Social Interactions in Mixed Realty based Immersive Virtual Nature Environments

Sophia Matar¹, Alfred Shaker¹, Saifuddin Mahmud¹, Jong-Hoon Kim¹, Jan-Willem Klooster²

¹ Advanced Telerobotics Research Lab, Computer Science, Kent State University, Kent, Ohio, USA [http://www.atr.cs.kent.edu](http://www.atr.cs.kent.edu)
² The BMS Lab, University of Twente, Enschede, Netherlands [https://bmslab.utwente.nl/](https://bmslab.utwente.nl/)

Abstract. The advancements in immersive technologies allow us to create more sophisticated environments designed to help engage users by merging the physical world with a digital or simulated reality. These can range from completely immersive virtual environments to mixed reality immersive environments, where the virtual world and real world collide. Virtual reality is a completely immersive environment where the users’ reality is replaced with a simulated environment, and the hardware works to convince the user that they are in a different world. In contrast, augmented reality is a mixed type of reality, combining both virtual and the natural world by augmenting the real world with digital assets and components. While both types of experiences contribute to creating rich collaborative environments, a limitation, and sometimes inconvenience, is present with the requirement of wearing a head-mounted device (HMD), creating restriction that prevents users from having physical interactions with others. Rather than interacting in the virtual space, we propose a concept that provides the structure for a physical space where users can interact with the shared mixed reality environment; an environment projected to help create the collaborative aspect in this project, without any wearable devices. In this paper, we will present the developed system and implemented four dimensional interactions and demonstrate the feasibility of the structured experience we have created.

Keywords: Immersive Environments, Mixed Reality Environment, Augmented Reality, Virtual Reality

1 Introduction

1.1 Background

Immersive technology helps create environments where the line between the physical world and the virtual world is blurred, producing a sense of immersion. The technology is able to trick your senses into thinking you are experiencing something different. Examples of these technologies are virtual reality and

* Email: jkim72@kent.edu, corresponding author
Augmented reality. Virtual reality is a technology that generates an environment replacing the physical world with a simulated environment with the use of various head-mounted devices (HMDs). In comparison, Augmented reality is a technology that enhances the physical world with interactable digital elements that are augmented on top of the real physical world, either using markers or depth-mapping. There are many facilities and labs where the purpose is to create immersive environments using all types of immersive technology. An example of these labs is the Curved Corner Room, a room-sized immersive projection display that provides an interactive high, present virtual world. The corner area of a room is used as a screen, and a wide-angle image is projected onto the curved surface. Using this system, one PC and projector system can generate an immersive virtual environment covering the user’s view. But immersive technology has been able to advance and become more impressive and sophisticated, expanding from a simple set-up to having multiple projectors as well as having a single synced screen wrapping around three walls of the room. Allowing bystanders to not only view the virtual environment but also interact with it in a more immersive way than before. There are various studies where this technology has been applied and iterated on, and in this study we show our approach to it using the Blank Lab facility.

1.2 Blank Lab

The Blank Lab serves as a "black box" environment for researching group activities that cross the boundaries of immersive technology, such as augmented, virtual, and extended reality tools. The area is adaptable, so projects incorporating these technologies can be developed and demonstrated. Whether users are experimenting with projections to create "cave-like" experiences or using AR/VR headsets, the objective is to support group experiences for up to 15 people in all circumstances. The main area of The Blank Lab includes a suspended grid ceiling that enables the installation of a hung curtain wall and the ability to reconfigure the support for cameras, projectors, etc. The curtain wall makes it possible to install speakers, wiring, and other supporting technologies behind the wall without the public being aware. The ability to create, modify, and support the presentation of these technologies in the main area is provided by servers and workstations housed in a control room next to the main space. To allow immersive experiences, the entire environment is sound and light isolated (not sound or light "proof"). The Blank Lab is a multipurpose space many use to have their projects projected. Since not every project is done with the needed setup and configuration, the lab has special software to ensure every project can be projected in the correct format. Allowing the Blank Lab to be a shared space has its pros and cons, pro in the aspect of being a space so many can use for a wide range of projects. Con in the aspect of not being able to create a specific configuration for the individual projects, since the cost of maintenance is quite high for the upkeep of the lab so, a single configuration is set and using the different software in the Labs computers, the various projects can be manipulated as needed, using scalable displays for the syncing of the nine projects, and
Pro-tools for the syncing for the 13 speakers in the lab as depicted at Fig.1. This is one of the critical challenges in this project that the proposed system should perform all intractable features as well as immersive virtual nature environments under restrictions of Salable display and Pro-tools driving software.

Fig. 1: The Blank-Lab system layout and configuration

This paper is structured as follows: Section Two describes similar projection room projects as related works. In Section Three, we have detailed the system overview behind the ATR Immersive Virtual Nature implementation. Section Four contains the discussion points to validate our system. Finally, Section Five depicts the future research plan and conclusion.

2 Related Work

Virtual reality allows users to experience an immersive virtual environment (IVE) in a multi-sensory fashion. While most previous works focused on providing the VR user with a realistic and highly immersive VR experience, bystanders in the natural environment are often not involved. Zenner [15] has introduced a projection-based system to include bystanders in the virtual experience by projecting the virtual environment onto the registered, physical counterpart. Using controllers, the system allows bystanders to interact with the IVE and perceive the virtual environment semi-immersively. Similar to this paper, this research plans to create an environment where multiple bystanders can interact with the virtual environment, except this environment will not use any controllers. Instead, the participants can use hand gestures to manipulate the environment.

A large-scale display system with immersive human-computer interaction (HCI) is an essential solution for virtual reality (VR) systems. In contrast to the traditional human-computer interactive VR system that requires the user to wear heavy VR headsets for visualization and data gloves for HCI. Wang [13] proposes a method that utilizes a large-scale display screen, with or without 3D glasses, to visualize the virtual environment, and bare-handed gestures are used to manipulate the virtual environment. Similar to this paper, gesture recognition
is used to have users interact with the virtual environment. In contrast, this research utilizes the 270-degree view it has, using the screen which stretches across three of the labs’ walls.

With the development of ubiquitous computing, current user interaction approaches with keyboard, mouse, and pen is insufficient. Due to the limitation of these devices, the usable command set is also limited. Roomi [8] proposes the direct use of hands can be used as an input device for natural interaction. The Gaussian Mixture Model (GMM) was used to extract hands from the video sequence. Extreme points were selected from the segmented hand using star skeletonization, and recognition was performed by distance signature. The proposed method was tested on the data-set captured in the closed environment, assuming that the user should be in the Field Of View (FOV). This study specifically proposed a real-time vision system for hand gesture-based computer interaction to control an event like the navigation of slides in a PowerPoint Presentation. In this paper, a hand tracking code using python OpenCV and CVZone is written. With the same goal as the GMM, this script helps detect the main segments of the hand using that data, and it can implement the hand model in the unity 3D environment. Similarly, a real-time hand tracking system will be used in the ATR immersive virtual reality system to have the users manipulate the virtual environment projected around them.

Rompay [12], inspired by research that demonstrated the positive effects of nature-based imagery on well-being and cognitive performance, the current research aims to study to what extent nature imagery can also enhance creative performance. Imagery presenting green settings varying in unpredictability and spaciousness was displayed before and during a creative drawing task in a high school classroom. After finishing the task, the students were given a questionnaire to complete, comprised of self-report measures for perceived creativity and positive affect. Unpredictability and spaciousness enhanced creative performance, with images combining these factors being particularly inspiring. This study helped provide the necessary findings to demonstrate that nature imagery can increase creativity in individuals and warrant follow-up studies that may further clarify the role of spaciousness, unpredictability, and other creativity-enhancing features of nature imagery. Using the virtual environment that the nature imagery came from, the implementation of the virtual nature in the Blank Lab, with the addition of the interactive elements, will help create an immersed participant when using the virtual environment. Instead of showing the imagery of the virtual nature, the user will be able to interact and manipulate the environment using simple hand gestures.

Lin [6] proposes a Virtual Reality system to reduce anxiety and stress using music therapy called Virtual Harmony. The system allows users to listen to music and play different instruments in a 3D environment with real-world panoramic video as background scenes. This system avoids using a traditional joystick or keyboard; the participants can use their hands to play the virtual instruments creating a more realistic feeling. Similarly, in this paper, the participants can use their hands to control the virtual environment, helping create an immersive en-
environment for the user. The user will also be able to choose between two virtual environment types, the first being an environment with a real-world panoramic video as background scenes and the second being a completely digitized environment as the background scene.

Houwelingen-Snippe [11] proposes that digital nature can substitute for real nature for those with limited access to green space or confined to their homes. In a large-scale online survey, participants watched videos of digital nature, varying in nature and spaciousness. Results show a significant increase in connectedness to the community after watching digital nature. Instead of watching a video of the virtual nature, participants will be able to manipulate and change the virtual environment projected around them. Without the need for any hardware, participants can use different gestures to help control the environment.

Amongst all these applications of VR technologies, there are also virtual tours that allow people to be immersed in remote environments, as seen in studies by Shaker et al [9] and Hendricks et al [4]. In Shaker’s work, the study involved using a virtual reality tour to quantify the effects VR has on individuals with developmental disabilities and see if VR can be used as a form of therapy to improve their mental state. The study had users interact with the scene using gaze and controller interfaces, and was created using 360 photographs of a real location, which made the experience more immersive. Their study showed that this kind of technology does indeed have a positive impact on individuals with developmental disabilities, and that VR has potential in the field of therapy for such individuals and others as well. Hendrick et al took the technology of the virtual tour a step further by creating a virtual tour that was dynamic in nature, by creating a content management system (CMS) for admins that allowed them to edit and add new content to the virtual tour. The client side application for the tour was comprised of the main interface and a skeleton scene which was populated by requesting it’s data from the server, which allowed for the previously mentioned CMS to function so well, and provide a seamless uninterrupted experience for the end-users.

3 System Overview

The ATR Immersive Virtual Nature System focuses on creating a mixed reality-based immersive environment. Immersive in the sense of being able to interact with the virtual environment. In this research, the main focus was to create an application where users can interact with the virtual environment without needing any hardware. The ATR Immersive Virtual Nature System is a system that combines both the audio and video systems in the Blank Lab which is one of the key challenges mentioned at Sec. 1.2 and the ATR immersive virtual nature severe to create an immersive environment where users can interact with the virtual environments without the constraint of needing to wear a headset or the limitation of having to experience the space alone. Figure 2 shows the system architecture for the ATR Immersive Virtual Nature System. Starting with the ATR immersive virtual nature severe, the server will be processing all the input
from the camera in the blank Lab to ensure that the projected scene and the ground projections are fully updated with the correct scenes.

(a) The video feed from the IP camera(s) will be used to ensure the environment is constantly up to date, fitting how the user interacts with it. The camera will stream its feed into the ATR immersive Virtual Nature server. In the server, the motion tracking module will be able to track the user’s position and hand gestures, which are used to control the virtual environment. With the motion tracking module, the Human-Computer Interaction Engine (Figure 3) will also be used to update the surround screen and the ground projection with the respected scene and the speakers with the required audio. There will be two ways to project the virtual environment in the Blank Lab.

(b) The first projection is for the ground scenes. Since an external projector will be installed in the Lab, the scene generator will mirror the scene fitting for the ground of the Blank Lab.

(c) The audio module, audio that gets picked up from the Ip camera(s), is used along with the user’s hand gesture to manipulate the virtual environment. From a voice command to help open the menu to having a specific sound cause a graphical element change in the background.

(d) The Blank Labs’ wall projectors. The Blank Lab has two separate computers, one for the video system, concentrating on the nine projectors in the

Fig. 2: Immersive Virtual Nature System Architecture
Lab. And the second dealing with the audio system, the 13 speakers, and two subwoofers in the main area of the Blank Lab.

(e) From the ATR Immersive Virtual Nature Server, the virtual environment is streamed to the ATR Immersive Virtual Nature Broker in the Blank Lab video system. Using the Scalable Displays software, the virtual nature stream is configured to the screen size in the Blank Lab’s main area. With the new configured stream, the video system can project the environment on the Lab’s main screen (14506 x 1080).

(f) The second computer, the Blank Lab audio system, has to get the audio output of the video system. Using the Pro-tools software, the audio is configured to be out through the 13 speakers and two subwoofers in the main area of the Blank Lab well.

(j) After the audio is in the correct configuration, the Blank Lab audio system can sync the audio to the projected scene and have the audio play from the main Lab’s speakers.

Fig. 3: Human Computer Interaction Architecture

The Human-Computer Interaction Engine (Figure 3) will be used to update the surround screen and the ground projection with the respected scene. The Human-Computer Interaction Engine uses the feed from both the motion tracking module and the audio detection module to generate the needed audio and the updated scene for either the ground projection or the wall screen projections.

4 Implementation

In this paper, we focused on the validity of key concepts and verification of important functionalities for the proposed system under restrictions of the current Black-lab environment as described at Sec. [12]. These included the ability to collect and process the data from the users’ actions to create a seamless application
where the user can interact with the virtual environment. The user’s position will be detected using the live video feed from the Wifi IP Cameras. The position of where the user is standing affects two main aspects of the project. The first is the ‘activation’ of the application. When the user is in the projected area, the main menu appears, and the user can start using the application. The participant will be able to manipulate the virtual environment by using different hand gestures. The motion tracking module and the human-computer interaction engine will recognize the various gestures and the different commands corresponding to each gesture. The motion tracking module will detect the hands of the participant, and depending on how far the hands are from one another, the different commands will be called. The second element is the interactive ground projection. Depending on which scene the user chooses as their background, the corresponding ground projection will also be displayed based on the scene the participant chooses to experience. The ground projection will also have interactive elements controlled based on the participant’s position. Different images will appear on the projected stage, and the different images will disappear as the user moves but reappear when the user is in a new position.

Fig. 4: Wall Projections in the Blank Lab. (left to right); Main Menu, Virtual Nature Healing Environment, Virtual Music Therapy

Main Menu: The application’s main screen introduces the opposition the user has for what type of scene they would like to experience. Both are beneficial for one’s mental health, except one focuses on the healing qualities of nature and the other through music.

4.1 Virtual Nature Healing Environment

This BMS software was created with the means of healing using nature. The same healing qualities were present in the virtual nature environment as in the real-world nature environments. With the Virtual healing environment, the user has the ability to design and experience the virtual environment of their choosing. In this research, we reconstructed the user interface to allow users to interact with the application through gestures, from looking around the environment to editing the space around them.
4.2 Virtual Music Therapy; Virtual Harmony

This virtual therapy system developed to reduce anxiety and stress by using music therapy is another possible experience the user can choose. The system allows users to listen to music and play different instruments in a 3D environment with real-world video as their background. In the Blank Lab, the user will be able to experience these environments in the isolated lab, helping to create an environment where the user can be immersed in whichever application they select to experience. The user can control the application with their hands, from choosing the real-world video they set as their panoramic background to choosing the instrument they choose to play. All of the applications can be manipulated using the users’ gestures.

5 Discussion

The concept introduced in this paper is the development from previous research. Houwelingen-Snippe [11], and Rompay [12] completed their study using the Virtual Nature Healing Environment [2], a software created by the BMS Lab [1]. Present in their research papers, a replica of the natural environment has been designed and used to test how virtual environments affect social aspirations. Also, Virtual Harmony [6], a virtual therapy system developed to reduce anxiety and stress by using music therapy, is another possible experience the user can choose. The system allows users to listen to music and play different instruments in a 3D environment with real-world video as their background. The main objective of this research was the development of interactive software with the inclusion of the BMS lab’s virtual environment, Virtual Harmony, and the ability to incorporate the software in a space where an interactive application could be constructed. The Blank Lab has a fixed setup, so the lab could not be customized to the specifics of this project. With the limitations present, the Blank Lab is set up to configure a multitude of projects to have them projected in the lab. For the correct configuration of the projects, the Blank Labs’ workstation has software installed to help sync all the projectors creating a seamless digital display; Scalable Displays, a software that automatically wraps and blends multiple projectors. For the proper audio play, Pro-tools, a digital audio workstation, is used to help distribute the audio for a more ambient sound. We could achieve our desired outcome by working around these limitations and with the facilities provided. In this research, we created an application that combined two different virtual environment projects and configured them to work in the Blank Lab to create an immersive experience that eliminates the need for users to handle any hardware while using the application. The screens in the blank lab surround the user from three directions, so the user will experience the environment as if they have stepped into the application; we have also added a ground projected stage to help immerse the users even more.
6 Conclusion and Future Work

In this paper, a concept that provides the structure for a physical space where users can interact with the shared mixed reality environment has been proposed. The environment is projected to help create the collaborative aspect in this project without any wearable devices. The developed system and implemented interactions demonstrate the feasibility of the structured experience we have created.

As done in past research, The Virtual Nature Healing Environment has been used to collect data and find the awe score of the users who experience the virtual space. Similarly, in future research, the application will be tried and configured for different devices, i.e., laptop and phone screens and a VR headset, in hopes of discovering how increasing immersion in the virtual environment could affect human aspirations. The introduction of bio-metric testing will also be necessary to help test the score of the awe factor that the ATR immersive virtual nature system has compared to experiencing the application on different devices.

Another possible addition to the project is an audio response module, which will be the next step for this application to help further the research. Users will be able to create a sound, i.e., clapping, and yelling, which triggers the respected response from the software. We believe that introducing phonic commands will help create a more notably immersive environment. Developing a software that can configure any virtual environment, helping it build an utterly immersive space, is where this project is advancing to.

7 Acknowledgement

This research was partially supported by the KSU Blank-lab and the ATR lab. We thank our colleagues Prof. J.R. Campbell and Shannon Hines from the KSU Blank Lab as well as Lucia Rabago Mayer from and the BMS lab who provided insight and expertise that greatly assisted the research, although they may not agree with all of the interpretations/conclusions of this paper.

References

1. BMS Lab, a lab of the social sciences faculty at the University of Twente . https://bmslab.utwente.nl/


