# ViBlock: Block-shaped Content Manipulation in VR

Miteki Ishikawa*, Takuma Hagiwara, Kazuki Takashima, Yoshifumi Kitamura
Research Institute of Electrical Communication, Tohoku University, Japan


(a) Blocks on the wall (b) Gestural action (c) Grasping a block (d) Perspective view

**Figure 1**: *Snapshots of ViBlock.*

**Keywords**: Finger interaction, Multi-modal content presentation

**Concepts**: • **Human-centered computing ~ Interactive systems and tools;** *User interface management systems;*

## 1. Introduction

VR is increasingly becoming an interaction platform that allows users to display and manipulate various digital content such as text, computer graphic, 3D model, amination, and sound in a 3D space. In this work, we seek an enjoyable interface to manage a large set of digital content. We propose ViBlock (Virtual Interactive Block) (Figure 1), a novel block interface in VR that creates enjoyable experiences through natural and playful interactions with block-shaped content. This is based on the well-known building block metaphor and tangible user interfaces [Kitamura et al. 2001, Hosoi et al. 2014], and it allows users to grasp block-shaped content arranged in a 3D space and customize their representations by composing multiple blocks.

ViBlock uses a HMD (Oculus Rift) and a finger tracker (Leap Motion). Each block has digital content with multiple modes such as 3D model, text, sound and so on, and its surface displays a representative image. Figure 1(a) shows the blocks spatially arranged in a 3D space. This block arrangement dynamically and flexibly changes based on D-Flip (Dynamic and Flexible Content Visualization) [Kitamura et al. 2013] algorithm responding to the users' head direction detected by the HMD's IMU sensor. Each block can be grasped and manipulated by users' finger or hand gestural actions detected by Leap Motion (Figure 1 (b) and (c)). Besides, the mode connector (Figure 2) is an actual interface customizes the presentation of blocks. Many sets of mode connectors are arranged in the 3D space. Once a block is snapped to one of the mode regions of a connector, the corresponding content is presented in the ground (Figure 1(d)). The presentation can be customized by snapping different blocks to the connector or moving the block to a different region of the connector. In the animal picture book application we proposed for VR Showcase, when users snap a horse block to the 3D model mode of a connector (top-right in Figure 2), a horse 3D model appears and starts running around on the ground (Figure 1(d)). If the users snap another horse block to the sound mode (top left in Figure 2(b)) of the same connector, the running horse will make a sound. Such block manipulations and compositions enable users to experience various content presentation in multiple enjoyable ways. In summary, ViBlock can encourage users to interact with digital content in VR by allowing novel and playful content presentations and explorations beyond real-world experience.

*e-mail: icd-office@ml.riec.tohoku.ac.jp

*SA '16 VR Showcase*, December 05-08, 2016, , Macao
ACM 978-1-4503-4542-2/16/12.
http://dx.doi.org/10.1145/2996376.2996391

## 2. ViBlock

We implemented ViBlock using Oculus Rift for 360 degree viewing and Leap Motion for accurate finger-based block manipulations. Leap Motion is attached on the Oculus Rift (Figure 1(b)). We used Unity to implement ViBlock on a Windows 10 computer (CPU i7-6700K, Memory 32GB, Graphic GeForce GTX 980 Ti). The following describes major components of ViBlock: block, wall, connector (Figure 2), and ground.

### 2.1 Block

Block represents digital content with multiple modes, such as 3D models, texts, sounds and so on. In the case of a horse block, the block has multiple types of data, such as a representative horse image that appears on its surface, an animated 3D model, a description of the type of the horse, and a representative sound of horse neigh.

To handle blocks, we implemented two types of gestures that can be detected by our Leap Motion setting. One is "pulling," to pick up a block from the wall (like block storage, described later). The other one, shown in Figure 1 (b) and (c), is "grasping", which allows users to move or rotate the selected block and snap it into a connector.

### 2.2 Wall

While there are many layout patterns, the current implementation spatially tiles block around users' surroundings like a wall (Figure1 (a)). They are also dynamically and flexibly represented like living objects based on D-Flip [Kitamura et al. 2013], an interactive photograph viewer that successfully handles a large set of digital photographs in effective and pleasant ways. With this algorithm,

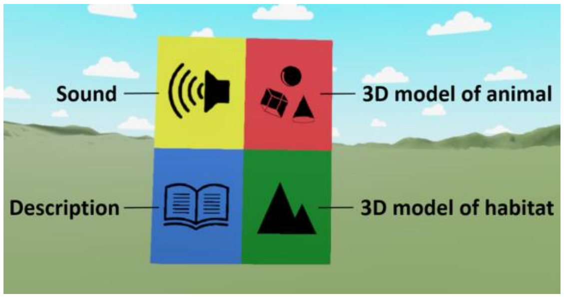



**Figure 2**: *Modes of a connector.*

blocks gradually change their sizes and positions responding to users' input; in this case, users' head direction. For example, when users are looking at a block, it becomes larger while maintaining its global layout without overlapping, by dynamically rearranging surrounding blocks. Also, since the wall is surrounding users, they can access all of them by looking around with HMD.

### 2.3 Connector

Connector is a core interface to manage the content presentation of the manipulating blocks. Figure 2 shows a current connecter design that consists of four regions. Each region indicates a different mode; showing a 3D model of the animal, showing a 3D model of its habitat, making a sound, and showing a description. Depending on the applications, its design can be further alerted.

Users can choose a presentation of content from multiple modes by snapping the block to the corresponding mode region of the connector. A unique point of the current design is allowing users to combine four blocks in the four different modes, which is expected to lead users' exploratory and playful experiences with the multi-modal digital content.

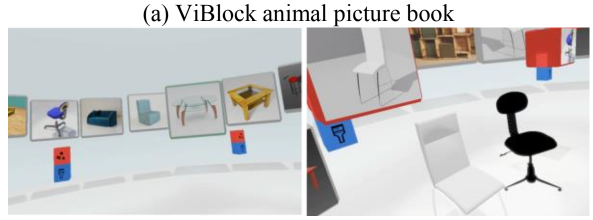
### 2.4 Ground

The ground is a place where content outputs are presented after blocks are composed. For example, 3D model, sound and text views and so on are presented within the users' visual field, according to the blocks that attached to mode connector. One region of the ground is coupled with one connector, and their multiple sets of them are arranged in the 3D space (Figure 1(d)). Thus, a possible extension is to support multiple users. By displaying avatars (top-left in Figure 3(a)) of each player, they could recognize the existence of others. This collaboration or mixed-focus interaction scenarios could benefit from a large VR space, and make block manipulations more tangible and engaging.

## 3. Application and Future Work

In this VR showcase, we developed two applications (Figure 3). Some of 3D models we used are licensed under the Creative Commons –Attribution / CC BY-NC 3.0 or CC BY 3.0. First application is "ViBlock animal picture book", an educational application that allows learners to observe and investigate animals' characteristics in multiple modes. Here, we used four modes to present an animal content, a 3D model of an animal, its habitat, its description and its sound. As previously explained, learners can choose how to present the content from the four modes based on their interest by manually connecting animals' blocks to intended modes of a connector. Because of its attractive and immersive features, the system can be used not only for leaning animals but also for creative play, thereby providing experiences beyond paper picture books.

(a) ViBlock animal picture book



(b) ViBlock shopping

**Figure 3**: *Application examples.*

Another application, "ViBlock shopping" is a novel VR shopping interface providing users with enjoyable and playful shopping experiences. This application focuses more on simple actions during the shopping such as browsing, comparing and customizing to find out better items. Thus, we used two modes, 3D model and material, on a connector. When users are looking for furniture, they can see a 3D model by selecting a target block and snapping it to the 3D mode region of a connector. When users want to see it in other material, they grasp another block whose item is made of the material they are interested in (e.g., color, texture) and snap it to the material mode region of the connector. Then the material of the presented furniture is changed accordingly. This example represents how users can combine blocks to produce one single output.

In the future, we will expand ViBlock system. The major challenge is to improve connectors, e.g., increasing the number of manipulations of content. It may need a new connector design. We are also planning to extend the system so that multiple collaborators can share the whole experience from the content at the same time. Our ViBlock is still in an early stage, but we expect that this simple interface will be an effective and enjoyable tool when exploring various digital content in HMD settings.

## 4. References

KITAMURA, Y., ITOH, Y., & KISHINO, F. 2001. Real-time 3D interaction with ActiveCube, *CHI'01 Extended Abstracts of Human Factors in Computing Systems*, ACM, 355-356.

HOSOI, T., TAKASHIMA, K., ADACHI, T., ITOH, Y., & KITAMURA, Y. 2014. A-blocks: recognizing and assessing child building processes during play with toy blocks. *SIGGRAPH Asia 2014 Emerging Technologies*, ACM, 1: 1-1: 2.

KITAMURA, Y., VI, C. T., LIU, G., TAKASHIMA, K., ITOH, Y., & SUBRAMANIAN, S. 2013. D-FLIP: dynamic & flexible interactive PhotoShow. *SIGGRAPH Asia 2013 Emerging Technologies*, ACM, 6: 1-6: 3.

# Be Closer as You Being There: HMD-based Social Interaction System

Joung-Huem Kwon, Yong-Ho Lee, Young-Uk Kim, Eun-Seok Choi, Hyuk-Min Kwon, Gyeong-Soo Noh, Eun-Mi Lee, Sang-Hun Nam, Joong-Jae Lee, Bum-Jae You
Center of Human-centered Interaction for Coexistence*

**Figure 1**: *HMD based social interaction system*

## 1 Introduction

The proposed system dose not only provides an immersive live 360 degree experience through the HMD-controlled remote stereoscopic cameras but also enables the users to perform social activities with an interactive virtual messenger. This system was originally developed to control a mobile robot/vehicle with monitoring purpose which is similar to DORA (Dexterous Observational Roving Automation) platform [ACKERMAN 2015]. However we duplicated and placed the system in a geographically dispersed location and connected between two systems over the real-time network. To enhance social interactivity, we implemented an interactive virtual messenger. As the result the system provides the feeling of social presence and the fun with an immersive experience.

The system has two key features. Firstly the user, wearing a HMD and headphone, is connected with a remote Stereoscopic Pan-tilt camera (SP-cam) and microphone, which is controlled by user's head motions and enables to capture full-HD 3D videos and audios remotely, through a real-time synchronized network software framework. It provides immersive live omnidirectional experience, hence the user can feel like he is present in a location where he is not actually in. Secondly, the system includes the function of spatial touch interface that enables users to select a menu, to push and move virtual objects, and to input texts in air by using their fingers as a naturally.

We showcased the system at the NAB (National Association of Broadcasters) Show 2016," which ran on April 22nd and 27th in Las Vegas, USA. We confirmed that the system has strong possibility hopefully as a further communication and interaction platform, and it would advance the impression of tele-communication (See Figure 2).

**Figure 2:** *The Showcase for NAB show 2016*

**Keywords:** Spatial User Interface, Virtual Keyboard, Stereoscopic Pan-tilt camera

**CCS Concepts:** Information systems → Collaborative and social computing systems and tools

*e-mail:{jhkwon, jason0720, yukim, riosnai, hmkwon, noh0602, lee.eunmi, sanghunnam, arbitlee, ybj}@chic.re.kr.

*SA '16 VR Showcase* , December 05-08, 2016, , Macao
© 2016 ACM. ISBN 978-1-4503-4542-2/16/12…$15.00
DOI: http://dx.doi.org/10.1145/2996376.2996389

## 2 System Overview

In this section, we describe more details of main device, design and control mechanisms of our key techniques.

### 2.1 HMD controlled remote Stereoscopic Pan-tilt camera

The pan-tilt module which is able to be cotrolled by HMD motion is essential to manipulate a stereoscopic camera. We designed our own stereoscopic cameras and pan-tilt module to satisfy requirements for the proposed system. HMD controlled remote SP -cam is depicted in Figure 3. The stereo camera must satisfy the high resolution/frame rate for full-HD display resolution, HMD display requirement (960X1080 per eye), and seamless video in drastic pan-tilt movement. We designed the stereoscopic camera so that each camera has full-HD resolution and is connected via USB3.0 seperately realizing 30fps.

The pan-tilt module also has several requirements. It has to be controlled in precise pan-tilt angle, low latency and smoothly regardless of discrete control input. We implemeted the pan-tilt module combining two identical motors, Herkulex DRS-0602 (0.02778 degree unit and full duplex asynchronous serial connection), to meet the requirements. The more precise pan-tilt angle and the less the latency are, the more immersive user experience becomes. Moreover, pan-tilt motion is not seamless if it takes next command after waiting for the current movement to be done because motor velocity decreases at the end of the current movement as depicted in Figure 3. left-bottom a). We calculated the moment the velocity is about to decrease and command the next control input as depicted in Figure 3. left-bottom b) to realize smooth(seamless) pan-tilt movement.


**Figure 3:** *Stereoscopic Pan-tilt camera combined with the camera (left-top), Pan-tilt module (right) and comparison of motor velocity depends on HMD control input ways*

### 2.2 Virtual Keyboard Interaction

To provide visual information transfer between remote users, we developed a virtual keyboard interface. The virtual keyboard allows users to input some words by their own hand movements in the air. Due to the difficulty of depth perception in binocular vision, a spatial touch based input interface often occurs the errors of back-touch or double touch. To improve the depth perception, we used multi-sensory feedbacks that include visual, auditory, and haptic using a miniaturized vibration device wearing on the finger. In addition to reduce the error of typing of virtual keyboard, we implemented not only an algorithm that prevent the back-touch by calculating the direction vector of fingertip and collision status, but also de-bouncing algorithm for reducing the error of double touch.

For the virtual keyboard based social interaction in ego-centric environments, we developed a messenger. Leap motion sensor was attached to the front of the HMD and captured the positions of the user’s fingertips. The proposed virtual keyboard based messenger was implemented to the SP-cam based collaboration. The texts and emoticons were enabled to share with remote users via real-time network, hence the sensual connection could be enhanced (See Figure 4).


**Figure 4:** *Virtual keyboard interaction*

## 3 Application

We integrated the HMD controlled remote stereoscopic pan-tilt camera and the virtual keyboard based messenger interface for a HMD based social interaction system. The figure 5 shows the overall structure of the system.

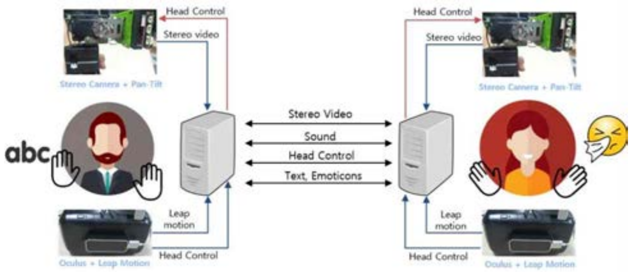



**Figure 5:** *The overall structure of the system*

The system consists of an HMD (Oculus rift DK2) for displaying stereo videos, a full HD stereo camera mounted to pan-tilt module for capturing omnidirectional images (see section 2.1), and a virtual keyboard based messenger for collaboration (see section 2.2). The system is run by our network engine that supports codec and multi-channel network module for efficient data transmission in real-time.

When the software framework captures multi-modal data from sensors (stereo camera, microphone, leap motion) with different intervals, the interface module ensures interval less of less than 2ms. Rendering engine mixes real image and virtual keyboard and performance has more than 75 fps.

The users in different space can talk and see remote users and surroundings with the remote eyes which rotates depending on the head motion. This enables users to be under illusion of being there. It is possible to exchange emotional feelings between users by sharing text message and emoticons with chatting interface as well as interaction with audio and video.

The system shows the possibility of an HMD based social interaction system with remote users. When the VR broadcasting have recently excited great interest in VR industry recently, it is worth considering an application for social VR broadcasting with interactions beyond the unidirectional broadcasting method using a 360 camera.

## Acknowledgements


This work was supported by the Global Frontier R&D Program on Human-centered Interaction for Coexistence funded by a National Research Foundation of Korea grant funded by the ministry of Science, ICT, and Future Planning in Korean Government (NRFM1AXA003-2011-0028374).


## References


ACKERMAN E. 2015. Oculus Rift-Based System Brings True Immersion to Telepresence Robots, IEEE Spectrum, http://spectrum.ieee.org/automaton/robotics/robotics-hardware/upenn-dora-platform.

JOLAU L. 2015. Intuitive Rift Explorer, http://www.jolau.ch

# Real-time Facial Tracking in Virtual Reality

Jihun Yu*  Jungwoon Park
BinaryVR. Inc.

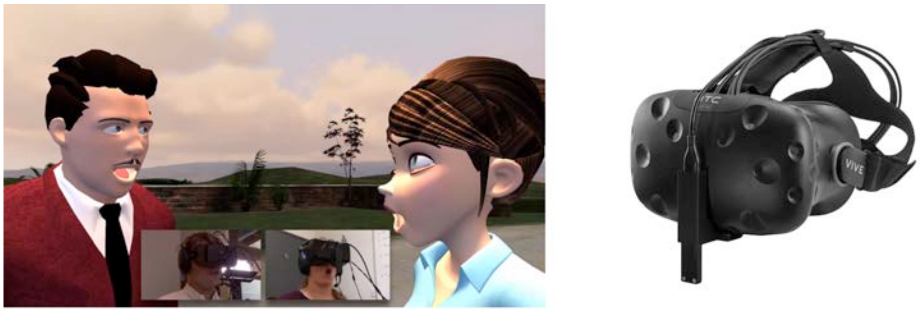


**Figure 1**: *Our facial tracking system for Virtual Reality is presented. (left) The facial performance is captured for Oculus DK2 and applied to virtual avatars in High Fidelity, an open sourced social VR platform, (right) Our capturing camera attached on the HTC Vive.*

## Abstract

Virtual reality (VR) emerges as the next social computing platform. For realizing immersive social interactions, projecting facial expressions onto the virtual avatar a crucial component. This is a challenge in VR as it requires capturing the facial motions behind the VR head mounted displays (HMDs). In this paper, we present a real-time facial expression tracking system in VR HMDs. The core of the system is a 3D camera attached to the HMDs, capturing motions on the lower half of the face, which enables users to track and retarget their facial animations in real-time onto CG avatars. The system is capable of capturing 20 facial expression parameters and transfer it onto the 3D character in real-time.

**Keywords**: virtual reality, facial capture

**Concepts**: • **Computing methodologies ~ Animation;** *Motion Capture;*

## 1 Related Work

Real-time Facial performance capture technology have been achieving significant progress in recent years. Faceshift [Faceshift] is one of the successful commercial products, which has been used in the movie/animation industries to animate CG characters. [Hao et at. 2015] built a real-time facial tracking system working on the Oculus Rift headset and demonstrated great potential to adapt the facial performance capture technology into VR HMDs.

*e-mail:jihun.yu@binaryvr.com.
 SA '16 VR Showcase , December 05-08, 2016, , Macao © 2016 ACM.
ISBN 978-1-4503-4542-2/16/12…$15.00
DOI: http://dx.doi.org/10.1145/2996376.2996390

The idea of facial performance capture using EMG sensors is proposed in the media such as Emteq [Emteq].

## 2 Facial Capture Technology

Our real-time facial tracking system for VR HMDs utilizes a 3D Time-of-Flight (ToF) camera to capture the depth map and 2D infrared (IR) image of the lower half of the face. Facial performance is captured at 45 fps and the system outputs 20 blendshape curves in real-time.

**Figure 2:** Our c*apturing ToF Camera attached on the oculus.*

The system requires a one-time calibration step when users wear the HMD for the first time. During the calibration, the system scans the face for a second and builds the personalized facial tracking model. Once the calibration step is completed, the system captures the real-time facial performance based on the depth map and the sparse 2D facial landmarks tracked on the 2D IR image. In order to complete the full facial capture for VR HMDs in the future, we will add the eye regions (eye and eyebrow) tracking feature by embedding high-framerate optical cameras inside the HMDs.

## References

EMTEQ. http://www.emteq.net/.

FACESHIFT. http://www.faceshift.com/.

LI, H., TRUTOIU, L., OLSZEWSKI, K., WEI, L., TRUTNA, T., HSIEH, P.-L., NICHOLLS, A., AND MA, C. 2015. Facial performance sensing head-mounted display. *ACM Transactions on Graphics (Proceedings SIGGRAPH 2015) 34, 4 (July)*

# The Battle for Hearts and Minds: Interrogation and Torture in the Age of War. An Adaptation for Oculus Rift.

Daria Tsoupikova*, Scott Rettberg†, Roderick Coover^, Arthur Nishimoto*
*University of Illinois at Chicago, †University of Bergen Norway, ^Temple University

**Figure 1:** *A scene of Hearts and Minds in the CAVE2 environment.*

## Abstract

*Hearts and Minds: The Interrogations Project* is a Virtual Reality art installation developed using a novel method for direct output of the Unity-based virtual reality projects into CAVE2™ [Febretti et al. 2013] environment. This artwork incorporates original research and technological innovation in an adaptation of veterans' testimonies detailing US military interrogations in Iraq during the American counter-insurgency campaign in the early 2000s. It uses VR technology to immerse participants in the minds of people who experienced torture and interrogation during the war to understand its current social and psychological consequences. The powerful content of this artwork focuses on the impact of war and trauma on veterans, and utilizes the power of VR as a medium to evoke empathy, understanding and awareness. This work was developed at the Electronic Visualization Lab in Chicago through a unique cross-disciplinary international collaboration between artists, scientists, and researchers from five different Universities. The methods developed for this project allow hands-on education of virtual reality by letting students create their own virtual environments and exhibit them in the CAVE2 quickly. These methods have been recently adapted by Design and Computer Science courses at the University of Illinois at Chicago.

**Keywords**: virtual reality, CAVE2™, art, storytelling, interaction

**Concepts**: • **Computing methodologies ~ Computer graphics ~ Graphics systems and interfaces;** *Virtual reality;*

*e-mail:datsoupi@gmail.com

SA '16 VR Showcase, December 05-08, 2016, Macao
ACM 978-1-4503-4542-2/16/12.
http://dx.doi.org/10.1145/2996376.2996383

## 1 Introduction

With the advancement of technology, virtual art gradually moved out of research laboratories and scientific centers into galleries, museums and public exhibitions. The Oculus Rift, Leap motion, Google Glass, Kinect, HoloLens, Unity, and other virtual technologies changing the way how contemporary VR art projects are developed and realized. VR art has however been consistently limited by the fact that there are no cross-platform standards allowing seamless portability of Virtual Reality Environments (VREs) and interfaces between various domains and technologies. The development of the portable versions of the VRE for different technologies became possible with the advancement of the Unity3D game engine creating multiplatform 3D interactive experiences. We describe the concept and the development of the Oculus Rift version of the virtual reality art performance *Hearts and Minds: The Interrogations Project* originally developed as the first performance using a CAVE2 environment.

One of the challenges for makers of immersive virtual reality artworks, particularly those developed in CAVEs, is that these artworks tend to be more often read about in the literature than experienced first-hand. The CAVE2 at the EVL for example is a graduate research lab facility with keycard access at the center of a large engineering building on the UIC campus. *Hearts and Minds* has been shown there at several special events and on specially arranged tours, but it is not the ideal situation for an artwork intended to reach a broad audience. While it is not possible to transport the large-scale CAVE2 environment, because *Hearts and Minds* was developed in Unity, it is possible to port the application to other platforms. In order to make the work more accessible for public, researchers, educators, veterans' groups and others particularly concerned with the issues highlighted by the work, the portable version of the project was developed for Oculus Rift platform.

## 2 Project Concept and Architecture

During the American-led counter-insurgency and counterterrorism campaigns in Iraq in the years following September 11, 2001, the torture and abuse of detainees was a commonplace tactic. However, there is little systematic research on the causal effects of violence on the memories, political attitudes, and psychology of American soldiers who were involved in the acts of interrogation and torture. As they were returning from wars in Iraq and Afghanistan, it has become clear that some participated in interrogation practices and acts of abusive violence with detainees for which they were not properly trained or psychologically prepared. The mental health impact of deployment during these wars is still being researched, as many veterans are at risk for developing chronic PTSD. Although the use of a VR for research and clinical treatment of PTSD is not novel, our project will allow exhibition participants to explore the psychological after effects and societal implications that torture and interrogation has on soldiers during war. The immersion provided by VR helps a participant to understand real world events and current consequences of interrogation and torture in the age of war through the minds of people who experienced them.

The structure of the project consists of nine VR Environments (VREs) linked together. The temple panorama, which is the entry point to the project, is positioned in the center. As the audience enters this space, they become acquainted with the four soldier characters who will be the focus of work, through monologues describing their reasons for enlisting in the military. The monologues are based on interviews of American soldiers conducted by political science researcher, Dr. John Tsukayama [Tsukayama J. 2014].

In *Hearts and Minds*, we navigate in 3D through ordinary domestic environments, such as a boy's bedroom, a kitchen, a living room or a suburban yard. In each of the rooms certain objects are "triggers"; when they are activated the room falls away and the scene moves to surreal desert landscapes, where soldiers recount acts of torture and its consequences. Each of the five rooms represents a different aspect or stage of the complex narratives of torture and its aftermath that the soldiers revealed. Four open doors allow participants to peak into ordinary domestic environments connected to this central panorama: a child's room, kitchen, living room and the backyard. Each connected room contains four interactive objects, the memory triggers, which serve as portals to the linked panorama environments. Users can click the objects using a virtual laser pointer to transport themselves into a surreal panorama connected to it, which is intended to represent a subconscious space of interiority, and to provide the audience with a sense of intimate communication with the voices they will hear. The room fades out and participants hear short monologues about the solders' wartime experiences. Once the story is complete, the war panorama fades out and users are transported back into the room. Once all four rooms are fully explored, the user is returned to the temple scene, which fades out to red accompanied by a heartbeat sound.

In the portable Oculus Rift version of the project, navigation is performed with typical first-person shooter interaction using an Xbox 360 controller. Instead of physically navigating through the CAVE2 space, movement is directly controlled by the joystick. Participants can look around inside the Oculus Rift headset and listen to the narratives through the stereo audio headset. Targeting of trigger objects is accomplished by using the orientation of the Oculus headset instead of pointing with the Wand in CAVE2. The performance navigation in which a performer could use his physical position and orientation in the virtual environment by walking to interactive zones was converted into a first-person interaction in which the participant had to navigate to each interactive entry using the joystick on the controller. The immersion of the Oculus Rift virtual reality headset allows for a personal type of affective experience of the narrative, activated through the visceral immersion into the visual and auditory environment. The powerful content of this artwork focuses on the impact of war and trauma on veterans, and utilizes the power of VR as a medium to evoke empathy, understanding and awareness. This work explores the aesthetic possibilities of new visualization technology, confronts some terrible truths about prominence and alarming regularity of sanctioned torture and provides a platform for discussion about military interrogation methods and their effects on detainees, soldiers, and society.

## 3 Development and Technology

The VRE was developed using the Unity game development platform (Unity Technologies Inc., CA) and the getReal3D plugin (Mechdyne Corporation), which were linked together to produce a system that achieves a novel direct output of the interactive 3D environments in the CAVE2 environment. Current applications for CAVE2 environment typically use Omegalib: a specialized application framework for hybrid reality display environments. However, Omegalib lacks the video game level of interactivity that Unity provides. To synchronize Unity across the CAVE2 cluster we used the getReal3D plugin. User interaction was scripted using the Omicron input abstraction library developed by EVL [Omicron, 2016]. We developed a plugin to streamline the integration of any Unity 3D application in the CAVE2 system, which was not possible before. By providing a series of tools to simulate the virtual reality interactions of CAVE2, we now allow non-programmers like artists, designers and undergraduate science students with minimal programming experience, to develop projects without the requirement for high-level programming frameworks such as Omegalib.

## References


FEBRETTI, A., NISHIMOTO, A., THIGPEN, T., TALANDIS, J., LONG, L., PIRTLE, JD., PETERKA T., VERLO, A., BROWN, M., PLEPYS, D., SANDIN, D., RENAMBOT, L., JOHNSON, A., AND LEIGH, J. 2013. CAVE2: A Hybrid Reality Environment for Immersive Simulation and Information Analysis. *In Proc. SPIE 8649, The Engineering Reality of Virtual Reality* 2013, 864903.

Mechdyne Corporation, getReal3D, accessed 06/8/2016, http://www.mechdyne.com/getreal3d.aspx

Omicron, accessed 06/8/2016, https://github.com/uic-evl/omicron

TSOUPIKOVA, D., RETTBERG, S., COOVER, R., AND NISHIMOTO, A. 2015. The battle for hearts and minds: interrogation and torture in the age of war. In *Proceedings of SIGGRAPH 2015 Posters*, ACM Press/ACM SIGGRAPH, New York, Computer Graphics Proceedings, Annual Conference Series, ACM, Article No. 12.

TSUKAYAMA, J. 2014. *By Any Means Necessary: An Interpretive Phenomenological Analysis Study of Post 9/11 American Abusive Violence in Iraq*. PhD thesis, University of St Andrews, UK.

# Tunable, a VR reconstruction of "Listening to a Guqin" from Emperor Zhao Ji

Chen Yuan,* Ze Yun†
School of Creative Media, City University of Hong Kong

**Figure 1:** *Screen Capture of VR Reconstruction*

## Abstract

With rumors of painted by the Emperor Zhao Ji, who subjugated his nation of Song, as a portrait of himself and his corrupted courtiers Cai Jing and Tong Guan. The work of art has been highly valued not only for being a masterpiece of the painter's unique portrait painting but also for its superb skills in composition, ingenuity, shaping, depicting and tinting. With a portrait aspect ratio so tall and thin of 1:3, the painter arranged all the figure and surroundings in the bottom half and the figures themselves bottom quarter only. The composition leaves out the space for sky and ground as the skill in later ages named "blank leaving", results in an ethereal and detached individual space, the orientation of still objects and figures wraps up the space towards inside while the pine tree reaching high up to the sky extended the dimension in altitude. Thus, the consideration of space makes it suitable for being a reference of recreation in virtual reality. The Tunable laid its foundation on prior research in the background and content of the painting and then step further in textual research of objects while bringing back the core elements hidden behind the image, the music. The painter and emperor compressed the feeling of music and motion into a still image, yet we are trying to bring it back to life.

**Keywords:** virtual reality, Chinese painting, interactive design

**Concepts:** •**Human-centered computing** → **Virtual reality;** •**Computing methodologies** → **Image processing;** *Motion capture;*

*e-mail:yuanchensam@126.com
†e-mail:geefalia@sina.com

SA '16, December 05-08, 2016, , Macao
ISBN: 978-1-4503-4542-2/16/12
DOI: http://dx.doi.org/10.1145/2996376.2996379

## 1 Visual Representation

### 1.1 Immersive Scene Construction

The aim of Tunable is an immersive audio-visual experience inside this traditional Chinese painting Listening to a Guqin. To create three dimensional scene from the original painting, we carefully observed the spatial arrangement of composition. The musician and audience are sitting roughly on the edge of an empty space facing inside, together with the trees and calligraphy on the original composition, they create a scene wrapping towards center. Which is just suitable for placing viewpoint within. Enormous research on reconstruction of three dimensional scene has been conducted afterwards, including every individual item appeared and all the figures as well. The research covers a wide range of subjects from textual analysis of historical correctness, to painting skill and the fading to colors. The result is a scene that is both a restoration of the court event from Song dynasty and a generative Chinese Gongbi painting from all perspective.

### 1.2 Character Design

Based on textual research from former scholars and the study of Chinese Gongbi painting from Song Dynasty, the 3D models and animations of each figure within the scene has been carefully designed. Take the musician as an example. The musician in the middle of composition appears to be the main character, sitting on a stone chair and dressed like a Taoist priest. As for the gesture, with his head slightly lowered and body tilted to the front, his both hands right on the Guqin and seems gently playing music. A closer look on hands indicate that he is holding the string with the left index finger and toggling with the right hand, the stillness of image does not weaken his momentum and dynamic at all. Musical performance Within the "eighteen Guqin playing gestures", several most common and typical moves are rigged, animated and aligned with arm movement. The musician uses his left hand for the tune and plucks the strings with right hand using multiple techniques.

### 1.3 Rendering Simulation

The usage of lines has been a critical skill in Chinese painting and especially those from Song Dynasty. The artist uses the solidarity, density, smoothness and thickness to express the shape and texture of an object. Take the face as an example, due to the absence of

**Figure 2:** *Pen Stroke Simulation with Edge Detection Method*

shading skills, it is the only way to emphasize the facial features. Here we programmed a special shader to simulate this lining technique and its effect on object and figure painting. Since the lines here are not restricted to the outlines of each individual object, here we introduced an edge detection algorithm that is based on both the depth and normal seen from the virtual camera. Therefore we are able to abstract both the outline and inner edges from the original mesh. A half transparent stroke with a color of ink is then overplayed upon the original rendering from viewport. Together with a smoothing component we managed to restore the usages of lines in the original work of art.

## 2 Interactive Design

### 2.1 Scene Build-up

3D models are implemented into the scene strictly according to the original painting in scale and position, together with bone rigging animations and realistic cloth and physics environment simulation. Besides the object and figures, there is also the calligraphy of the title and poetry floating around between the object and background.

### 2.2 virtual reality

To achieve the effect of merging into the painting, the audience position is tracked and mapped in 1 to 1 scale into the virtual space. We are using the Kinect motion tracker to accurately locate the viewpoint and continuously tracking the movement within the scene. Virtual camera for VR image has been placed according to this space and render viewport according to the orientation of Oculus Rift.

### 2.3 3D reconstruction

With the development of technology, the audience is no longer easily satisfied with only the vision in virtual reality space, and it is one significant component for enhancing the realistic and degree of reduction to reconstruct proprioception for the user. Here we are using the depth image of Kinect sensors and mapping it back to 3D space to generate a real-time 3D point cloud as a visual representation of the audience himself.

### 2.4 Interactive experience

To echo with the elegant and refined atmosphere of the original painting, we did not introduce too obvious and abrupt interaction into this process of appreciation, only the calligraphy floating around following ones sight and the servant saluting when he found the audience looking. The aim of this interaction is to be as transparent as possible yet the audience has been part of the painting himself while appreciating.

## 3 Future Vision

As a starting point of a series of study upon Chinese paintings and an experiment for immersive experience as a new way of appreciating these art works. Further works can be done regarding both technical and aesthetic aspects. The work showed a promising vision of bringing life back to masterpieces in traditional Chinese paintings.


**Figure 3:** *Reconstructed Scene Overview*

## Acknowledgements

We would like to extend our warm appreciations and gratitude to the following persons for making this project possible. Their supports, inspirations, criticisms, comments and suggestions contribute a valuable strength to make this paper presentable and knowledgeable. We would to acknowledge our helpful and over-supportive advisers, Prof. Tamas Waliczy, Dr. Ip Yuk-Yiu and Dr. Zheng Bo's contribution in the ideas to find the best solutions to our dilemma. We would also like to thank them for motivating us to do our best. To Mr. Li Yue for his exellent skill in musical performance and his generousity of handling his piece of music for us. To our schoolmates Bruce Liu Xiaobin, Echo Zhao Qian, and all the other MFA fellows who helped us in making, testing and documenting this project and kindly provided their advice on how to improve it. Additionally we would like to express our gratitude to our former Dean, Prof. Jeffrey Shaw for introducing us to this programme and for the facilities without which this project could not be accomplished. To those who are not mentioned but whose help are truly contributing in adding some significant information will not be forgotten, we thank you and best wishes for you all.

# Interactive virtual reality animation *STRAY SHEEP*

Tomonari Michigami
MFA Computer Art School of Visual Arts

Figure 1 Interaction with the sheep

## Abstract

*"STRAY SHEEP"* is a virtual reality character animation, which uses Oculus. This narrative film follows a quirky and curious lost sheep. The viewer will explore various imaginative environments made from common items of a child's daily life by following the sheep along its journey. The project *"STRAY SHEEP"* explores and illustrates, how narrative content and user interaction can coexist in VR.

## 1.Technical interest

Unlike most games, the audience is not required to learn or follow any rules. Intuitive interaction allows the audience to experience the VR story like a film. Interactions between the sheep and viewer determine the course of the story the audience can see a different story every time. This is exactly what real time graphics can do.

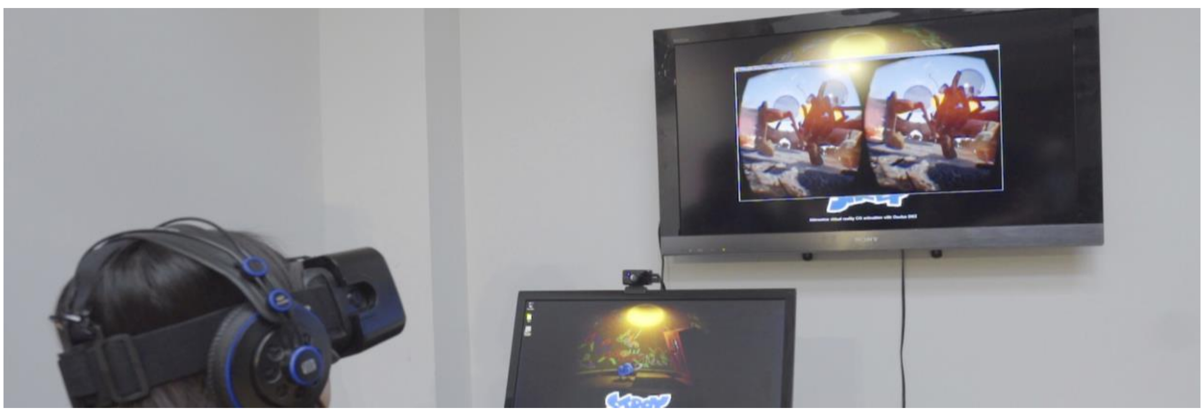


Figure 2 The viewer watching the animation (Photo is taken by Darren Santa Maria at MFA Computer Art School of Visual Arts)

**Keywords:** Animation, Art & Design, Real-Time, Storytelling, User Interaction, Virtual Reality

**Concepts: •Human-centered computing → Interaction design;** *Interaction design theory, concepts and paradigms;*

E-mail: naritomo@me.com



SA '16 VR Showcase , December 05-08, 2016, , Macao
ACM 978-1-4503-4542-2/16/12.
http://dx.doi.org/10.1145/2996376.2996384

## References

Michigami, Tomo. 2015 "STRAYSHEEP_Midyear_Preview." *YouTube*. http://www.youtube.com/channel/UCT3470TKYTawbNPHTSpVGfg .

Michigami, Tomo. 2015 "Minecart Coaster." *Vimeo*. https://vimeo.com/134675050.

Michigami, Tomo. 2015. "Unreal Engine 4 360_scene_creature." *YouTube*. https://www.youtube.com/watch?v=XViVXOqj56o.

Epic Games. 2013."Unreal Engine 4 "Elemental" Demo for PlayStation 4." *YouTube*. https://www.youtube.com/watch?v=8saq9O4pWPQ.

## Acknowledgements

To everyone who is around me, for all your support.

# Real-Time Diagnostic Data in Multi-User Virtual Reality Post-Stroke Therapy

Daria Tsoupikova*[1], Kristen Triandafilou[2], Saumya Solanki[1], Alex Barry[2], Fabian Preuss[3] and Derek Kamper[4]
[1]University of Illinois at Chicago, [2]Rehabilitation Institute of Chicago, [3]University of Wisconsin Parkside,
[4]North Carolina State University

**Figure 1**: *Virtual environments and multi-user interaction within the immersive scene. Participants play three scenarios designed to promote repetitive practice of specific movements. Left: Tracing game; Center: Ball game; Right: Food Fight game*

## Abstract

We present a novel multi-user virtual reality (VR) environment for post-stroke rehabilitation that can be used independently in the home to improve upper extremity motor function. This project represents a collaborative multidisciplinary approach to upper extremity therapy that reinvents engagement with health, social communication and well-being for stroke survivors. This work is in the pre-clinical phase of an ongoing interdisciplinary research effort at the Rehabilitation Institute of Chicago which involves a team of artists, engineers, researchers and occupational therapists. This work bridges art, science and healthcare research. Our project attempts to extend traditional occupational therapy and make virtual reality art accessible for all people. It inspires a playful and natural social interaction in the comfort of the home setting for stroke survivors with hemiparesis by furthering social engagement through the rehabilitation exercises. It fosters interaction and collaboration between individual users and encourages the exchange of user-generated content. At the same time, the system captures continuous kinematic data, which can be used to better tailor therapy to the individual.

**Keywords**: Virtual reality, immersive environments, design, visualization, rehabilitation, stroke

**Concepts**: • **Computing methodologies ~ Computer graphics ~ Graphics systems and interfaces;** *Virtual reality;*

---

*e-mail:datsoupi@gmail.com.

SA '16 VR Showcase, December 05-08, 2016, Macao
ACM 978-1-4503-4542-2/16/12.
http://dx.doi.org/10.1145/2996376.2996387

## 1 Introduction

Stroke is a leading cause of major, long-term disability in adults in the US [Go, et al. 2014], typically impacting upper extremity function. While repetitive practice can lead to neurological changes [Kleim, et al., 2002], these therapy regimens can become monotonous and arduous, eventually leading to reduced adherence and compliance with therapy [Dunkan, et al. 2002]. The monotony is compounded by difficulties with travel and scheduling which limit face-to-face interactions with therapists. Virtual reality (VR) has the potential to improve engagement and compliance while providing a means for client-therapist interaction [Novak, et al. 2014]. A multi-user VR environment enables the stroke survivor and therapist to share the same virtual space even though they may be physically separated by a considerable distance. It also provides new possibilities for therapy by continuously monitoring client movement during the session, permitting facile alteration of task parameters to maintain an appropriate level of challenge, and providing biofeedback such as the display of a movement trajectory.

## 2 Virtual Environment

Our project is designed to reach a large number of stroke survivors who currently have limited access to therapy. The system is centered on competitive and collaborative multi-user interaction and inspirational art created with 3D computer graphics. The goals of our project are to design and test a multi-user virtual reality environment for upper extremity rehabilitation following stroke. This would enable home therapy, but with fellow stroke survivors and/or therapist rather than in isolation. We hypothesize that this will improve engagement and motivation.

This is a low-cost system adapted to everyday environments and designed to run on a personal computer. Up to 4 users can connect via the Internet to a single server which updates the overall scene and sends the proper view to each user's computer for display. Each user's movement is tracked locally using a Kinect system

(Microsoft Corp., Redmond, WA). The Kinect joint angles are mapped to a custom skeleton which defines the avatar representing the user in the VR environment. The avatars can interact with virtual objects located within the scene. Users are connected through audio as well as video. The VR environment was created using Unity 4 (Unity Technologies, San Francisco, CA) and C#.

Our system features three different multi-user scenarios that encourage repetitive task practice, collaboration and competitive interaction. The goal is to encourage upper extremity movement, especially to locations in the workspace not typically explored by the user. The three scenarios are named: Ball, Tracing, and Food Fight (Figure 1). In the Ball game, participants hit a ball back and forth across a table using left and right hands. The collisions and dynamics of the ball and other game objects are determined by Unity's physics engine. This can be a collaborative game, in which the participants try to make as many successful passes as possible before the ball falls off the table, or a competitive game in which each player tries to hit the ball past the other player. In the Tracing game one participant draws a 3D trajectory in the air and other participants erase the trajectory. The curve is anchored to the avatar, such that the user must reach with the arm rather than using the trunk. To help with the perception of depth, we designed and scripted the semi-opaque 3D cube outlining the constantly changing boundaries of the drawn 3D shape in real time. In this game we measure accuracy and speed of motion using custom developed algorithms. In the Food Fight game participants grab and throw different food items. We integrated mesh deformations and special effects for crashed objects.

We have examined the robustness of the system through installation in a public forum (Fig. 2) and through testing with stroke survivors (Fig. 3). Modifications, based on acquired feedback, are currently being implemented prior to initiation of a home-based study.


**Figure 2:** *Virtual Reality system and interaction with the immersive environment in the gallery setting. Image courtesy Erich Theiss, National Museum of Health and Medicine, Chicago.*

## 3 Demonstration

Our presentation will demonstrate our system with multi-user stroke-specific games as a tele-immersive network event in the gallery setting. We will connect to the server at the Rehabilitation Institute and have a fellow participant interacting with gallery demo participants remotely in the virtual environment. We will demonstrate three stroke-specific games requiring repetitive hand and arm coordination and collaborative interaction.

The work offers a models for social and cultural engagement with post-stroke therapy and addresses the efficacy of home-based multi-user environments in promoting therapeutic training. The visualization is used to bridge clinical assessment, challenge, collaborative interaction and fun.

## Acknowledgements

Funded by the US Department of Health and Human Services, National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR), Grant #H133E070013. IRB#: STU00200533 Approved by Northwestern University IRB.

## References

GO A. S., ET AL. 2014. Heart disease and stroke statistics--2014 update: a report from the American Heart Association. Circulation. 129(3), e28-e292.

KLEIM, J., ET AL. 2001. Motor-learning dependent synaptogenesis is localized to functionally reorganized motor cortex. *Neurobiology of Learning and Memory*. 77(1), 63-77.

DUNCAN, P. W., ET AL. 2002. Adherence to postacute rehabilitation guidelines is associated with functional recovery in stroke. *Stroke.* 33(1), 167-77.

NOVAK, D., NAGLEL, A., KELLER, U., AND RIENER, R. 2014. Increasing motivation in robot-aided arm rehabilitation with competitive and cooperative gameplay. *Journal of NeuroEngineering and Rehabilitation*, 11, 64.

# VRgram

Tamar Hei Ting Wong*, Kee Ka Ki Wong
School of Creative Media, City University of Hong Kong

## Abstract

In this work, we will present our virtual reality experiencing application, VRgram. We will describe its concept, mechanism and functionalities.

**Keywords**: Virtual Reality, Online platform, Multi-Editing

**Concepts**: **Virtual worlds software**; Interactive games; Virtual reality

## 1 VRgram

VRgram is a virtual reality experiencing application on smartphone. Users can log in via their Facebook account and control their avatar to explore/create their own created 3D virtual immersive environment. VRgram provides a VR scene editor to let users edit/create 3D objects inside VR world and an online platform that let the users edit a VR environment with their friends synchronously.

## 2 Objective

The main objectives of this project are to explore the latest VR technology applied to a mobile application, to create a new VR experience and to develop a multiple user virtual reality editing platform. We would like to discover the new way of human interaction between user's input and VR device.

1. Develop a platform that allows users to explore and share customized experience in 3D Virtual Reality.
2. Develop a mobile application that lets users experience Virtual Reality in anytime, anywhere.
3. Develop an application that allow user to create their Virtual Reality experience with their friends in anywhere.
4. Make Virtual Reality experience shareable.
5. Popularize Virtual Reality technology and experience into our society

## 3 Virtual Reality

Virtual Reality emerged as new trend of technology in 2016 although the idea is not new. A user gets immersive images by wearing a blindfolded headset instead of traditional display screen. The headset is able to track the motion of user's head and give an instant corresponding rotated images to user in the virtual world. The user can get an instant response and interact with the computer in virtual environment.

---------------------------
*e-mail:tamrwong3839@hotmail.com

SA'16 VR Showcase , December 05-08, 2016, , Macao
ACM 978-1-4503-4542-2/16/12.
http://dx.doi.org/10.1145/2996376.2996380

**Figure 1**: *Mobile Virtual Reality Experience*

## 4 Past/Now

Virtual Reality is not a new thing and it has mass aspects of application. It emerged in a large range such as military, education and entertainment in past. Virtual reality devices were expensive and composited with a lot customized components. NASA developed a head-mounted stereoscopic display system, the Virtual Interface Environment Workstation in 1990. In that time, this headset could generate only a very simple 3D artificial environment and the cost of equipment was not affordable to normal user. The VR technology was mainly utilizing in research purpose. Now, the cost of VR device has become significantly cheaper and more affordable to regular people. Furthermore, we can generate more realistic 3D environment in computer. Google Cardboard offers a cheap choice for those people who have never experienced virtual reality before and facilitates the advancement of VR applications in the market.

## 5 How?

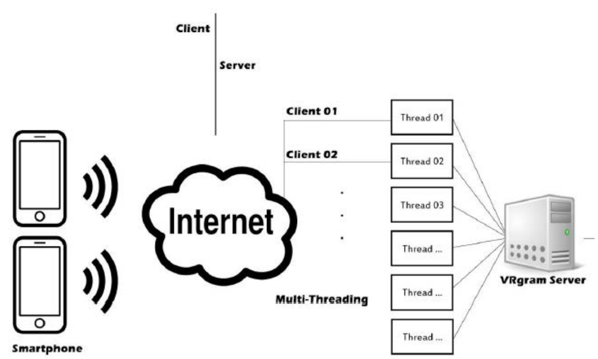



**Figure 2**: *Mechanism of Client-Server Connection*

As shown in Figure 2, the server is the data information center of integrated network mechanism. It takes responsibilities of transiting all users update information exchange and controlling party session.

The smartphones take the roles of rendering immersive virtual images, retrieving update information from server and as a client-side application that interacts with user.

### 5.1 Login

Firstly, the users are required to login their Facebook account either with party invitation code or not. They can opt for either creating new VR (Virtual Reality) scenes or joining the existing editing party of their friends.

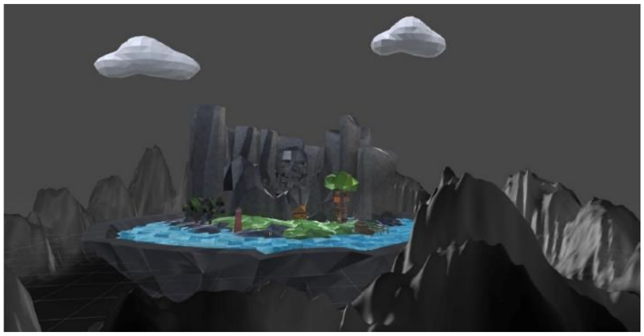


**Figure 3**: *Virtual Reality Scene*

### 5.2 Edit scene

In editing scene, the users can select their objects and add new objects into the scene by pressing buttons on the joystick. Furthermore, they can send the invitation code to their friends and ask them to join their current party session and edit the same scene simultaneously.

### 5.3 Objects

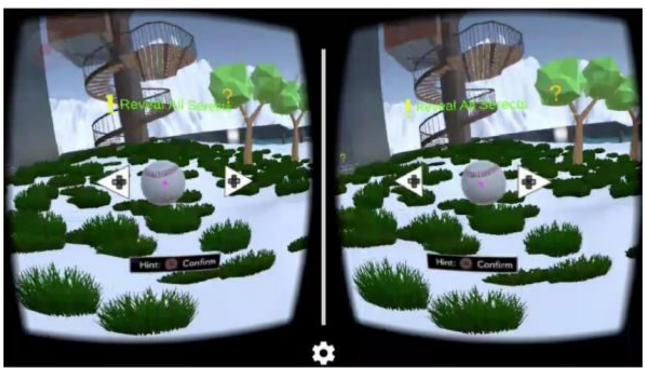


**Figure 4**: *Editing 3D Object*

The objects are predefined in the application. Each user can select a particular object among the model sets. Objects can be rotated, shrunk and escalated during the deployment. The users can cooperate with each other to create any unique scene they want.

### 5.4 Screen-Shot capture

The users can call up a menu by pressing "start" button and select "Screenshot" tab in order to capture the moments they have made inside the scene. The captured photograph will be automatically saved in the local storage of their smartphone. The users can share those images on the internet.

**Figure 5**: *Captured screenshot in VR scene*

## Acknowledgements

This work was mainly based on our Final-Year Project. We would like to thank our FYP advisors, Dr. Hongbo Fu and Dr. Chong-Wah Ngo.

## References

NASA, 1990. THE VIRTUAL INTERFACE ENVIRONMENT WORKSTATION.
https://www.nasa.gov/ames/spinoff/new_continent_of_ideas/#.V9wGSJh96U.

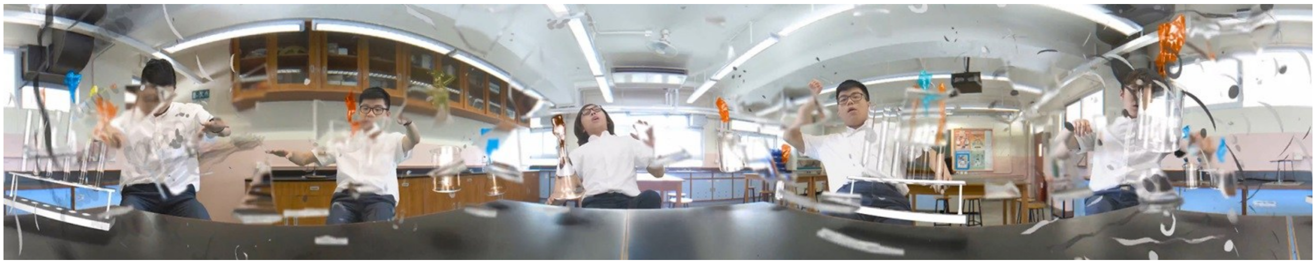
GOOGLE, 2016. TILT BRUSH/ TILT BRUSH GALLERY.
https://www.tiltbrush.com/.

SMART2IT B.V, 2016. SMART2VR.
http://www.smart2vr.com/.

ROOMLE ,2015. ROOMLE.
http://www.roomle.com/.

# Rhapsody

Ken LEE C. K.
Lecturer, Hong Kong Design Institute (HKDI, Member of VTC Group)



## Abstract

Rhapsody is a music video created with live-action video and visual effects. Audience can experience a fantastic environment with virtual reality device.

Urbanite's life is busy for the miserably long working hours. An old photo on your office desk may bring you back to the happy memories in high school: laughing in classroom, chasing in corridors, escaping from teachers, as well as enjoying musical concerts in the assembly hall.

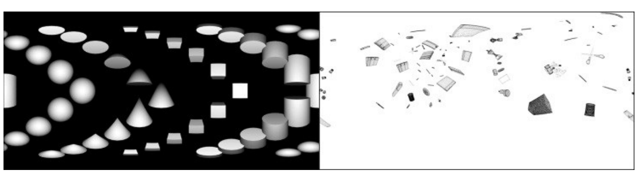
**Keywords**: virtual reality, vr, immersive, visual effects

**Concepts**: • **Human-centered computing;** Interaction paradigms; *Virtual reality;*

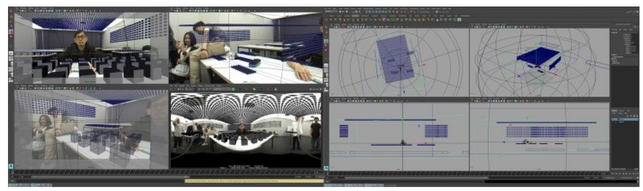
## 1 Design

To further extend the potential of virtual reality, we designed different magical moments, such as frozen time, upside down camera angle and zero gravity, to enhance the visual experience.

## 2 Frozen Time

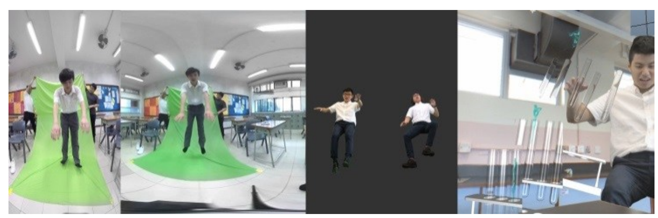


Frozen Time applied the 3D production elements in virtual reality. It was a challenge to apply camera tracking in 3D production process, which was hardly to merge the 3D elements into the panorama camera background.



Autodesk Maya was used for the 3D modeling, texturing, lighting and motion.

## 3 Zero Gravity



Zero Gravity combined different footages by normal digital camera and 360 immersive camera. To enhance the zero gravity, we need slow motion production. However we could only get one with 15 to 30 fps. By adjusting the speed and perspective, the effect was completed in post-production compositing.

## 4 Upside down

Upside down was another testing of camera angle design in virtual reality environment. We tried to create an imbalance audience experience by changing the up and down camera angles.

## 5 Conclusion

Virtual reality provided a unique visual experience and new platform for video production. Not only the changing of shooting

*e-mail:kenl@vtc.edu.hk.

SA '16 VR Showcase , December 05-08, 2016, Macao
ACM 978-1-4503-4542-2/16/12.
http://dx.doi.org/10.1145/2996376.2996381

method and perspective views, but also a new way of thinking and post-production design.

## Acknowledgements

The music provided by Universal Music Hong Kong

*The Wynners. "溫拿狂想曲". Universal Music Hong Kong. 1975*

## References

BRINKMANN, R., 2008. *The art and science of digital compositing: techniques for visual effects, animation and motion graphics,* Morgan Kaumann/Elsevier, Burlington.

LANIER, L., 2010. *Professional digital compositing*: *essential tools and techniques,* Wiley, Indianapolis

KERLOW, I. V., 2009. *The art of 3D computer animation and effects*, John Wiley and Sons, Hoboken, N. J.

WOODY, B. G., 2007. *Exploring visual effects,* Thomson Delmar Learning

# Journey to the Centre of the Cell (JTCC)*: A 3D VR experience derived from migratory breast cancer cell image data

John McGhee [1], Benjamin Bailey [1], Robert G. Parton [2], Nicholas Ariotti [2], Angus Johnston [3]
[1] 3D Visualisation Aesthetics Lab, The University of New South Wales, Australia.
[2] Institute for Molecular Bioscience, The University of Queensland, Australia
[3] Pharmacy and Pharmaceutical Sciences, Monash University
* The JTCC is a research initiative funded by the ARC Centre of Excellence in Bio-Nano Science.

## Abstract

Journey to the Centre of the Cell (JTCC) is a multi-disciplinary initiative exploring the visualisation of nanotechnology. This particular VR research work demonstrates how Virtual Reality (VR) on HTC Vive head mounted display (HMD) can be used as a platform to interact with cell structures in a compelling immersive experience. Contemporary scientific cellular imaging modalities such as Fluorescence Microscopy and Serial Block Face Scanning Electron Microscopy can capture detailed cross-sectional image slices of molecular structures. The subsequent post-processed 3D data visualisation can provide additional educational insight for lay users. For the artist-researcher, this potential to educate raises valuable questions for further investigation, such as what 3D visualisation narrative should we adopt?

In research work being carried out at the 3D Visualisation Aesthetics Lab (VAL) at UNSW Australia, arts-led modes of data augmentation are being developed to widen access to lay users, such as undergraduate science students. The prototype VR experience allows users to see nanoparticle cellular interactions on the surface of the cell as they enter the internal structure. The immersive visual work is a hybrid of ISO surface data and 3D arts-based representation. The prototype illustrates three cellular processes for nanoparticle internalisation: caveolar, macropinocytic and clathrin-mediated. This work builds on previous visualisation work carried out in the 3D-VAL using clinical imaging data in VR [1][2] for patient communication.

1. Caveolae are 60–80 nm wide pits in the plasma membrane that play a role in endocytosis.
2. Macropinocytosis is an actin-dependent endocytic process that leads to non-selective internalisation of fluid and membrane into large vacuoles (known as macropinosomes).
3. Clathrin-mediated endocytosis is initiated by the binding of a ligand to a membrane receptor.

**Keywords:** visualisation, medical imaging, virtual reality, interaction design, interface design, Microscopy, Science Education and Communication, Serious Gaming

**Concepts: • Human-centered computing ~ Virtual reality; Human-centered computing ~ Scientific visualization;** *Human-centered computing ~ User interface design;* Applied computing ~ Imaging; Applied computing ~ Media arts

[1] e-mail: <john.mcghee@unsw.edu.au>

SA '16 VR Showcase , December 05-08, 2016, , Macao
ACM 978-1-4503-4542-2/16/12.
http://dx.doi.org/10.1145/2996376.2996385

## 1 Workflow

Raw serial block face scanning electron micrographs (Figure 1) are filtered and aligned using the xfalign program in IMOD software. The three-dimensional ISO surface is generated using semi-automated segmentation tools in 3Dmod. The membrane-bound organelles including the plasma membrane, mitochondria, the nucleus, early endosomes and late endosomes are treated as separate objects. All surfaces of each separate object are manually traced every 10 slices and linear interpolation is utilised to fill the contours between these slices. This process is repeated until an accurate three-dimensional representation of all surfaces of each organelle in the cancer cell is generated. Contours are then meshed to generate surfaces. The 3D files are imported to Autodesk Maya for optimising the topology and UV Mapping. Once this process is complete, the model is imported into Unity software to build the real-time interaction and the player controller.

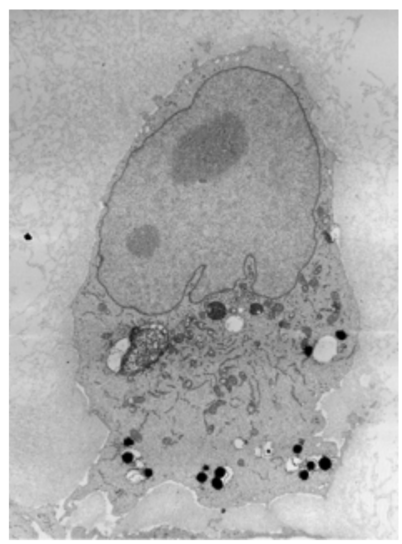


**Figure 1:** *Raw serial block face scanning electron micrographs – Migratory breast cancer cell. Robert Parton, The University of Queensland.*

## 2 Art Direction and Interface Features

The development of the real-time interactive prototype has been carried out in Unity for output on the retail HTC Vive headset. A landscape approach is used, allowing the user to walk on the cell structure and navigate between two levels; the membrane and internal nucleus. These areas are termed 'The Cell Paddock'

(Figure 2) and ‘The Cell Cathedral’. A horizon line has been set up for the player controller on the cell paddock, with a lunar landscape driving the art direction. The interface features are as follows:

1. **Dynamic mapping:** If the user twists the HTC Vive controller a dynamic map appears
2. **Teleporting across the surface:** On both the Cell Paddock and inside the Cell Cathedral
3. **Reactive information panels**: these panels pop up as you approach the cell internalisation process
4. **Portal doorway:** A popup doorway that allows users to navigate between the two levels of the cell
5. **Contextual interaction in the Cell Cathedral:** Users can reach out with the control and touch structures and object audio tagging.

Please see attached video associated to this submission.

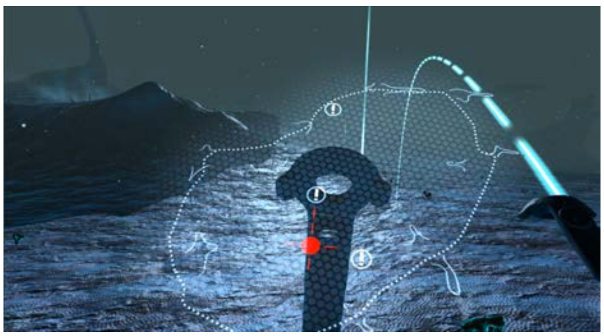


**Figure 2:** *Cell Paddock – Screenshot, John McGhee and John Bailey UNSW Australia*

## 3 Future Development

Commercial game developers have entered the scientific education field with products such as ‘InCell VR’ [3] that allow users to navigate representational cell structures. However, in this collaborative multi-disciplinary work, the 3D-VAL in Sydney uses actual cancer cell data from scientific laboratory microscopes to inform the visualisation process, rather than a purely artistic rendering of the cell. This can potentially provide lay users with a much more informative experiences within the science education and communication sectors.

Two areas have been identified for future development: user-testing with a student cohort and also the introduction of data driven dynamic movement within the cell structure. User testing will compare the JTCC VR’s immersive learning experience with more traditional modes of learning, such as 2D diagrams and 3D animations. Introducing data driven temporal and dynamic components will provide an even more accurate representation of the inner workings of the migratory breast cancer cell, for even greater scientific understanding.

## References


MCGHEE, J. B., THOMPSON-BUTEL, A. G., FAUX, S., BOU-HAIDAR, P., & BAILEY, J. (2015). The Fantastic Voyage: an arts-led approach to 3D virtual reality visualization of clinical stroke data. In *VINCI* Japan.

BUTEL, A. G., FAUX, S. G., BOU-HAIDAR, P., & BAILEY, J. B. (2015). Oral Presentations in Order of Conference Program. The role of personalised virtual reality in education for patients post stroke: A case series. In *International Journal of Stroke*, 10, 40-51.

NIVALVR. InCell VR. 2016 [30/07/2016]; Available from: http://store.steampowered.com/app/396030

# Robo Recall

Hao.Wu*, Tianmin.Xie*, Ning.hu*
Epic Games

**Figure 1**: *Robo Recall*

## Abstract

Robo Recall is an action-packed virtual reality first-person shooter with gratifying gameplay and an in-depth scoring system. Explore immersive environments as you take on a variety of rogue robots, unlock an expanding arsenal of weapons and access all-new challenges.

**Keywords**: virtual reality, motion control, interactive, Unreal Engine, real-time rendering.

**Concepts**: • **Computing methodologies ~ Image manipulation;** *Computational photography;*

## 1 Introducing Robo Recall

Epic Games took to the stage at Oculus Connect 3 today to announce Robo Recall, an action-packed virtual reality first-person shooter with gratifying gameplay and an in-depth scoring system that takes full advantage of the Oculus Touch controllers. In Robo Recall, players explore immersive environments in VR as they take on a variety of rogue robots and unlock an expanding arsenal of weapons. Robo Recall is coming in early 2017 and will be free for all Oculus Rift owners.

In this new Unreal Engine 4-powered game, players earn high scores by using creative combat tactics and skill shots as they teleport through city streets and rooftops in an awe-inspiring ballet of bullets.

"VR provides a level of immersion like never before. Our goal with Robo Recall is to take advantage of these new tools to provide an over-the-top, memorable and replayable experience that defines a new generation of shooter," said Producer Tommy Jacob. "Robo Recall builds on what we learned from Bullet Train in regard to creating an exciting, visceral and comfortable VR experience. We've refined and expanded our Touch integration and interaction mechanics, added free movement teleportation that allows the player to explore the environments and made significant improvements to our art quality."

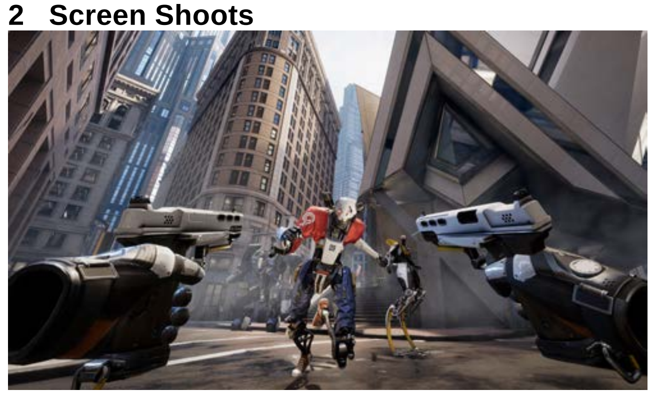
Players can tear apart their interactive robot foes and use them as weapons against the enemy onslaught. Throughout the course of the game, players will unlock, customize and test weapons back at Robo Ready HQ before taking on the increasingly challenging missions that put their newfound skills to the test.

And now, it's time for something new. Using the Oculus Touch controller for locomotion, we've built a world-scale VR gunfight experience with gameplay that weaves in and out of bullet time. Presenting: Bullet Train.

### 1.1 Gameplay

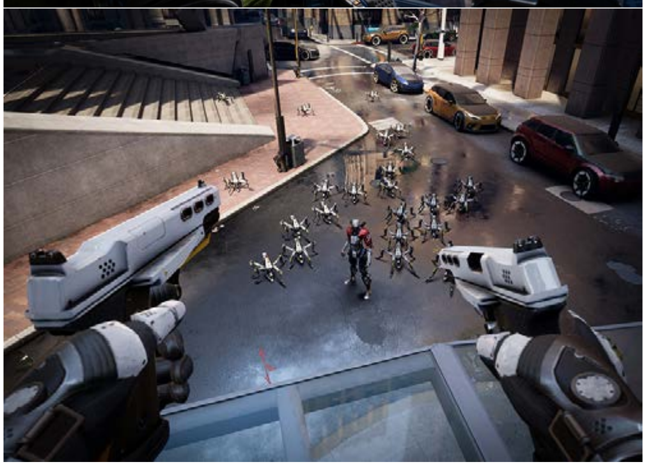
Earn the high score by using various combat tactics and skill shots as you teleport through city streets and rooftops in an awe-inspiring ballet of bullets. Tear apart your interactive robot foes and use them as weapons against the enemy onslaught. Unlock, customize and test weapons back at company HQ before taking on the increasingly challenging missions that put your newfound skills to the test!

## 2 Screen Shoots



*e-mail: Hao.Wu@epicgames.com
Tianmin.Xie@epicgames.com
Ning.Hu@epicgames.com

 SA '16 VR Showcase , December 05-08, 2016, , Macao
ACM 978-1-4503-4542-2/16/12.
http://dx.doi.org/10.1145/2996376.2996386



## Acknowledgements


To Epic Games stuffs, for all the bagels.

| | |
|---|---|
| **Art** | |
| Ignacio Guajardo-Unanue | Sr. Artist - Generalist |
| Pete Hayes | Sr. Artist - Mechanical |
| Aaron Herzog | Lead Animator |
| Scott Homer | Sr. Artist - Generalist |
| Wyeth Johnson | Lead Technical Artist |
| Jerome Platteaux | Lead Artist |
| Edward Quintero | Sr. Materials Artist |
| Mark Van Haitsma | Sr. Hard Surface Artist |
| **Audio** | |
| Zak Belica | Audio Director |
| Tom Bible | Lead Audio Designer |
| Aaron Brown | Audio Designer |
| Paul Stoughton | Audio Designer |
| **Design** | |
| Evan Champlin | Sr. Designer |
| Nick Donaldson | Lead Designer |
| Aaron Johnson | Game Play Designer |
| Brian Kindregan | Narrative Director |
| **Engineering** | |
| Jeff Farris | Lead Technical Engineer |
| Stan Hayes | Game Play Programmer |
| Zak Middleton | Sr. Programmer |
| Seth Weedin | Game Play Programmer |
| Nick Whiting | Lead Engineer |
| **Production** | |
| Dan Bullard | QA Tester |
| Jeff Frost | Lead QA Tester |
| Tommy Jacob | Lead Producer |


## References


Daniel Kayser ROBO RECALL ANNOUNCED AT OCULUS CONNECT 3 https://www.unrealengine.com/blog/robo-recall-announced-at-oculus-connect-3

# Rectifeye: A Vision-Correcting System for Virtual Reality

Pierre-Yves Laffont, Tobias Martin, Markus Gross
ETH Zurich

Wei De Tan, CT Lim
Moveon

Affa Au, Rick Wong
Spacemap


**Figure 1:** *We present a vision-correcting VR system for users who normally wear corrective eyeglasses. Most VR headsets are designed for users with perfect eyesight, and are difficult to use for users with eyeglasses (left). In contrast, we measure the eyeglasses prescription of each user through a smartphone app (center, top) and use it to automatically adjust a virtual reality headset (center, bottom). This system allows multiple users to experience Virtual Reality comfortably without their eyeglasses (right), while still seeing a clear image of the virtual world.*

Most head-mounted displays for Virtual Reality (VR) are designed for users with perfect eyesight. Wearing prescription eyeglasses inside such a headset can be uncomfortable, or even impossible if the glasses do not fit (Fig. 1, left). While some headsets offer manual focus adjustment, they need to be manually adjusted for each user through trial and error, and may not fully correct the user's eyesight. A majority of the population wears prescription eyeglasses (e.g., 65% of the American population[1] as of 2007). In order to realize the potential of immersive VR, we need to ensure that these users can experience Virtual Reality comfortably while still seeing a clear image of the virtual world.

**Keywords:** vision correction, myopia, astigmatism, virtual reality, augmented reality

**Concepts:** •**Computing methodologies** → **Virtual reality;**

**Our system.** We propose a novel vision-correcting system for users who normally wear corrective eyeglasses. For each user, our system automatically adjusts the VR headset according to the user's eyeglasses prescription. Since the optical correction is automatically embedded into the headset, the user no longer needs to wear eyeglasses inside the headset or manually adjust wheels and knobs. The key idea behind our system is to determine the user's eyeglasses prescription using a lightweight method, and use it to drive the automatic adjustment of the headset optical properties. The adjustment can be repeated for each user, enabling the headset to be passed around and automatically providing a customized and appropriate adjustment. The process consists of two steps, illustrated in Fig. 2:

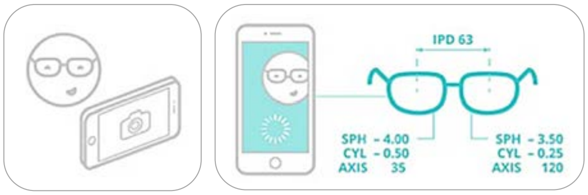
1. **Measurement of the user's eyeglasses prescription.** First, the user and eyeglasses are scanned using the smartphone's camera. An objective estimation of the user's eyeglasses prescription is inferred through a new video-based method that we developed; this step will be described in a separate technical papers submission. The estimated eyeglasses prescription is stored on the smartphone and associated to the user's profile, as illustrated in Fig. 1 (second column, top).

2. **Automatic adjustment of the VR headset.** We built a prototype vision-correcting headset based on a Samsung GearVR (Fig. 1, second column, bottom). The original headset is augmented with the ability to adjust the focus automatically based on the estimated prescription, and enables the correction of myopia and hyperopia between -6D and 1D. We adjust the position of each lens in the headset with servomotors, which are controlled remotely to take into account the user's eyeglasses prescription. While the focus could be adjusted through electronically tunable lenses or by modifying the position of the screen, our solution enables the independent correction of each eye, and a wide field of view comparable to the original headset; it is also cost-effective as it preserves the original headset lenses. The modified headset is fully functional and retains the original capabilities of the Samsung GearVR, including motion tracking sensors, touchpad, and compatibility with the Oculus software platform.

**Validation.** It is difficult to reproduce what a human eye sees using a camera; instead, we validate the vision-correcting capabilities of our prototype through simulation. We generate images of the smartphone display, as seen through the headset lens, using ray-tracing and the Gullstrand eye model [von Helmholtz et al. 1909]. This well-known model is used in biomedical optics to simulate the human eye and better understand eye defects such as myopia, hyperopia, or astigmatism. The model is initialized using values from [Fink and Micol 2006], which correspond to an unaccomodated eye with ideal vision, and is adjusted to simulate different degrees of myopia. Fig. 3 shows simulation results for a user with -2D to -6D myopia on both eyes. Myopic users see a blurred version of the virtual world when the headset lens is placed at its default position (with a virtual image at infinity); in contrast, the same user sees sharp images of the virtual world with our adjusted headset.

[1] http://www.visionmonday.com/article/americans-embrace-vision-correction-in-larger-numbers/


SA '16, December 05-08, 2016, , Macao
ISBN: 978-1-4503-4542-2/16/12
DOI: http://dx.doi.org/10.1145/2996376.2996382




(a) Measurement of the user's eyeglasses prescription

(b) Automatic adjustment of the VR headset

**Figure 2:** *Overview. Our system consists of two steps: (a) The user's eyeglasses prescription is estimated based on a video captured with a smartphone, and associated to the user's profile. (b) The headset is then automatically adjusted according to the eyeglasses prescription, allowing the user to use the headset without eyeglasses and to see the virtual world clearly.*

**Related work.** Most headsets available today are designed for users with perfect eyesight. For example, the consumer version of Oculus Rift allows manual adjustment of the IPD (distance between eyes), but no adjustment of focus. The Samsung GearVR includes a focus wheel to manually adjust the position of the screen, which applies the same optical correction to both eyes. The GO headset by Immersion VRelia enables the correction of myopia independently for each eye. All these adjustments are manual and subjective, using a trial-and-error approach which needs to be repeated for each user. Recently, Konrad et al. [2016a; 2016b] use focus-tunable displays to evaluate adaptive display modes such as monovision.

To the best of our knowledge, we are the first to describe an end-to-end vision correcting pipeline for Virtual Reality. It includes smartphone-based measurement of eyeglasses prescription, storing of the user's personal characteristics on the phone, and customized automatic adjustment of the VR headset for each user.

**Interactive presentation at SIGGRAPH Asia.** We bring two vision-correcting headsets for the visitors to try at the SIGGRAPH Asia VR Showcase. Our current vision-correcting headset prototype focuses on the correction of myopia and is fully functional. We aim to create a participative presentation where two users can try the system at a time, while onlookers can follow the demonstration through the use of a large screen which simulates what a user sees. Fig. 1 (right column) illustrates our vision for this presentation: while one user is wearing the headset, we will stream the images of the virtual world and process them with our raytracing simulations. The simulated renderings will be shown interactively on a large screen, allowing visitors to compare what the user would normally see without her eyeglasses with no headset adjustment, and what she sees with our vision-correcting headset. In addition, we intend to collect data for a user study and ask volunteers how their experience wearing the vision-correcting headset compares to the simulations.

Our setup contains the following components: (i) two vision-correcting headset prototypes, (ii) one personal computer and screen to display content for multiple onlookers, and (iii) one smartphone to perform the measurement of eyeglasses prescription. We will provide all these components. In addition, one part of the demonstration area should be sufficiently lit for the video-based estimation of eyeglasses prescription.

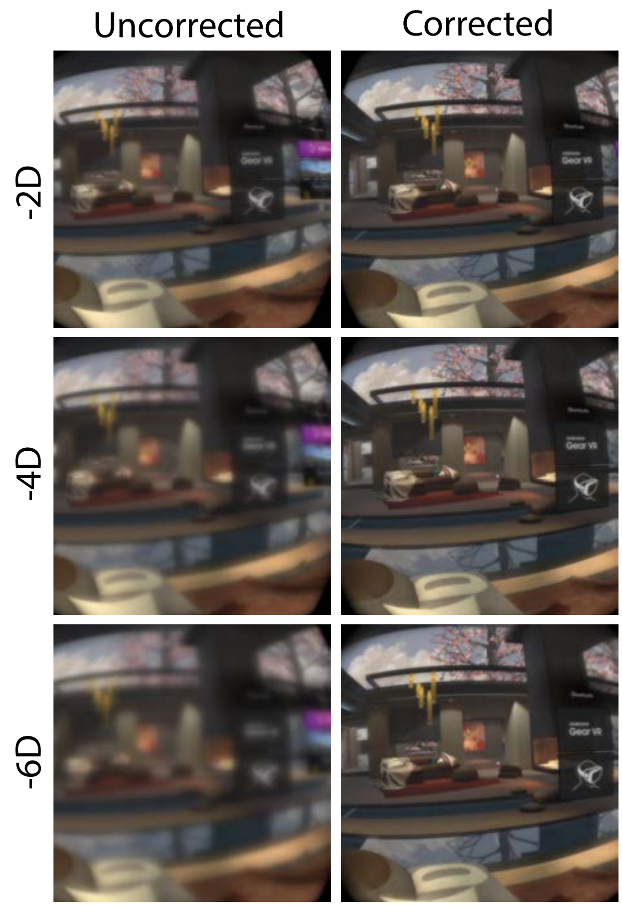



**Figure 3:** *Screenshots of a simulated VR headset session of a user with -2D, -4D, -6D myopia on both eyes. In this simulation, the left eye is uncorrected: the VR headset lens in its default position creates a virtual image of the screen at infinity, and the myopic user sees a blurred image. On the right side, the position of the VR headset lens is adjusted according to the user's eyeglasses prescription, such that the user is able to see virtual content sharply in focus.*

## Acknowledgments

This research, carried out in part at the BeingThere Centre, is supported by the Singapore National Research Foundation under its International Research Centre @ Singapore Funding Initiative and administered by the IDM Programme Office.

## References

FINK, W., AND MICOL, D. 2006. SimEye: computer-based simulation of visual perception under various eye defects using zernike polynomials. *Journal of Biomedical Optics 11*, 5.

KONRAD, R., COOPER, E. A., AND WETZSTEIN, G. 2016. Novel optical configurations for virtual reality: Evaluating user preference and performance with focus-tunable and monovision near-eye displays. In *CHI '16*.

KONRAD, R., PADMANABAN, N., COOPER, E., AND WETZSTEIN, G. 2016. Computational focus-tunable near-eye displays. In *SIGGRAPH '16 Emerging Technologies*.

VON HELMHOLTZ, H., GULLSTRAND, A., VON KRIES, J., AND NAGEL, W. 1909. *Handbuch der Physiologischen Optik*. Leopold Voss.

# A Novel Dexterous Instrument Tracking System for Augmented Reality Cataract Surgery Training System

Yu-Hsuan Huang Wan-Ling Yang Yi-Lung Kao Yu-Kai Chiu Ya-Bo Huang Hao-Yu Chang
Ming Ouhyoung

National Taiwan University

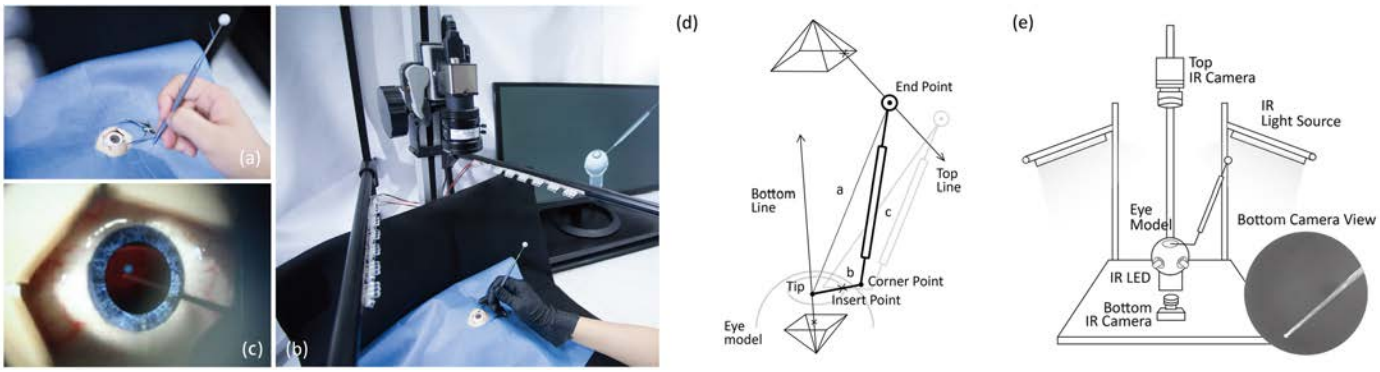



**Figure 1:** *(a)(b)Pictures during the training process, surgical instrument movement can be localized in real-time (c)An instrument handling exercise under Augmented Reality.(d)Geometry of solving the instrument pose (e)System components.*

## Abstract

Cataract surgery is one of the most common operations performed worldwide. Therefore, the computer aided training system is important to reduce the risk resulted from an inexperience surgery performance. We introduced a novel optical tracking method for the surgical instrument in a cataract surgery training system, which is equipped with infrared cameras on top of and inside the eye model. Our system is suitable for augmented reality training environment and allowed trainees to manipulate with a real surgical tool. Also, our system used only 2 cameras for tracking and provided high resolution on the tip of the surgical tool.

**Keywords:** Cataract surgery training, Real-time object localization, Augmented reality

**Concepts:** •**Computing methodologies** → **Tracking;** *Mixed / augmented reality;*

## 1 Introduction

Cataract is the leading cause of blindness and more than 20 million people underwent cataract surgery each year. However, the procedure is complex and requires training. Computer based simulation training gained popularity since it can reduce the exposure of patients to inexperience operation. Real-time localization of instrument motion is the first step in the training system, which is extremely difficult in such dexterous manipulation task.

There are three main limitations in existed solutions: using modified models to represent surgical instruments, constrained movements of instruments manipulation and magnified motion scale. Most current system didn't support real surgical tool. For instance, the commercial product EYESI[Liu et al. ] is an optical based system with 3 cameras under the eye model, and modified surgery tools with wires and sensors are needed to detect the axis rotation. In INRIA's [Dequidt et al. 2013] work, they used nylon replicas of surgical tools with 3-4 budging markers which may disturb the surgeons. Moreover, error would accumulated when markers are far from the tip. HelpMeSee[Broyles et al. 2012] is a global campaign aimed to eradicate the cataract blindness. They use articulated arm in their training system, which provides good precision, but trainee's motion is constrained by the mechanical structure. The constraint in EYESI is that the insertion points are fixed. The INRIA set up 6 cameras from the top offering a bigger working area, however, the system is bulky and requires complex registration. The works mentioned above are all built in Virtual Reality. They tracked the instrument then rendered the tool-eye interaction in virtual environment, and therefore the physical instruments cannot be seen. Besides, an eye model with magnified scale is used. The movement will vary a lot from the real surgery, although it is unnoticed in a virtual environment.

To tackle those limitations, we proposed a novel setup of an infrared optical based localization method in cataract surgery training which is suitable for Augmented Reality.

## 2 Our System

Our approach is based on an optical tracking system instead of an articulated arm because the haptic feedback during an eye surgery is subtle and the surgeons mainly rely on the visual feedback. Considering the procedure and the movement pattern during cataract surgery, we designed an eye model with a circular opening repre-


SA '16 VR Showcase ,, December 05 - 08, 2016,,Macao
ISBN: 978-1-4503-4542-2/16/12
DOI: http://dx.doi.org/10.1145/2996376.2996388

senting the cornea part (10mm-diameter of a real eye) and IR LEDs to light up the interior. An infrared camera is mounted inside the model to capture images of surgical tool entering the opening as shown in Fig1.(e).

After Hough line detection, the position of tip and the insert point on the border is tracked in 10ms per frame. Another IR camera and light source targeted the working area from the top. We added one reflective marker at the end of tool which could be easily extracted as a 2D position. Two IR cameras are precalibrated, so we could back-project the 2D tip point and end point to two lines in space with projection matrices, and the insertion point in space is known given the height of the insertion plane on eye model. Finally, with two back-projected lines, insertion point and the pre-measured of tool, there is a pose, which satisfies the geometry illustrated in Fig1.(d). Using multigrid method to search on the bottom line with a finest resolution of 0.01mm, the transformation is found within 1ms. We use a $685 \times 685$ image for the opening area which preserves a high resolution of 0.015mm/pixel for the important tip position. With the use of a real surgical instrument during training and with an eye model visible at the scale of a real human eye, the scene is suitable in Augmented Reality. Fig1.(c) showed an instrument handling exercise of moving virtual balls, the rendering result is overlaid on iris and pupil region in the real-time capturing eye model image. Thus, the area requiring simulation is reduced and the rendering loading is relieved under augmented reality.

## 3 Application

We have designed several applications for young surgeons to familiar with the procedures and enhance their skills step by step. For example, Experienced cataract surgeons will take the entrance wound as an invisible pivot to traversal the instrument around the circular area without giving force to the cornea. However, inexperienced surgeons will usually push the wound laterally and may cause injuries to the cornea. With our system, the intersection point of instrument and the circular opening will be monitored continuously while performing the assigned task. If the intersection point is moved away from the original position and the distance between two point is exceed a safe range, users will get warnings from the system. We also place some virtual balls inside the model eye. Users have to move the balls to the assigned destination bimanually.Users can also practice the rotation and crushing actions in the advanced mode.

In conventional residency training programs, the subtle movement is hard to learn from the teachers because the tip position and the hand motions can not be observed at the same time. With our system, all the subtle movements can be recorded as the 3D animations. Users can replay the recorded motion and observe from any viewing angles they want. Furthermore, they can record their movements on the same task to compare their movements to teacher's.

## 4 Conclusion

We contributed a system where it only used 2 cameras for tracking, displayed high resolution images on the tip of the surgical instrument, and provided full freedom for using surgical tools. Moreover, trainees could hold and see a real surgical instrument and experience movement in real scale under AR in our system.

## References

BROYLES, J. R., GLICK, P., HU, J., AND LIM, Y.-W. 2012. Cataract blindness and simulation-based training for cataract surgeons.

DEQUIDT, J., COURTECUISSE, H., COMAS, O., ALLARD, J., DURIEZ, C., COTIN, S., DUMORTIER, E., WAVREILLE, O., AND ROULAND, J.-F. 2013. Computer-based training system for cataract surgery. *Simulation 89*, 12, 1421–1435.

LIU, B., MAIER, D., SCHILL, M., MAENNER, R., ET AL. Robust real-time localization of surgical instruments in the eye sugery simulator (eyesi).

# How Oculus Story Studio Created an Immersive Illustrated Story

Robert Chen*
Oculus Story Studio

**Figure 1:** A screenshot from Dear Angelica

## Abstract

In many ways, Oculus Story Studio's upcoming VR experience, "Dear Angelica" (Fig. 1), is a unique project. We wanted to immerse the viewers inside a series of hand-drawn illustrations, and tell a story by artfully transitioning between different drawings. In trying to create this ground-breaking experience, we had to create a brand-new pipeline: From inventing the tools to create these 3D illustrations, to processing and animating the drawings, to rendering them in virtual reality.

**Keywords:** virtual reality, real-time rendering, 3D illustration

**Figure 2:** Illustrator Wesley Allsbrook demoing Quill

*email: robert.chen@oculus.com


SA '16 VR Showcase , December 05-08, 2016, , Macao
ACM 978-1-4503-4542-2/16/12.
http://dx.doi.org/10.1145/2996376.3016090

## 1. Painting in VR

In the pre-production phase, we experimented on many techniques to bring hand-drawn illustrations into VR. However, methods such as projecting paintings as textures on proxy models or manually model out the drawings in traditional 3D programs quickly proved to be too time consuming with mediocre results. Eventually, we created a program called Quill that lets our artist, Wesley Allsbrook, to paint directly in VR with Oculus Touch controllers. (Fig. 2) This allows the artist to use 3-dimensional space as canvas to create truly immersive drawings.

## 2. Processing and Animation

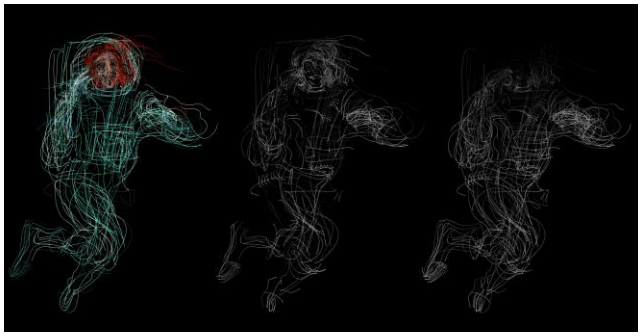


**Figure 3 (Left-Right)**: original line data from Quill, original draw-in attributes visualized as colors, modified draw-in attributes visualized as colors.

The drawings are then brought into Houdini as 3D lines, along with all the attributes defined by the artist such as color, opacity, width, line direction and drawing orders. We then used the information to process every single stroke. For example, when we need an illustration to "draw in" as if there's an invisible hand painting, we calculate the timing and direction attributes on the strokes, attach them onto the vertices, and animate the vertex opacity by comparing these attributes against the global time. (Fig. 3) When there are too many vertices on a stroke, we resample the stroke intelligently to reduce the points without losing the curvatures. Furthermore, when we create more advanced effects such as lines that fly around the viewer or animating illustrated characters, we convert all the animation data into positional textures, and import them into shaders that can move the lines via vertex offsets.

## 3. Rendering & Shading

After the illustrations are processed, they are then exported into Unreal Engine as lines for real time rendering. The engineers created a tessellation shader that takes curve data points as inputs and produce polygons at render time. Since no lighting is required, we created a custom forward rendering engine that can handle lots of transparencies with 8X MSAA super sampling to render the illustrations with the highest possible quality.