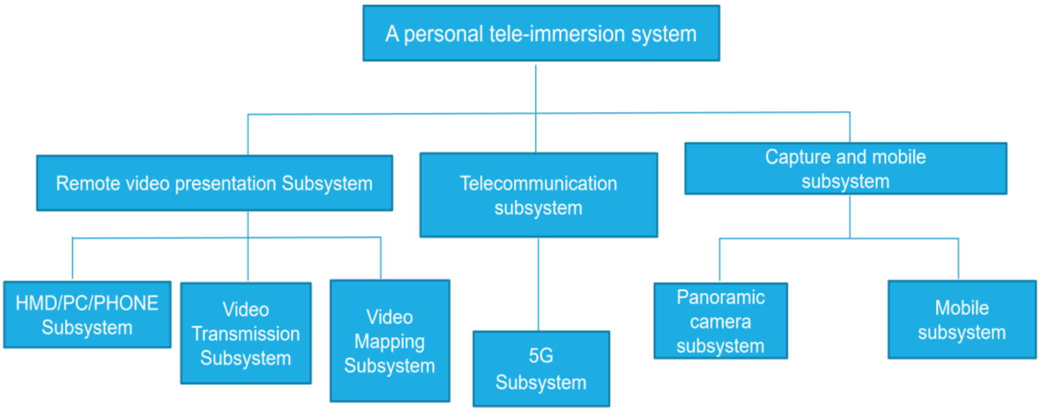


Figure 3.3: System architecture definition

The connection and inclusion relationship between the three subsystems is described in Figure 3.4.

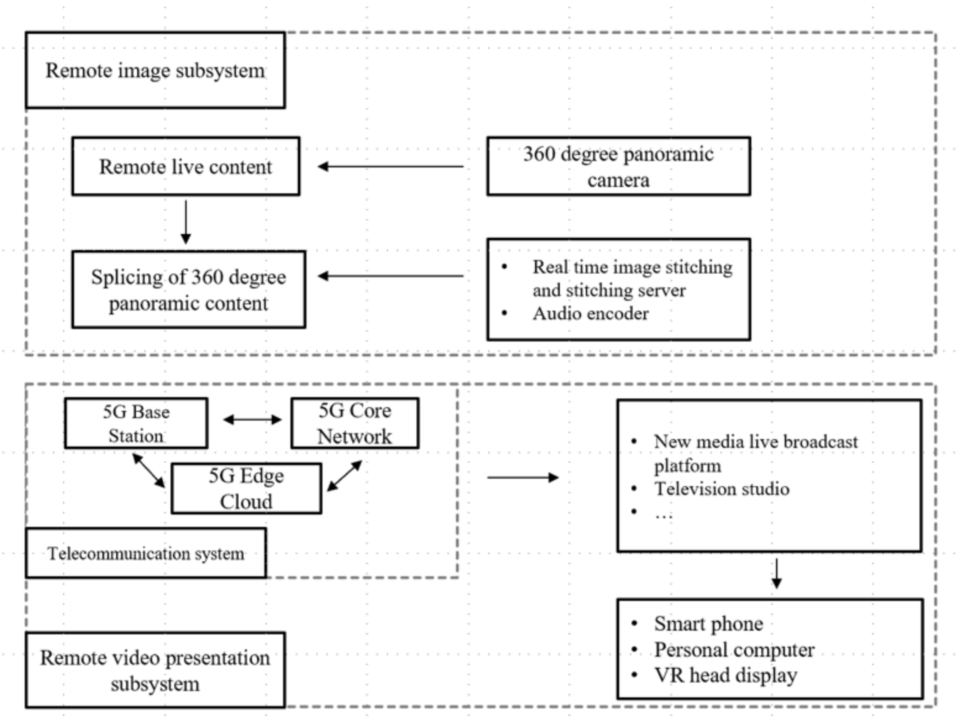


Figure 3.4: A tele-immersion system framework for personal use

3.3 Remote Video Presentation Subsystem

A remote video capture system is constructed to display the VR content of remote scene on various high-resolution displays. The system will use the 360-degree panoramic camera to take the real-time panoramic picture, and use the real-time mosaic server interface of the camera to make the real-time mosaic of the video in the camera. Users can view it in real time on their mobile phones, computers, or VR head-monitors by using a server on a new media live platform, such as YouTube or Kuai shou and accessing it in different areas via a published public or intranet address.

3.3.1 Panoramic camera and its advantages

The 360-degree camera can capture the surrounding images with one or more cameras at a time. Therefore, unlike a stereo camera, the observation field of view is limited by the field angle of the lens. So far, several different schemes of 360-degree panoramic camera have been proposed, and their implementation methods are as follows:

● Method of camera rotation itself

By rotating one camera, a panoramic image of all directions is obtained. In recent years, some smartphone apps also revolve a single camera to generate a Norah image. Although such a method is capable of acquiring a high-resolution image, it takes time for photographing one scene, and therefore it is not suitable for photographing a dynamic environment or a real time image.

● Method using fish eye lens

The invention relates to a method of using a fish eye lens as a camera to expand the photographic field angle by optics. Because the resolution of images taken through this lens is easy to become low, and the viewing content will become deformed from the center to the edge of the image. Therefore, relevant image algorithms need to be modified. Kodak's sp360 is a representative of this type.

Figure 3. 5: Kodak's SP360

● Method using mirror

The 360-degree panoramic image is obtained by photographing the scene on the mirror with a spherical mirror or a conical mirror set vertically downward and a camera set vertically upward. Like the fisheye lens, the resolution is easy to become lower, and the deformation increases with the center of the image. In addition, since a lens or a camera is provided above, information about the up and down directions cannot be obtained. Hyper omni vision is one of them.

● Method using multiple cameras

This panoramic camera is composed of two or more fish eye lenses, which can collect all-round image information around the camera. High resolution images can be obtained. Most of the early panoramic cameras were composed of more than 6 standard cameras, and these images were combined into panoramic images through image mosaic technology. Nowadays, most panoramic cameras are composed of 2-4 fish eye lenses (wide-angle lenses). These images are synthesized into panoramic images through fish eye image distortion correction technology, image mosaic technology and image fusion technology. The well-known brands include Giroptic, Ricoh, etc. Common panoramic cameras are shown in Figure 3.4.

(a)Giroptic 360cam (b)Ricoh Theta (c)Insta360 Air (d)Upano J2vr

Figure 3. 6: panoramic camera using multiple lens

According to the four mainstream panoramic implementation methods appearing in the market, we compared and classified them with real-time and high-resolution as indicators.

Figure 3. 7: characteristics of various types of 360-degree cameras

Subsystems that use panoramic cameras require a 210-degree view to shoot and support wireless transmission. To meet the above conditions, choose the direct selection of a 360-degree panoramic camera. In the above types of comparisons, the images presented varied depending on the type of photography used, but taking into account real-time wireless communication, the required range of photographs, the system ended up with Insta360's ONE X2 (figure 3.5), which uses 2 fisheye lenses for panoramic imaging. This camera has good endurance and excellent communication standard specifications while meeting the functions required by the system. The parameters related to the experiment are shown in the following Table 3.1 Insta360 ONE X2 performance.

Figure 3. 8: Insta360 ONE X2

Video resolution	360 ° panoramic mode: 5.7k @30fps
Angle of view	360 × 270 degrees
Communication standards	WIFI 6 and Bluetooth 4.2
Battery life	5.7k @30fps 80min

Table 3- 1 Insta360 ONE X2 performance

The camera also can sync the recorded panoramic VR content to the phone and computer via the same WIFI as shown in the figure 3.7, and the PC side Web Page Web VR viewer displays images with a resolution of 4K 3840×1920 @30fps.

Figure 3. 9: Syncs the recorded panoramic VR content

3.4 Remote communications through the 5G

The main application scenario of 5G is high data transmission rate. The peak transmission rate of 5G network can reach 10 Gbps, which is 100 times that of 4G long term evolution (LTE) cellular network. It can meet the transmission of HD video, 4K video, VR and other big data [5]. Then, the real time messaging protocol (RTMP) server of each new media platform is used to distribute VR panoramic content. Users can view VR panoramic content in real time on mobile phones, computers or VR head displays by using the published public network address or intranet address in different regions.

Figure 3.8 shows the mobile phone connection test after 5G signal is converted into wireless fidelity (WIFI) signal through CPE terminal. The upload speed reaches 79.1 Mbps, jitter is 22 MS, and packet loss rate is 0, which well meets the transmission requirements for stable upload of VR signal.

Figure 3. 3: Mobile phone connection test

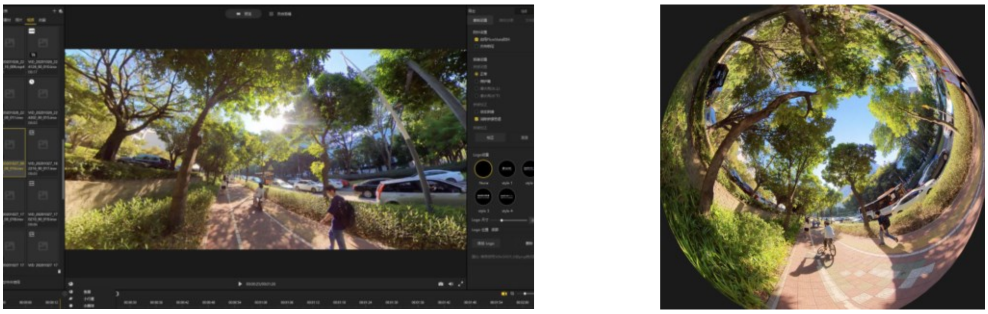


Figure 3.10: Video splicing inside the camera

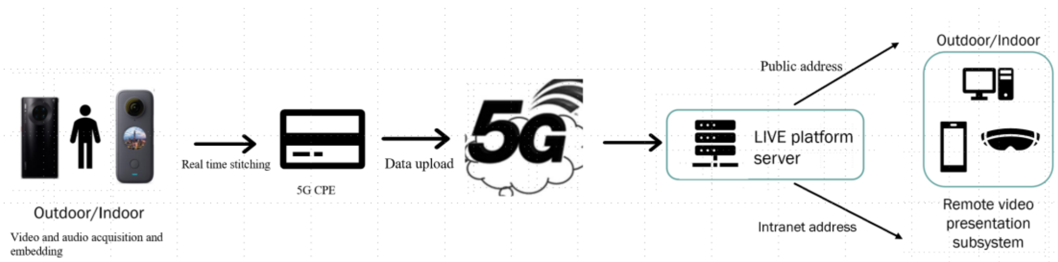


Figure 3. 11: Live broadcast flow chart

3.4.1 VR content in real space and display

In order to paste the image obtained from the 360-degree camera onto the screen of any shape display screen and obtain the perspective projection image, a VR content simulation system is constructed. The image transmitted from the above camera is the following fish eye image (Fig. 3.11). In order to present in a form closer to the actual space when the experimenter views through the mobile terminal HMD, paste it on the inner side of the surface of the sphere model set in the virtual space in unity, so as to regenerate it as a virtual dome. The experimenter uses the mobile terminal HMD to view the image displayed on the imaginary spherical screen.

Figure 3. 12: fish eye image in PC

During the experience of the system, viewers who cannot come to the scene can open the specific insta360 player software through their mobile phones to watch. They can use the office computer to access the specific streaming address through the web browser in the office to watch. Viewers who pursue higher immersion can also use the VR head display to watch the live broadcast. With the rapid development of browsers, it is now easy for users to view VR content from a free angle by visiting live sites with H5 players. This greatly satisfies people in the outdoors can also access the WebVR browser to watch the panorama live, get a better immersion. In WebVR browsers, users can adjust their viewing angle using a touch screen or gravity-sensing function to get more access to content than traditional live broadcasts as shown in figure 3.12.

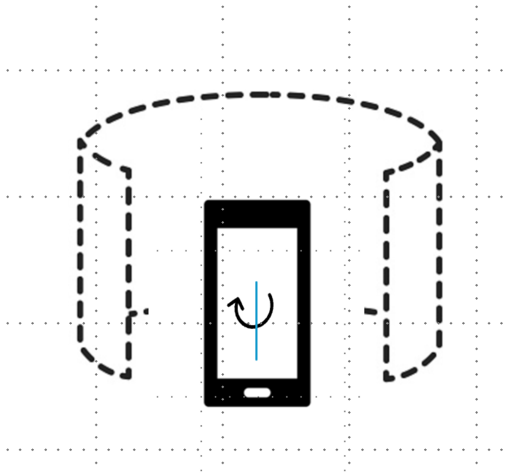


Figure 3. 13: Free viewing of panoramic content on the mobile terminal

3.4.2 VR display compatible with outdoor and indoor

Mainstream head displays in the market, such as Oculus rift and HTC Vive, are monitors in nature. But they have a common disadvantage that they need to be connected to a PC or game console as shown in figure 3.13. Cumbersome connections affect the user's 360 ° view switching experience. At the same time, these head displays cannot meet the outdoor system experience environment.

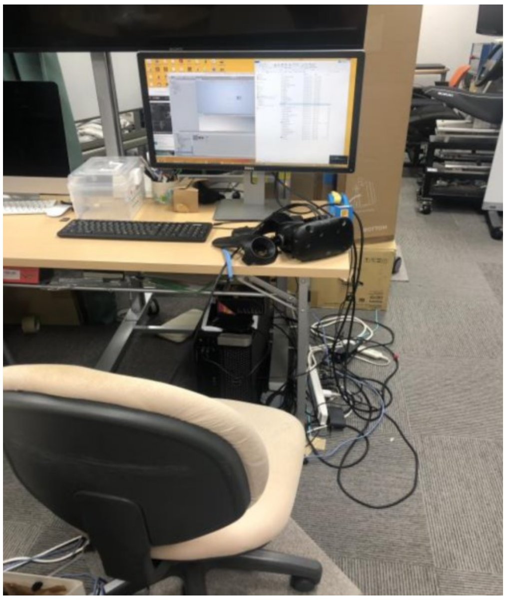


Figure 3. 14:HTC vive connected to PC

Cardboard is an inexpensive 3D glasses made from cardboard boxes that can be combined with any smartphone to create a virtual reality experience. The Cardboard suite shown in Figure 3.14 includes cardboard, two convex lenses, magnets, rubber bands, and NFC stickers. According to Google's installation instructions, anyone can build these simple 3D glasses in a matter of minutes. The installed Cardboard is shown in Figure 3.14. The mobile phone needs to be placed into a cardboard box as display and computing equipment. The inner space of the cardboard box has vertical baffles, and the inner space is divided into two parts. The left part encapsulates the left half of the mobile phone screen and the right part encapsulates the right half of the mobile phone screen. When the user wears the Cardboard, the left and right eyes of the mobile phone can see the left and right part of the mobile phone image respectively through the lens, and the brain can fuse the two pictures into a stereo image to realize stereo vision. The user can use the sensor devices such as the accelerometer and gyroscope of the mobile phone to calculate the posture of the head in real time, and the user can move the perspective in the virtual environment by the left and right of the head through the swing of the head.

Figure 3.15: Assembled Cardboard

Cardboard has the advantage of being easy to make and inexpensive, using the phone directly as a computing and display device, breaking the wires, adapting to a wider range of phone models and low barriers to development. The disadvantage is that the structure is too simple, easy to damage, can only be used as a tool to initially try to experience virtual reality. This head makes it possible for users to experience VR content both outdoors and indoors.

For users who want to try to experience the effects of virtual reality, the simple and easy-to-use, low price and many adaptive devices of the cardboard are undoubtedly the most attractive. However, the cardboard also has the disadvantages of general experience effect and easy damage. Now the improved "VR glasses" in the market have solved this problem very well. As shown in Figure 3.15, the package of the improved VR glasses is tighter and tighter than that of the cardboard. The glasses case is made of plastic, which is more durable and has improved the effect. Its working principle and use method are consistent with that of the cardboard and can be regarded as an enhanced version of the cardboard. Because this kind of VR glasses has the advantages of easy to use, more widely applicable mobile phone models, low price, and convenient for users to understand the key principles of virtual reality technology, this paper selects VR glasses as the hardware infrastructure for building a personal tele-immersion system.

Figure 3.16: Improved universal VR glasses

3.4.3 Actual Distance and Visual Proximity

In this system, in order to improve the perception of real space, the PC side will paste the panoramic image on the inside of the simulated sphere generated on Unity to produce 360-degree panorama. Moreover, the panoramic image itself is taken in multi-channel mode, but when the experimental object is viewed in mobile HMD or PC panoramic mode, the parallax of both eyes is produced due to the use of the imaginary spherical screen. The focal length of conventional HMD imaging systems is usually set at about 1.3m. Therefore, for users, the distance of the photographic image, the focus adjustment of the eyes, binocular parallax, resolution, etc. will become the interference factors of panoramic video. In particular, there has not been much discussion about the specific specifications for the size of a hypothetical sphere when making 360-degree panoramic images. Therefore, according to the panoramic image displayed, as well as the experimenter's feedback "sometimes feel the image of the oppression" and other views. In this paper, by changing the radius of the hypothetical sphere, the effects of binocular parallax and convergence on the distance perception of images are investigated.

Experimental environment

Using an enhanced version of VR glasses, an immersive system of image space composed of 360-degree panoramic images of individuals was constructed. To create a 360-degree panorama, insta360's one x2 uses a binocular camera made up of two fish cameras. According to the captured image, two or more images are mosaic by image mosaic technology to obtain the complete panoramic image. Image mosaic technology has been studied for a long time, and it is approaching maturity. Image mosaic technology includes preprocessing, registration and fusion: the aim of image preprocessing is to enlarge the features of two images and improve the accuracy of image registration; the aim of image registration is to find all the same or similar feature points in two images so that the corresponding spatial points in two images correspond one by one; image fusion is to over-process the overlapping areas of two images so that the two images are stitched into one complete image.

Experimental method

In the experiment, the radius of the imaginary sphere on unity is set to 0.7m, 1m, 2m, 10m and 100m respectively, and the difference between the content felt by the experimenter and the distance sense of the captured panoramic image is measured. Since this system is a remote immersive system that can have both indoor and outdoor scenes at the same time, two sets of panoramic images of indoor scenery and outdoor scenery were prepared for the experiment (Fig.3.21. Let the subjects watch each panoramic image at random, and use numerical values to answer how many meters the indicated object feels. In the experimental scene of watching indoor panoramic images, the subjects will be asked to answer the distance from themselves to the panel placed in front. For the experimental scene of the panoramic image outside the house, the subjects need to answer the distance to the view in front. Each actual distance is 1 meter and 20 meters. The experiment was conducted on 10 male subjects in their twenties.

Figure 3.17: Panoramic image viewed by subjects

Result and Analysis

Based on the experimental results, the responses of 10 subjects and the video compression radius were analyzed by variance analysis. There are great individual differences in the cognition of image. It is believed that the results of each answer are very different, because the answer is based on the individual's personal criteria for the subjects' perceptions of the images. For indoor images, the screen radius changes by 5 per cent ($P = 0.020$). This shows that the radius of the screen affects the distance of the subject when rendering a 360-degree panorama of the interior image. Some people believe that distance between screens affects distance perception. As for the difference between the two images, the focus of the HMD is constant, which seems to be due to a lack of perspective over long distances. The figure 3.16 shows the average and standard deviation of the indoor and outdoor graphic answers. When the screen distance is close to the video object distance, the perceived distance becomes close to the actual distance. In the case of indoor panoramic image testing, the radius of indoor scene is 0.4m to 2m, and the distance of outdoor scene is close to the actual distance from 10m to 100m. From these results, it can be seen that when the HMD displays the real image, the position of the camera and the screen is at an appropriate distance. In the image of the present presentation, we can explain the distance of the target. There are more than 10 meters in the outside of the display, and the shadow is less than 10 m, and the amount is 10 m or more.

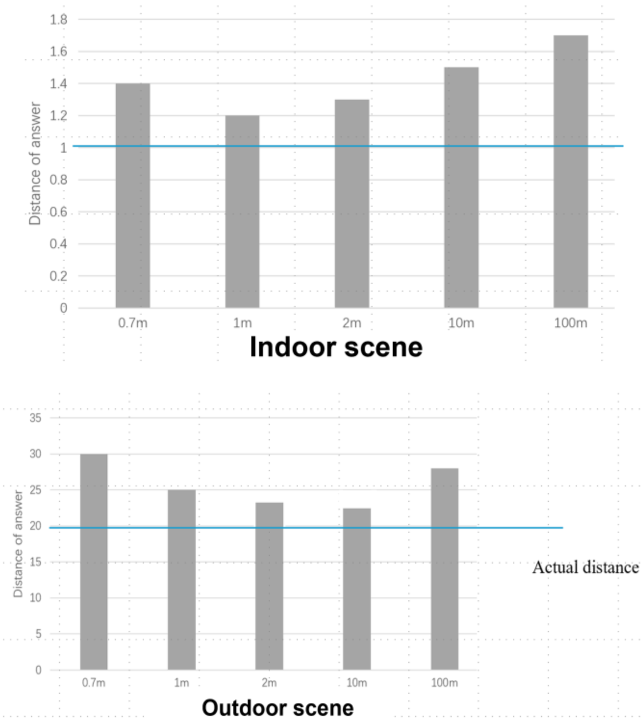


Figure 3.18: Average and standard deviation

We have constructed a system that satisfies functional requirements derived from the requirements of a remote immersion experience. Fig. 3.17 shows a function request issued from the request to each subsystem.

3.5 System verification

In order to meet the research purposes of this paper, the main aim is to develop a personal remote immersion system that can be viewed from a free angle and used indoors and outdoors. After verifying that the designed system meets the needs of both indoor and outdoor use scenarios and basic functions, the new goal is to enable the experiencer to move the remote area to where he or she wants to go through the system, both outdoors and indoors. Therefore, a new experimental design is developed for the system. At this point, it becomes important to satisfy two things:

1.Can you move exactly where you want to go?

2.Whether can resemble the person in actual space to hold the position relation of the space equally.

With regard to the two verification objectives, if the real-time panorama captured by the system is no different from the free movement in real space, the system can provide users with "free viewing perspective, and the feeling of movement”. The accuracy of each action is evaluated as the whole performance by the test of whether the above two points are satisfied. In order to evaluate the influence of "round-view" on the movement correctness, the deviation between HMD and the existing display was verified. In order to evaluate the influence of "moving" and "looking around" when grasping the position of space, the deviation of space grasping between moving and not moving is verified.

In addition, some subjective indicators such as "immersion" and "system operability" are evaluated qualitatively by means of subjective questionnaire.

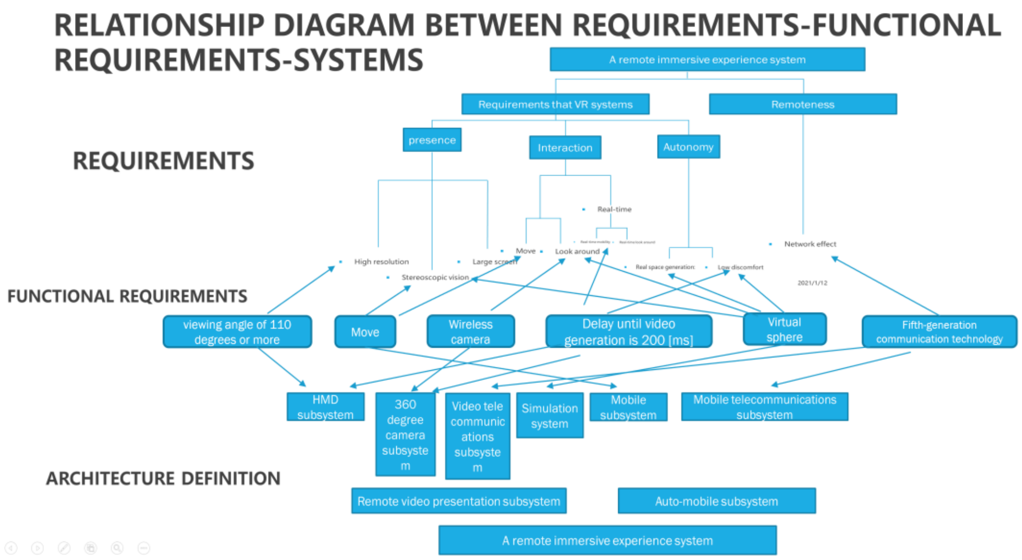


Figure 3.19: Function Request - relationship between systems

3.5.1 Experiment spatial grasp ability

In order to grasp the spatial position of the space in the same way as the real human, we examined the effect of "movement" and "turning around" in order to assess the system "free look around" on the accuracy of movement.

Figure 3.20: Panoramic VR screen displayed to subjects: HMD, mobile WebVR

3.5.2 Experimental methods

First of all, the system designed in this paper can be used for both outdoor and indoor scenes. Because most people choose to use mobile phones to view panoramic content on the mobile side (Figure 3.19) when outdoors, while in indoor scenes, more people choose the PC（Figure 3.20）with higher immersion and freedom. Therefore, we conducted experiments in two different scenarios to verify people's spatial control over actual locations when using the system.

Figure 3.21: Panoramic VR screen displayed to subjects: PC side WebVR

The 16 English letters A-D, a-d, and the letters that make up “hello SDM” sentences are randomly attached to a rectangular corridor room, in which white patterned walls with lengths of 2.67 m and 6.73 m are arranged on both sides (sides A and B) (Fig. 4.3).

By using the "free look around" function of panoramic video live broadcast, the subjects observed the pictures from the scene 360 degrees and directed the operators of the panoramic camera to find out the corresponding prompt letters of each pattern node from the patterns of the two walls according to the established track A-a-B-b-C-c-D-d. When the operator of the on-site panoramic camera followed his instructions to find all the letters, the subjects would be asked to answer the sentence composed of the symbols finally spelled together, and answer the distance relationship between the letters on the answer sheet and the distance between the patterns on the wall. In this experiment, 10 subjects aged 20 to 50 with different familiarity with VR and electronic devices were searched to verify and test their spatial mastery.

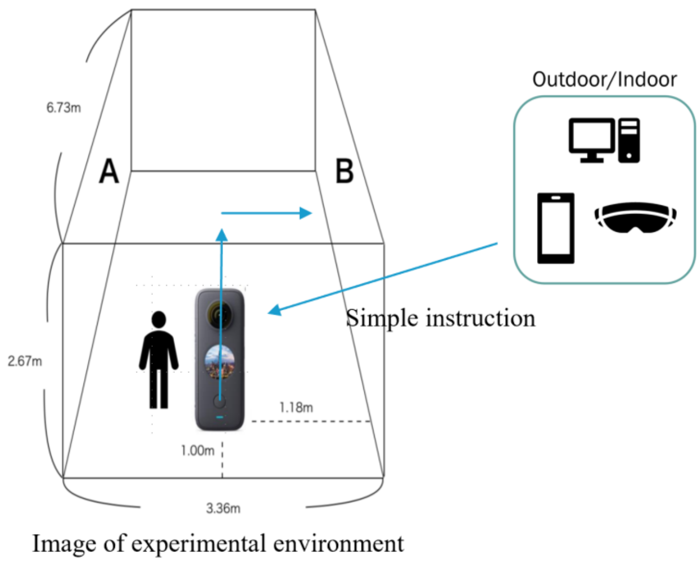
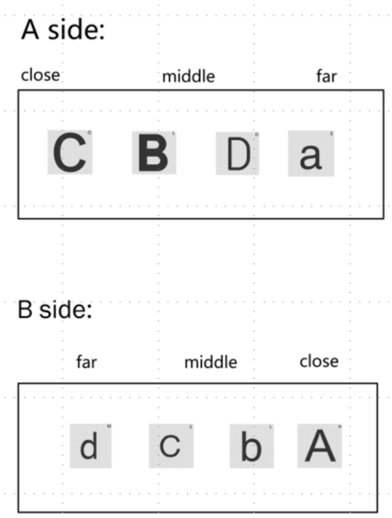


Figure 3.22: Image of experimental environment



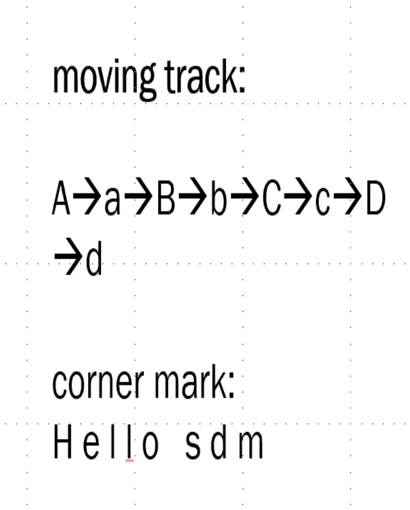


Figure 3.23: The location of symbols **Figure 3.24: Image of moving track**

For the experimenter who controls the panoramic camera on the spot, it is necessary to check the room where the actual experiment is conducted for distractions or human interference. A corresponding experimental test was then performed, while the remote immersion system was placed 1m and 1.18m from the marked wall. Figure 4.3 shows the captured image of the camera and the rendered image to the display object at the beginning of the experiment. Each model was tested twice and the relationship between the icon and the wall and the time needed to complete the experiment were recorded as collected data.

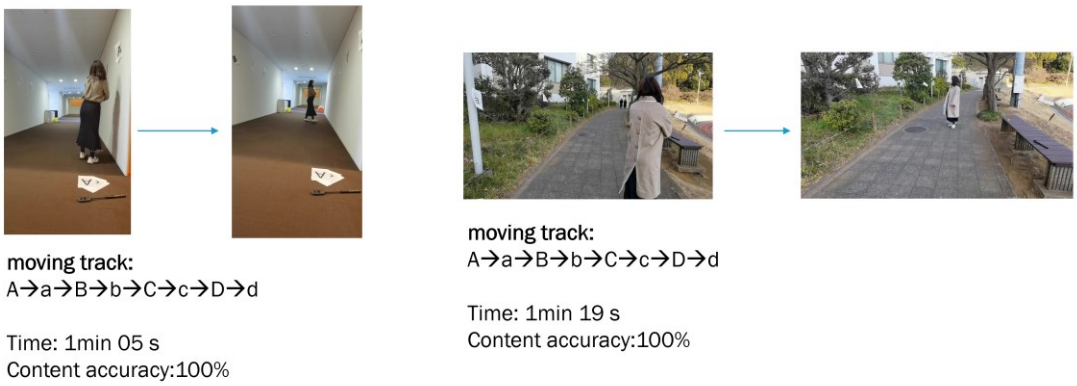


Figure 3.25: Control group in outdoor and indoor scenes

After setting up the initial experimental environment, in order to explore the degree of immersion this remote immersion system can provide, an additional control group was set for two different scenarios, as shown in Figure 4.6. Experiments for this control group were conducted indoors and outdoors at Keio University's Hiyoshi campus. Since there was no 5G base station built near the campus during the experiment, we used 5G PGE to broadcast 5G signals. The device can convert 5g signals into high-speed WiFi signals that can be received by panoramic cameras, thus meeting the needs of panoramic cameras for high-speed transmission of panoramic images in outdoor and indoor scenarios. In the two control groups, the experimenters were free to look around and record the alphabet patterns along the agreed route, recording all the time needed to complete the path and calculating the accuracy of the alphabet

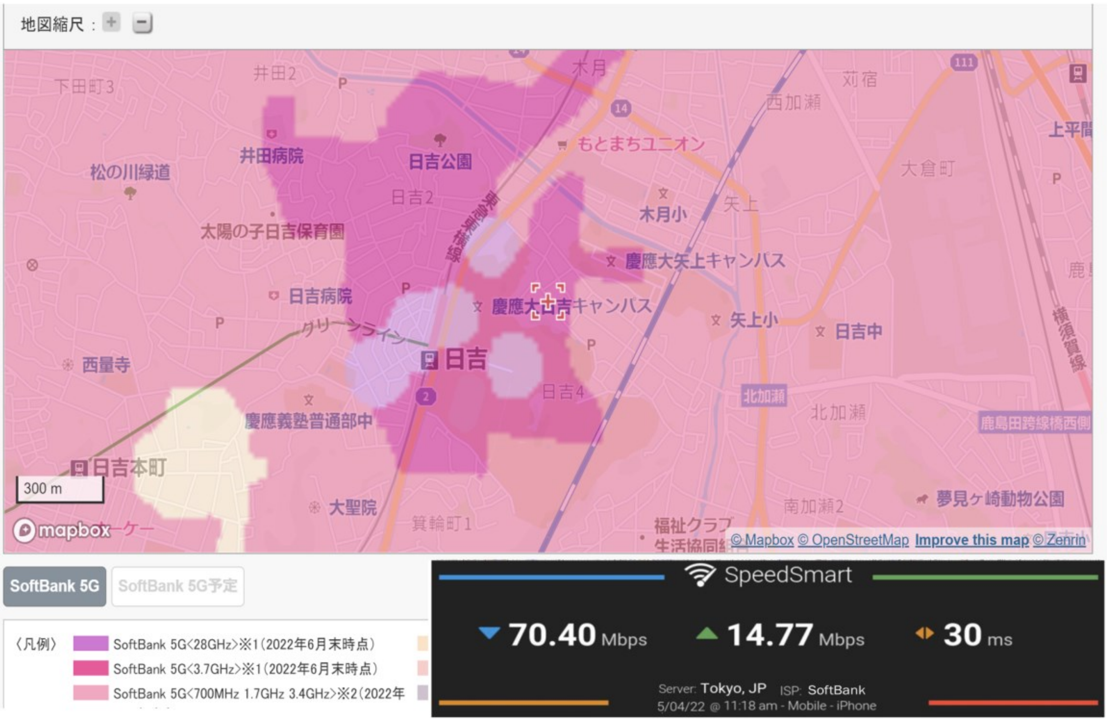


Figure 3.26: 5G signal distribution map of Softbank near Hiyoshi campus

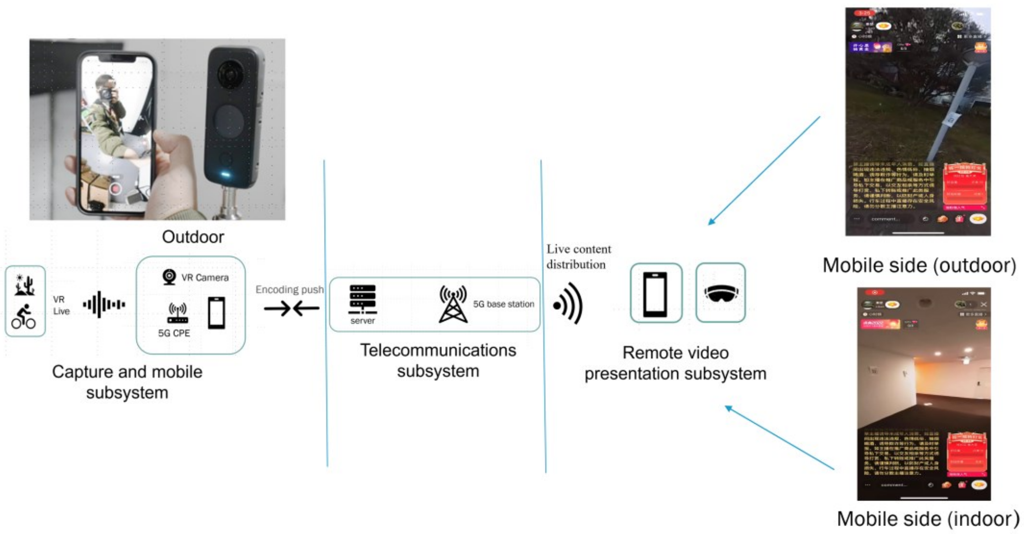


Figure 3.27: Experiment in outdoor and indoor scenes

Then, the experiment involved 10 20-year-olds in two scenarios, outdoors and indoors, where we tried to ensure as much randomness as possible. The time needed for each target to complete the experiment and the matching degree of the letters recorded with the correct answers were recorded. The average score of the 10 data groups is shown in the table 4.1.

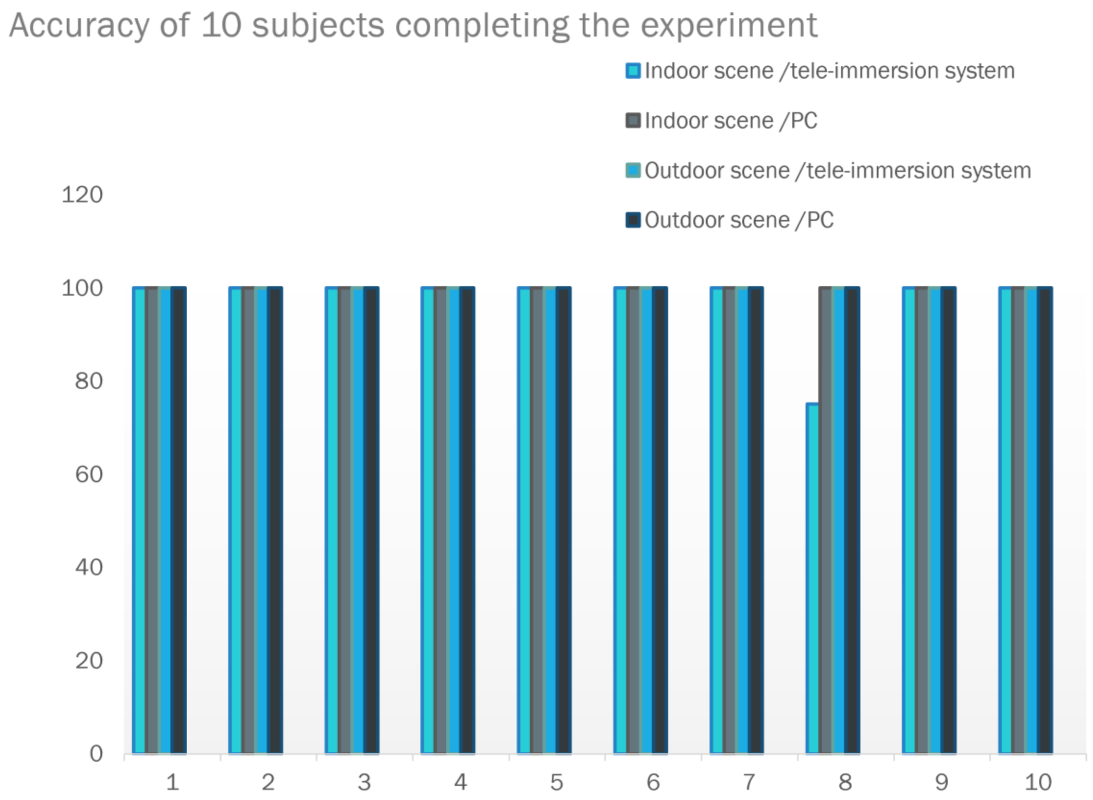


Table 3.28 Comparison of experimental scenes

3.5.3 Result and Analysis

Figure 4.8 shows the average and standard deviation of response time for each subject. With regard to response time, a one-way ANOVA and multiple comparisons were performed among the subjects, and the results showed significant differences among the subjects. For each test object, in the "display difference", "use of mobile devices" and "individual difference", a 2-yuan allocation analysis of variance was conducted. The results showed that for the "display", the significant difference of p = 0.008 and

1%, for the "use of mobile devices", p = 0.015 and 5%, and for the "individual difference", the significant difference of p = 0.001 and 1% were found.

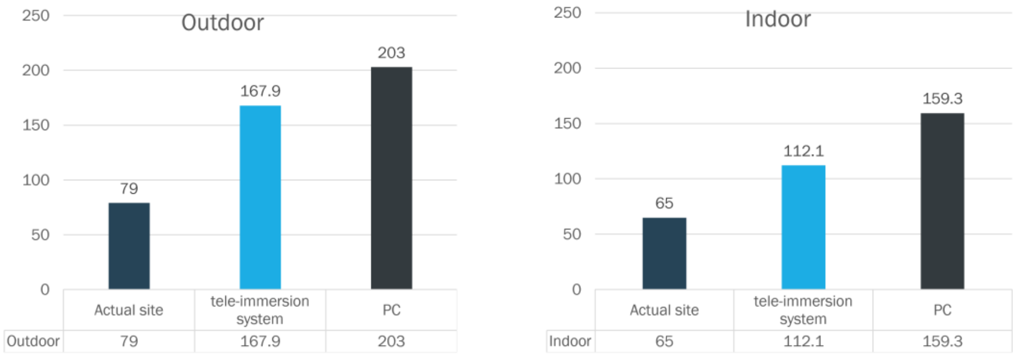


Figure 3.29: average answer time and standard deviation

The reasons for the increase in test time, the speed of movement in a moving scene, the speed of rotation of the scene, and the time needed to determine where the marker can be seen, were mentioned. In addition, when setting the panoramic camera position, because the static scene is set "even if the monitor does not move, all the marks can be contained in the camera's field of view position," so some subjects only through the round-view monitor display of the screen to complete the final experiment questionnaire. That's part of the reason some people in this scenario need less time to master real space than others.

4. Evaluation of System

4.1 Virtual presence evaluation

4.1.1 Elevation item

Virtual presence is a subjective feeling, which is the intuitive feeling of users when they experience the virtual world. Therefore, the subjective reporting measurement model method is the most suitable. Most of the existing studies have adopted the posttest questionnaire analysis. The questionnaire used in this design practice measurement is modified based on the ws-pq questionnaire (Witmer & singer presence questionnaire).

Table 4- 1: Questionnaire list

Evaluation factors	**Questions**	**Item number**
Sensory factor	**How much do all your senses put in?** **Can you focus on the visual effects of this space?** **How strongly do you feel the motion of objects in space?** **Don't you feel confused or disoriented at the start of a break or at the end of an experiment?**	2, 3, 6,10
Immersion factor	**How much do all your senses put in?** **You don't know what's going on around you during the experience system?** **Does this space interact with you?** **Do you think the experience in this space is consistent with that in the real world?** **Is there little time difference between your action orders and the expected environmental response?** **Is there little time difference between your action orders and the expected environmental response?** **At the end of the experience, how well do you know how to move and interact in a virtual environment?**	1, 4, 8, 9, 14, 15
Interaction factor	**Can you focus on experiencing content, rather than operating the device?** **Are you immersed in this virtual space?** **Control devices don't distract you?** **Does the quality of the visual display interfere with or distract you from your**	5, 12, 13, 16, 17,18

	ongoing activities?	
Reality factor	**Is the information from the senses inconsistent or inconsistent?** **Do you think the experience in this space is consistent with that in the real world?** **Don't you feel confused or disoriented at the start of a break or at the end of an experiment?**	7, 8, 11

There are 18 items in the questionnaire, which belong to the following four evaluation factors: sensory factor, control factor, distraction factor and reality factor. But the five-level scale was changed to the seven-level scale Figure 4.11, and a middle point is set at the fourth level, where 1 means no at all, 7 means very, and the middle point means medium. Among the 18 items, items 2, 3, 6and 10 represent sensory factors, items 1, 4, 8, 9, 14, 15 control factors, items 5, 12, 13, 16, 17 and 18 distractor factors, and items 7, 8, 9 and 11 reality factors. According to the statistics of 18 items, the value between 6 and 7 obtained by each item is considered as high score, 4 to 6 as medium, and 1 to 3 as low score. See Appendix 1 for specific project design.

4.1.2 Result and Analysis

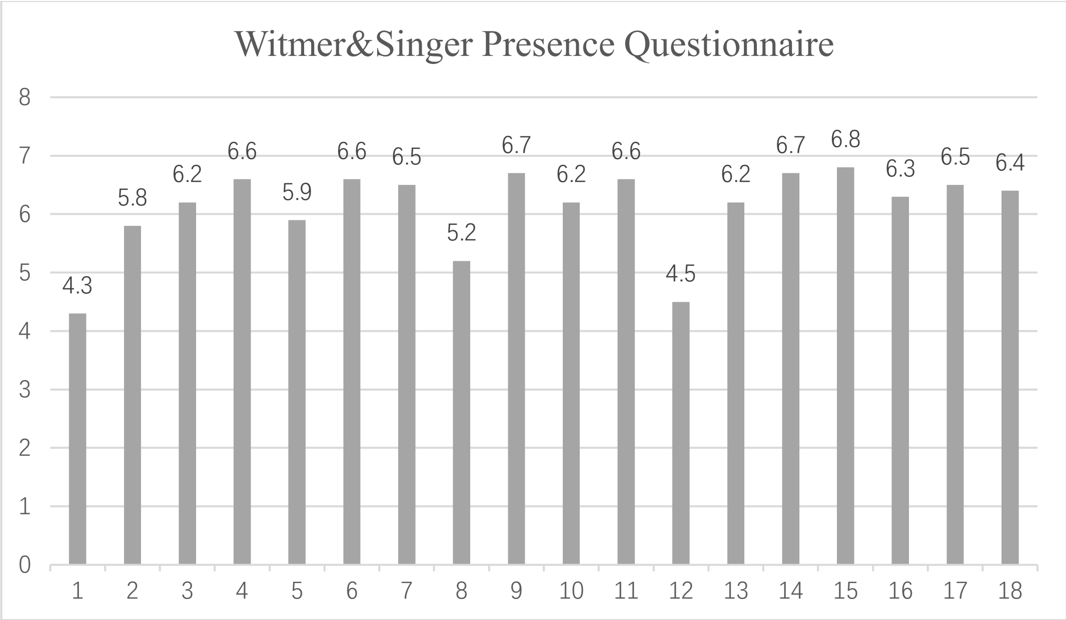


Figure 4.1: Average of Presence Questionnaire items

Classify the above statistics into four evaluation factors and recompute the average as shown in the figure 4.1.

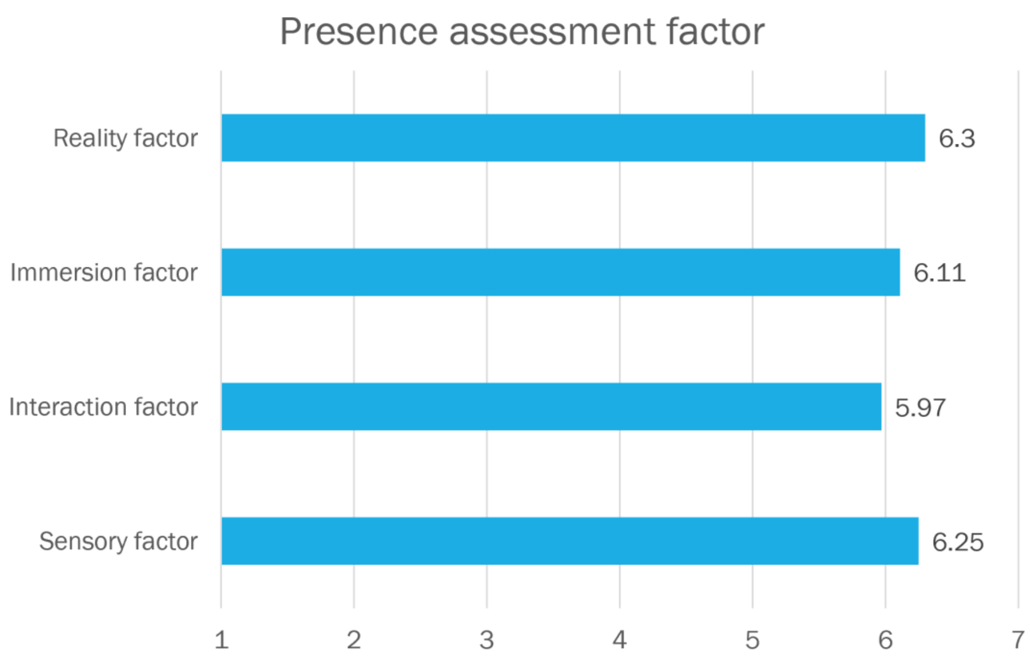


Figure 4. 2: Average of Presence assessment factor

Figure 4.2 shows that the design practice in the presence of the four factors are at a higher level of evaluation, of which the sense factor and reality factor at a higher level. Distraction factor and control factor are affected by items 1, 8 and 12, which shows that in mobile terminal does not give users enough interaction, experience and experience are slightly different, users are not easy to integrate into virtual scene. The sensory factor score of the content displayed by the system is high, mainly because the visual effect, spatial guidance and sense of motion of the scene are good, which makes the user feel telepresence. The design is mainly used to communicate directly with the user and real-time guidance, in guiding the effect and space can allow users to quickly understand and easy to use.

The design is mainly used to communicate directly with the user and real-time guidance, in guiding the effect and space can allow users to quickly understand and easy to use.

The control factor may be due to the single way of VR content interaction in the mobile terminal, which leads to the lack of interaction in the process of experience. The distraction factor can show that users are not easily distracted in visual effects and control operations, but it is easy to be distracted by the external environment. Reality factor score at a higher level, indicating that the design of the virtual scene looks more natural, the user's own sense of good, smooth display process.

According to the result analysis, the following three tips are obtained:

1. This experiment is to invite users to experience. For users, it is a passive attempt, and they will not spend too much energy on studying how to use the device. This is different from the users who actively use the VR device of the mobile terminal. If it is used in museums, science and technology museums and other places, this problem needs to be considered.

2. The application scenarios of VR content of mobile terminals are more diverse. Due to the simplicity of the equipment, it is more necessary to take the environment in use into account in the design, which should fall within the design principles of physical characteristics.
3. The optimization of interaction mode still needs to be supplemented. The current optimization is mainly at the software level. International scholars have used the controller of wire-controlled headphones to replace a single case of staring interaction. However, whether the increase of external devices means that the VR content of mobile terminals needs to be further classified, and whether the all-in-one VR and mobile VR should be studied differently is worth considering.

During the creation process, according to the previous research, the virtual telepresence experience in the scene was designed and optimized, and finally released on various mainstream VR live platforms. After the completion of the production, the overall effect of the design practice is verified through two experiments of design satisfaction and telepresence measurement, and good user feedback is obtained. Therefore, the developed system can become a tele-immersive system that general individual users can easily use in daily outdoor and indoor life.

4.2 System Usability Assessment

4.2.1 Evaluation item

This design experiment measures the effect of experience through subjective measurement and performance measurement. It will measure the satisfaction of user experience with the help of the SUS Scale, a 5-level Likert scale that can be used to assess the usability or user satisfaction of a system. Therefore, it is often found in the virtual reality literature [29]. It is important to note that there is no correlation between the SUS Scale and the SUS-PQ (Slater-Us oh-Steed Presence Questionnaire) which is a kind of on-the-spot measurement questionnaire. The five scales ranged from "total disapproval" to "full approval," and 10 20-year-olds were invited to fill out questionnaires after the experiment. (Figure 4.9)

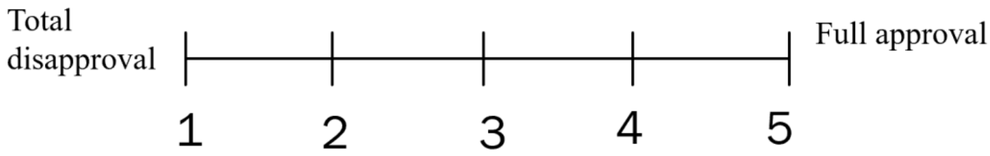


Figure 4. 3: 5-level Likert scale

The results showed that the SUS scale consisted of 10 items, with odd items being positive and even items being negative. In the calculation, the scores of each topic need to be converted. Odd items are scored with "original score - 1", and even items are scored with "5-original score". Since the scale is a 5-point scale, each item is scored in a range of 0-4 (a maximum of 40) and SUS is in a range of 0-100, so you need to add up the conversion scores of all items, and finally multiply by 2.5 to get the SUS score. SUS scores reflect overall usability, and for overall usability, researcher Bangor [40] has developed relationships between text, letters, acceptable ranges and SUS scores, which can be visually viewed and explained in Figure 4.11.

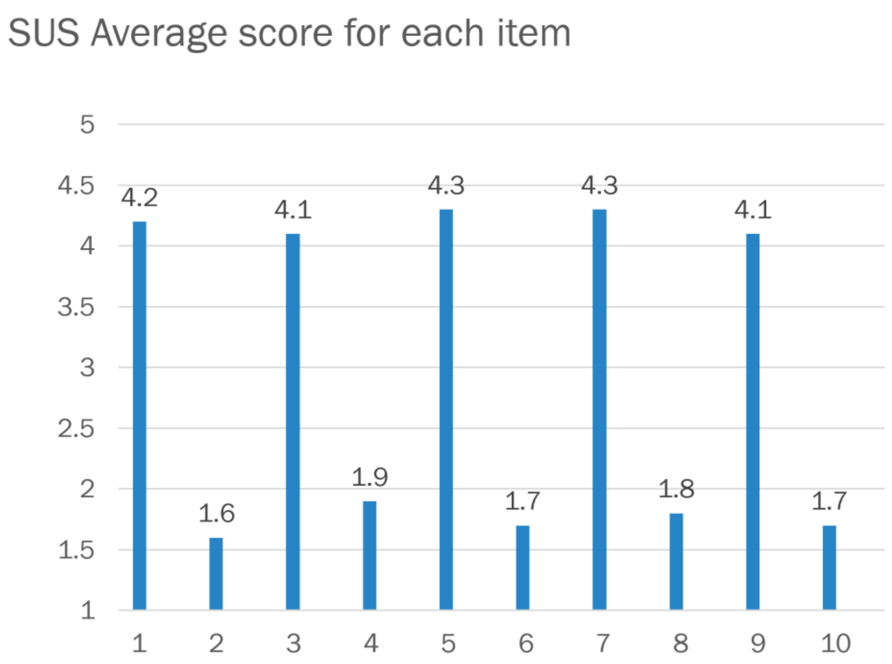


Figure 4. 4: SUS Average score for each item

4.2.2 Result and Analysis

With the help of design evaluation, the average sus score of participants reached 80.85. Compared with the chart above, it can be concluded that the overall satisfaction of users is high. Thus, the developed system may be a remote immersion system for general users that can be readily used in everyday life

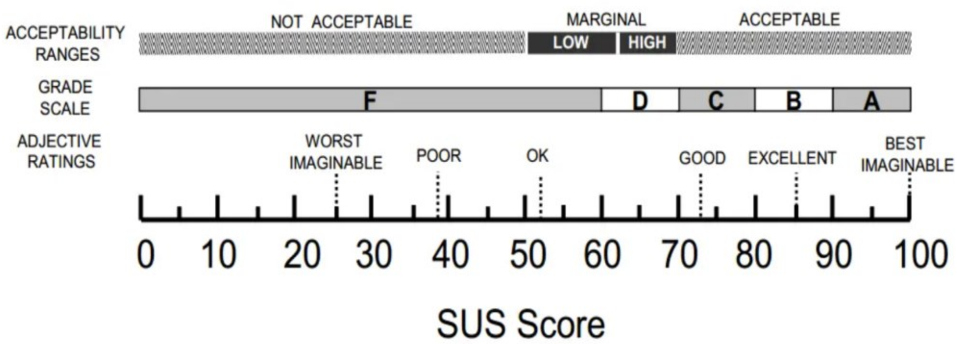


Figure 4. 5: SUS score and satisfaction chart

4.3 Discussion

This chapter introduces the overall process and design content of completing the design practice. During the creation process, according to the previous research, the virtual telepresence experience in the scene was designed and optimized, and finally released on various mainstream VR live platforms. After the completion of the production, the overall effect of the design practice is verified through two experiments of design satisfaction and telepresence measurement, and good user feedback is obtained. Therefore, the developed system can become a tele-immersive system that general individual users can easily use in daily outdoor and indoor life.

5. Conclusion

5.1 Summary

The aim of this study is to develop a remote immersion experience system that can easily deal with outdoor scenes and indoor scenes in daily life. Therefore, the development of a remote immersion system to meet the basic functional requirements of the system has become the basis for research. In addition, in order for users to get a better remote immersion experience, the goal of the development system is to become a remote immersion experience system with a free look around and mobile experience on a basic remote immersion system. In order to achieve a "free viewing" and "mobile" remote immersion experience system. Firstly, this study extracts the requirements of "free viewing and mobile" which should be satisfied by the two advanced systems.

Based on our goal of providing immersive experience of all remote local scenes, and without dedicated high-speed networks, this experiment built a network-based system based on mobile data Internet communications. In addition to this, a remote present system was built that combined a multiplatform display device (mobile, portable HMD, PC, etc.) with a 360-degree panoramic camera. Then two experiments are carried out to verify the feasibility and functionality of the initial architecture. At the same time, in order to verify whether the experimental object could grasp the spatial relationship of the real site like the human being in the distance, we found that the mobile display or the portable HMD could be used to grasp the space close to the real human being in multiple display devices and experimental background. For the remote experience in the "mobile" scene, there are significant individual differences in the experimental objectives. Therefore, it can be said that this experiment built a "free look around" and "mobile", multi-scene (outdoor and indoor) use of long-range immersion experience system. This fulfills the basic functions required for a remote immersive experience system, while the average individual user can easily use it in multiple scenes (outdoor and indoor) in daily life. As a general-purpose private user system, its users are highly motivated to try and show that it can be used in common scenarios. The advent of this new remote immersion system allows for a unique and customized experience, such as an immersive private tour or remote class through our system. For example, in areas with extensive 5G coverage, the system could help managers of famous attractions reduce overcrowding and create more revenue streams by selling virtual tickets.

5.2 Limitations and future applications

A few years ago, virtual reality presented a number of performance problems that caused only a limited degree of immersion. With the development of virtual reality technology, hardware performance is also improving, giving users more and better virtual reality experience. Mobile terminal display devices and portable HMD have the characteristics of light, cheap, is the friendliest virtual reality experience for ordinary consumers choice. How to bring the good experience of advanced virtual reality devices to mobile devices with limited capabilities is an important step for virtual reality technology to reach a wider audience. In this paper, the virtual presence, which is one of the unique user experience characteristics of virtual reality, is used to reduce the distraction factor and solve the user's psychological confusion. But there are limitations and areas for improvement in the future.

1. In the mobile terminal virtual environment, the picture quality is affected by the performance of the body, and the interactive mode is also limited. Therefore, when choosing the mobile terminal or portable HMD as the carrier, it is necessary to determine whether the scene displayed is suitable.

2. When the display VR devices are wearable devices, it is easy to bring fatigue to users. As for mobile terminals, users are easy to pay attention to the devices and their hands, thus affecting the user experience.
3. To increase the sense of self-presence, the best way is to increase users' emotional feelings and self-suggestion. So, in the future, we can add the role design and guide the design before reading to enhance the user's cognition of themselves and the scene, and increase the acceptance of the experience.

The development of virtual reality technology has brought new opportunities to all walks of life, and its unique technical characteristics have brought different forms of experience to people. With the development of technology, the differentiation of virtual reality equipment came into being. Mobile VR improves user experience in science, education, entertainment and other aspects. The research found that the optimization of mobile VR mainly focuses on the software level, and further subdivision of VR and mobile VR can optimize the user experience of different terminals. At present, whether it is a mobile terminal, a portable HMD, or related virtual reality works, it is still in its infancy. With the continuous development of technology, its application and research prospects are very broad.

This research project is mainly based on somatosensory control and virtual reality technology, and proposes a design scheme of a tele-immersive experience system. The system has the advantages of long communication distance, high degree of freedom, and small delay.

On this basis, we can carry out corresponding hardware transformations for different scenarios. For example, if the remote information transmission capability of the system can be further improved in the future. In terms of business and engineering management, we can use it to conduct remote inspections and direct the construction process of large factories, buildings, etc. And we can use it to complete 3D imaging of the factory building for remote access by visitors.

In terms of sports event broadcasting, the marathon has a long time, a large number of people, and a fixed race track. If a machine that can automatically track and track is added to the system, it can identify and track specific athletes and record their running progress.

In terms of agriculture and online shopping, both online farms (health management) and online agricultural products (VR live sales) can be good application areas, combining remote immersive systems with robots with automatic cruise function, if the cows are healthy problem, it will automatically move to the sick cow to observe its condition. In addition to this, people shopping can choose products and learn about the picking process by watching live seedings from different orchards at home. This allows for more assured and targeted purchases. Traditional shopping malls can also use this system to provide people with a better shopping experience. On the basis of the original online and remote shopping, people can better experience and understand the details of the products they want to buy. At the same time, the combination of the remote shopping guide service and this system will make people's online shopping more personal, daily, and immersive.

Of course, there is no doubt that the system designed in this paper still has good application fields and prospects in terms of communication in people's daily life. This system can provide a more convenient and immersive experience for people's private communication. In the future, people who use the improved and mass-produced system can share the happy content of their environment and experience with their close friends anytime, anywhere. This enables people to better communicate and share their daily lives without being constrained by time, space, and environment.

Combining the future applications described above, it can be foreseen that our daily life will change when the current communication using smartphones is transformed into communication using the proposed personal tele-immersion system.

Acknowledgement

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Appendix

Appendix 1: WS-PQ Presence Questionnaire

Please rate the following questions on a 5-point Likert Scale

1. Does this space interact with you?

No interaction at all	O 1	O 2	O 3	O 4	O 5	Very interactive

2. How much do all your senses put in?

No input at all	O 1	O 2	O 3	O 4	O 5	Very input

3. Can you focus on the visual effects of this space?

No sense of	O 1	O 2	O 3	O 4	O 5	Very focused

3. How does it feel to move to another scene?

Not at all realistic	O 1	O 2	O 3	O 4	O 5	Very realistic

4. You don't know what's going on around you during the experience system?

Totally disagree	O 1	O 2	O 3	O 4	O 5	Very much agree

6. How strongly do you feel the motion of objects in space?

Not strong at all	O 1	O 2	O 3	O 4	O 5	Very strong

7. Is the information from the senses inconsistent or inconsistent?

Not coherent at all	O 1	O 2	O 3	O 4	O 5	Very coherent

8. Do you think the experience in this space is consistent with that in the real world?

Not at all	O 1	O 2	O 3	O 4	O 5	Very consistent

9. Can you properly use visual search in this space?

Not at all	O 1	O 2	O 3	O 4	O 5	Very consistent

10. Will the movement in this space be realistic?

Not at all	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Very consistent**

11. Don't you feel confused or disoriented at the start of a break or at the end of an experiment?

Not at all	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Very consistent**

12. Are you immersed in this virtual space?

Not at all	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Very consistent**

13. Control devices don't distract you?

Not at all	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Very consistent**

14. Is there little time difference between your action orders and the expected environmental response?

Not at all	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Very consistent**

15. At the end of the experience, how well do you know how to move and interact in a virtual environment?

Not at all	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Very consistent**

16. Does the quality of the visual display interfere with or distract you from your ongoing activities?

Not at all	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Very consistent**

17. Control devices rarely interfere with your experience in this space?

Not at all	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Very consistent**

18. Can you focus on experiencing content, rather than operating the device?

Not at all	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Very consistent**

Appendix 2: System Usability Scale Questionnaire

Please rate the following questions on a 5-point Likert Scale (1 = " Totally disagree ", 5 = " Strongly agree")

1. I am willing to use this system.

Totally disagree	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Strongly agree**

2. I think the system is complicated.

Totally disagree	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Strongly agree**

3. I think the system is easy to use

Totally disagree	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Strongly agree**

4. I need professional help to use the system

Totally disagree	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Strongly agree**

5. I have found that the various functions of the system are well integrated

Totally disagree	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Strongly agree**

6. I think there are a lot of inconsistencies in the system

Totally disagree	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Strongly agree**

7. I can imagine most people learning to use this system quickly.

Totally disagree	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Strongly agree**

8. I think this system is very troublesome to use

Totally disagree	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Strongly agree**

9. I am very confident in using this system

Totally disagree	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Strongly agree**

10. I need a lot of learning to use this system

Totally disagree	**O 1**	**O 2**	**O 3**	**O 4**	**O 5**	**Strongly agree**

Appendix 3: WebVR browser code for experiment

Here is the programming of WebVR content.
See the reference program provided by the official page.

Initialization example

```
<script src="./build/three.js"></script>
   <script src="./build/mxreality.js"></script>

   <!-- HLS live broadcast (import on demand) -->
   <script src="./libs/hls.js"></script>
   <!-- Flv live broadcast (import on demand) -->
   <script src="./libs/flv.js"></script>

   <div id='example'></div>
   <script>
   container=document.getElementById('example')
   renderer = new THREE.WebGLRenderer();
   container.appendChild(renderer.domElement);
   scene = new THREE.Scene();
   var vr=new VR(scene,renderer,container);
   vr.init(function(){

   })
   vr.playPanorama('360.mp4',<vrType>);

   // <vrType> Playback category:
   // vr.resType.video Play VR video
   // vr.resType.box Sky box mode
   // vr.resType.slice Panorama slice mode    /
     / vr.resType.sliceVideo
     Panoramic video slice mode or HLS live broadcast mode
   // vr.resType.flvVideo  lv live mode
   </script>
```

vr_hls_live_video.html

```
<!DOCTYPE html>
<html lang="en">

<head>
   <title> HLS live stream example </title>
   <meta content="text/html; charset=utf-8" http-equiv="Content-Type">
   <style>
```

```
        #example {
            position: absolute;
            top: 0;
            left: 0;
            right: 0;
            bottom: 0;
        }
    </style>

</head>

<body>
    <div id="example"></div>
    <script src="../build/three.js"></script>
    <script src="../build/mxreality.js"></script>
    <script src="../build/hls.js"></script>
    <script>


        window.onload = function () {
            init();
        }
        //var vr=new VR(scene,renderer,container);
        function init() {
            var scene, renderer;
            var container;
            //renderer = new THREE.WebGLRenderer();
            if (navigator.userAgent.match(/iphone os 14_0/i) ||
navigator.userAgent.match(/iphone os 14_1/i) ||
                navigator.userAgent.match(/iphone os 14_3/i)) {
                AVR.__fixHlsRender = true;
            }
            renderer = new THREE.WebGLRenderer();
            renderer.setPixelRatio(window.devicePixelRatio);
            container = document.getElementById('example');
            container.appendChild(renderer.domElement);


            scene = new THREE.Scene();

            // fov Option to adjust the initial video distance
            var vr = new VR(scene, renderer, container, { "fov": 50 });
```

```
            //vr.playText="<img src='img/play90.png' width='40' height='40'/>";
            vr.vrbox.radius = 600;
            if (AVR.isCrossScreen()) {
                // Adjust VR window offset
                vr.effect.separation = 1.2;
            }
            vr.loadProgressManager.onLoad = function () {
                // Video Mute
            }
            //AVR.useGyroscope=false;
            vr.init(function () {

            });

            var options = { 'muted': true, 'autoplay': true };
            vr.play('http://ivi.bupt.edu.cn/hls/cctv5phd.m3u8', vr.resType.sliceVideo,
options);
            vr.video.setAttribute("loop", "loop");
            vr.video.crossOrigin = "Anonymous";



            vr.video.onended = function () {
            }
        }
    </script>
</body>
</html>
```

vr_dash_live_video.html

```
 <!DOCTYPE html>
<html lang="en">

<head>
    <title> Dash live stream example </title>
    <meta content="text/html; charset=utf-8" http-equiv="Content-Type">
    <style>
        #example {
            position: absolute;
            top: 0;
            left: 0;
```

```
            right: 0;
            bottom: 0;
        }
    </style>

</head>

<body>
    <div id="example"></div>
    <script src="../build/three.js"></script>
    <script src="../build/mxreality.js"></script>
    <script src="http://cdn.dashjs.org/v3.1.0/dash.all.min.js"></script>
    <script>
        window.onload = function () {
            init();
        }
        //var vr=new VR(scene,renderer,container);
        function init() {
            var scene, renderer;
            var container;
            //renderer = new THREE.WebGLRenderer();
            AVR.debug = true;
            if (!AVR.Broswer.isIE() && AVR.Broswer.webglAvailable()) {
                renderer = new THREE.WebGLRenderer();
            } else {
                renderer = new THREE.CanvasRenderer();
            }
            renderer.setPixelRatio(window.devicePixelRatio);
            container = document.getElementById('example');
            container.appendChild(renderer.domElement);

            scene = new THREE.Scene();

            // fov Option to adjust the initial video distance
            var vr = new VR(scene, renderer, container, {
                "fov": 50
            });
            vr.liveSettings.usePlugin = true;
            vr.liveSettings.loadPlugin = function (video) {
                var url = "https://dash.akamaized.net/envivio/EnvivioDash3/manifest.mpd";
                var player = dashjs.MediaPlayer().create();
                player.initialize(video, url, true);
```

```
            video.addEventListener('loadedmetadata', function () {
                video.play();
            });
        }

        //vr.playText="<img src='img/play90.png' width='40' height='40'/>";
        vr.vrbox.radius = 600;
        if (AVR.isCrossScreen()) {
            // Adjust VR window offset
            vr.effect.separation = 1.2;
        }
        vr.loadProgressManager.onLoad = function () {
            // Video Mute
            // vr.video.muted=true;
        }
        //AVR.useGyroscope=false;
        vr.init(function () {

        });

        vr.playPanorama('http://ivi.bupt.edu.cn/hls/cctv5phd.m3u8',
vr.resType.sliceVideo);
        vr.video.setAttribute("loop", "loop");
        vr.video.crossOrigin = "Anonymous";



        vr.video.onended = function () {}

    }
  </script>
</body>

</html>
```

vr_flv_live_video.html

```
<!DOCTYPE html>
<html lang="en">
<head>
  <title> Example of FLV live stream </title>
  <meta content="text/html; charset=utf-8" http-equiv="Content-Type">
  <style>
```

```
        #example {
            position: absolute;
            top: 0;
            left: 0;
            right: 0;
            bottom: 0;
        }

    </style>

</head>
<body>
<div id="example"></div>
<script src="../build/three.js"></script>
<script src="https://cdn.bootcss.com/flv.js/1.5.0/flv.min.js"></script>
<script src="../build/mxreality.js"></script>
<script>


    window.onload=function () {
        init();
    }
    //var vr=new VR(scene,renderer,container);
    function init() {
        var  scene, renderer;
        var container;
        //renderer = new THREE.WebGLRenderer();
        AVR.debug=true;
        if( !AVR.Broswer.isIE() && AVR.Broswer.webglAvailable() ) {
            renderer = new THREE.WebGLRenderer();
        }else {
            renderer = new THREE.CanvasRenderer();
        }
        renderer.setPixelRatio( window.devicePixelRatio );
        container = document.getElementById('example');
        container.appendChild(renderer.domElement);
        scene = new THREE.Scene();

        // fov Option to adjust the initial video distance
        var vr=new VR(scene,renderer,container,{"fov":50});
```

```
      //vr.playText="<img src='img/play90.png' width='40' height='40'/>";
      vr.vrbox.radius=600;
      if(AVR.isCrossScreen()) {
        //Adjust VR window offset
         vr.effect.separation=1.2;
      }
      vr.loadProgressManager.onLoad=function () {
         vr.video.setAttribute("loop","loop");
         vr.video.crossOrigin="Anonymous";
      }
      //AVR.useGyroscope=false;
      vr.init(function () {
      });


  vr.playPanorama('http://localhost:8000/live/test.flv',vr.resType.flvVideo);
      vr.video.onended=function () {
      }
    }
</script>
</body>
</html>
```