The Living Environments Laboratory

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Figure 1: (Left) Multidisciplinary art showcase of Lisa Frank's $< 1 >$: *"der"*, (Middle) Saturday of Science public tour of LEL's CAVE (Photo Credit: Jeff Miller/University of Wisconsin-Madison), (Right) Home environment visualization on the DSCVR system.

ABSTRACT

To accelerate the design of home care technologies, the Living Environments Laboratory uses a 6-sided CAVE and other visualization spaces to re-create every home environment on earth. We employ a LiDAR to capture actual home environments; the point clouds are then processed to enable the virtual renditions of these spaces to be experienced in CAVE and head-mounted display systems. Our basic research focus is on improving the virtual reality experience through better rendering techniques, natural interfaces (e.g. spoken, gesture) and more precise calibration of displays. Finally, the LEL has demonstrated a deep commitment to outreach in a variety of ways, such as through dance performances, art installations, and public events which have showcased the lab to over 3,500 citizen visitors in the three years since the lab has been open.

1 INTRODUCTION

The primary motivation of the Living Environments Lab (LEL) is to accelerate the design of home care technologies.[1] We utilize immersive virtual reality (VR) to assist in the study of these authentic, informal environments. Our desire to better understand the relationship between an individual, their home environment, and their ability to effectively manage their health outside of the clinical setting drives the development of our advanced visualization tools and spaces. Repeated, intrusive and potentially disruptive in-vivo assessments are minimized by combining LiDAR scanning of home environments with processing and redisplay in our CAVE. Additional research goals include advancing the basic science of virtual reality and contributing to advancements in digital humanities.

The LEL is a medium-sized lab comprised of faculty, post docs, graduate and undergraduate students, a systems programmer, an associate scientist, and a managing director. We have a broad reach within our University; our faculty have home departments in Industrial and Systems Engineering, Nursing, Design Studies, Computer Science, Dance, Library and Information Studies, Optical and Computational Instrumentation, and Classics. This structure provides us with the wide range of skills — technical, clinical, artistic, and operational — needed to make advancements at the intersections of traditionally segmented fields. Since the opening of the LEL in 2011, we have been awarded over $3.5M in grant funding, including a recent award of $2.3M from the US Agency for Healthcare Research and Quality (HS22548). Additional financial support is provided by the University of Wisconsin - Madison Graduate School.

The LEL has a remarkable commitment to outreach, complimenting our portfolio of research projects. The lab hosts gratis tours for the general public and community organizations. As shown in this paper, the Living Environments Laboratory is unique in its visualization tools and spaces, research focus, and breadth of outreach activities.

2 VISUALIZATION SPACES AND EQUIPMENT

The LEL is part of the Wisconsin Institutes for Discovery (WID) on the University of Wisconsin - Madison campus.[2] WID has a novel research culture and innovative approach to science; it reflects our University's vision for the future of specialized scientific research.

CAVE and Development Lab: The CAVE laboratory contains a fully immersive six-sided VR CAVE. Each CAVE wall is rear projected by two Dual Titan 3D 1080p projectors for a 1920x1920 resolution resulting in a total resolution of 22 megapixels for the CAVE. The Development Lab contains a power wall that is the same size of one wall of the C6 CAVE. The two labs contain Intersense IS900 Ultrasonic tracking systems with two six degrees of freedom head tracking units and two tracked six-button wands each. Both labs contain a 5.1 surround sound system. The CAVE and Development Lab allow for a *dual-view* hardware mode which allows for two users to be head and wand tracked simultaneously.

DSCVR: DSCVR is an immersive 3D tiled VR display system consisting of 20 consumer-grade 3D televisions arranged in a half cylinder driven by 10 Alienware PCs with nVidia GeForce graphics cards. User tracking is accomplished via a Microsoft Kinect 2 depth camera and interaction occurs via a tracked PS3 dual analog controller. Total resolution of the display system is 41 megapixels.

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[1] wid.wisc.edu/research/lel/

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Technical Infrastructure, Mobile Equipment and Software: The CAVE and Development Laboratory are driven by a cluster of Intel Xeon CPUs with 24 GB RAM and 2 nVidia Quadro 5000 graphics cards with 2.5 GB of graphics memory and 1 TB of hard disk space each. The LEL possesses a Faro Focus S120 LiDAR scanner to enable rapid acquisition of real world environments. The lab also uses four Oculus Rift development kits (two DK1 kits and two DK2 kits), six Microsoft Kinect RGBD cameras, a Leap Motion, and a 63" 3D HD television. A common middleware framework was developed in-house that allows for immersive visualization of a variety of data types across all three laboratories on different VR hardware.

3 Research

Our basic research targets the acceleration of scientific and artistic discovery through visualization of data and concepts. We gravitate towards multidisciplinary projects located at the intersections of traditionally segmented fields. The LEL conducts research at the intersections of virtual reality, 3D user interfaces, computer graphics, home health care, industrial engineering, digital humanities and nursing. Much of the work involves creation of VR applications as well as exploring visualization techniques for data. Our research mixes both hands-on practical solutions, borne out of the necessity of some collaborations, with fundamental VR research.

Improving the Immersive Experience: A recent significant research effort of our lab focused on visualizing point cloud data using our VR display resources. We have designed a 'pipeline' of point cloud data management, from capture to storage and compression and finally efficient rendering.

Improving the interface between humans and VR is another interest of ours. We investigated a novel method called Virtual Exertions, which utilizes real-time visual feedback from VR and biofeedback from muscle activity for users to interact with virtual objects. Users experiencing virtual exertions can co-contract muscle groups that are usually involved in the same physical task to perform tasks in VR. Not only is this method evocative of actual physical exertions in VR, but it also eliminates the need of a wand to manipulate objects in the CAVE.

We are also interested in better understanding and improving the virtual experience for a user. Our work generated methods to enable viewers external to the CAVE to better understand the experience of an immersed individual. We also developed techniques that enable individuals to more accurately perceive position, distance and shape inside of immersive display systems.

Advancing Health Care: We are driven to utilize immersive visualization to create home environments and technologies that support a person's ability to effectively manage their health at home. Our work with the vizHome project[3] involves the exploration of interactions between the home environment and the management of personal health information. The highly personal and idiosyncratic nature of the informal environments we study has historically posed challenges to researchers seeking to repeatedly access and study them. By leveraging advanced 3D data capture and replay techniques, we are able to gain insight on how the home environment and technologies support or hinder a person's ability to effectively manage their health. In addition to minimizing repeated, intrusive, and potentially disruptive in-vivo assessments, this project will also provide designers and clinicians with visualization tools to support the development of innovative home health technologies that are designed to fit the context in which they are used.

An additional focus is on physical rehabilitation. We are exploring the use of commercially available VR products, including Microsoft Kinect and Oculus Rift, to enable patients to perform rehabilitation exercises safely without physical resistance. There are potential benefits to both patients and healthcare providers. By enabling individuals to perform prescribed rehabilitative exercises at home by following a VR avatar, patients would spend less time traveling to the clinic for appointments and be able to perform these activities in the comfort of their homes, and the healthcare system would achieve cost-savings by shifting these activities from the clinic to the home.

Exploring Digital Humanities: In striving to collaborate across a variety of disciplines, our lab has engaged in arts and digital humanities research. One project, WordCAKE, visualizes sequential text documents in order to gain a better understanding of word frequencies across several texts. The SculptUp project allows users to sketch free-form models within the confines of the CAVE using a tracked wand as a sculpting brush and speech recognition to change colors. Other efforts have sought to explore the role of lighting from a historical perspective and to visualize photographic images in new and unique ways.

4 Outreach

The LEL approaches outreach efforts in three different ways.

Public Outreach: WID has a strong commitment to public outreach and broad scientific communication. We have demonstrated our commitment to outreach by hosting over 3,500 visitors to the LEL in a variety of formats, ranging from formal tours to artistic exhibits to informal open houses. Our outreach efforts provide scientific expertise to support innovation in a wide variety of industries, initiate conversations with our research colleagues to foster unexpected, multi-disciplinary collaborations and engage the public's imagination and interest in science and technology. We also partner with other campus wide events, such as Sciencefest[4], Saturday of Science, and the UW Extension's Annual 4-H Youth Conference, in an effort to inspire youth to pursue careers in science, technology, engineering or mathematics.

Multidisciplinary Showcases: We recently hosted several collaborative and unique outreach events, including modern dance performances of "RISE OVER RUN: Off the Wall Dances". RISE OVER RUN utilized the CAVE as part of a performance installation. The audience had the rare opportunity to participate in an innovative, site-specific performance. In addition, as part of a partnership between the LEL and the Wisconsin IceCube Particle Astrophysics Center (WIPAC), we welcomed the general public to our laboratory to experience visualizations of the world's largest neutrino detector and see neutrino events in 3D for the first time. We have also showcased works in the art and design fields, such as Lisa Frank's $< 1 >$: *"der"*. All of these events demonstrated the multidisciplinary nature of the collaborations while engaging the imagination of the public.

External Partnerships: In addition to hosting the general public, the LEL also hosts members of industry. We work with construction firms, design firms, and law enforcement agencies. In the most unexpected extension of our work to date, our lab recently captured and processed a 3D scan of a crime scene to provide onsite assistance to a local law enforcement agency. We applied what we learned in the VizHome project to assist with the investigation, and supported the process from data capture to the final display.

5 Summary

Presented is a subset of the types of equipment, research, and outreach undertaken by the Living Environments Laboratory. The diverse set of interests and knowledge bases of our group enables us to approach challenges from varied angles. In the coming years, we seek to further expand our research inquiries, welcome additional members of the general public to our lab to generate interest in science, and remain diligent in our pursuit of advancing the fields of VR, digital humanities, and home health design.

[3] www.vizhome.org

[4] www.wisconsinsciencefest.org