Interactive Visualization Lab

Daniel F. Keefe*

Department of Computer Science & Engineering, University of Minnesota, USA

Abstract

This presentation describes the philosophy and ongoing interdisciplinary research projects of the Interactive Visualization Lab at the University of Minnesota.

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1 Introduction

The ability to *picture* and *interact with* concepts in new ways has always been intrinsic to the process of discovery. Muybridge's classic stroboscopic photographs of horses led to the discovery that all four of a horse's hooves leave the ground during a gallop; at the time this hypothesis was called, "unsupported transit". Da Vinci's hand-drawn studies of rushing water informed not only his art, but also the science of hydrodynamics. Today, engineers, scientists, and artists routinely rely upon physical models and 3D prototypes – often it is the physical act of touching, rotating, and annotating these models that brings forth new insights. Imagine if all these visual, physical human activities could take place in a virtual space, where powerful computational techniques could be combined with natural human interactions and visual communication.

Research in the University of Minnesota Interactive Visualization Lab focuses on creating methods for deepening the synergistic relationship between humans and computers. Our objectives are: (1) to understand how computer graphics can most effectively amplify the capacity of the human visual system to understand challenging spatial concepts and large multidimensional datasets; (2) to develop the new interface technologies needed to improve our abilities to explore complex data, design 3D structures, and reason about spatial problems; and (3) to train a new generation of computer scientists in the interdisciplinary research methods necessary to advance computer science while also opening up new applications of computer science in fields such as biology, orthopedics, medicine, engineering, and art.

Since the PI has a background in both computer science and art, we approach the lab's research from a standpoint that integrates knowledge of theory and practice from both these fields. As we research new computer graphics techniques for depicting multidimensional, time-varying datasets, we draw not only upon knowledge of graphics algorithms, hardware, and interactive techniques, but also knowledge of color, texture, form, narrative, and metaphor, as utilized in drawing, painting, and other art practice. This approach of informed visual computing is the first cornerstone of our research program.

The second cornerstone is our belief in the power of interactive systems. Our research is characterized by developing and studying systems that not only display data in new ways but also introduce novel interactive techniques for interrogating data, particularly in 3D environments. In a recent *IEEE Computer* article, "Reimagining the Scientific Visualization Interaction Paradigm", Keefe and Isenberg map out a 10+ year agenda for research in this style [1].

The third cornerstone of our research program is the collaborative group and physical lab space needed to support research in interdisciplinary scientific visualization, virtual reality, and 3D user interfaces. At the University of Minnesota, we have created a lab space that consists of a variety of high-end hardware, including a 4-wall CAVE, a multi-touch table, multiple head-tracked stereoscopic displays, Phantom force feedback devices, tablets, and several 3D tracking systems. Our research group consists of about 5 Ph.D. students, and together we work with interdisciplinary collaborators in orthopedics, medical device engineering, biology, psychology, writing studies, graphic design, and art. We have made a purposeful, major investment in developing interdisciplinary relationships because we believe that computer science research is often enriched when it is coupled to difficult, real-world problems. Also, driving problems can provide exciting opportunities for the research to benefit society.

2 Some Ongoing Research Projects

This research philosophy is illustrated by ongoing projects in the lab [2]. To provide a sense of the breadth of these projects, we present some representative images and short descriptions here.

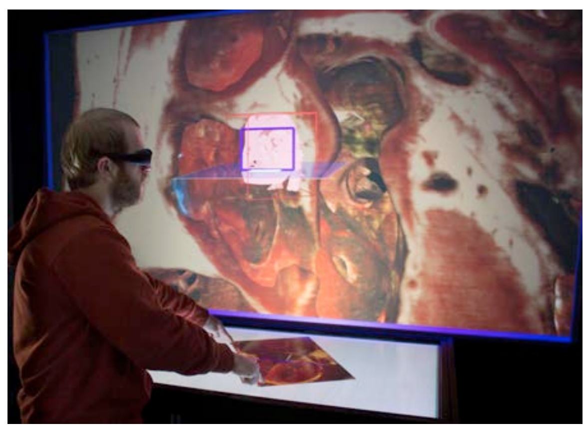

Figure 1: Exploring medical volume data by combining VR with multi-touch interfaces.

Figure 1 shows the Interactive Slice WIM (World-in-Miniature), a tool for exploratory visualization of volumetric medical data, which we have developed in collaboration with medical device engineers. Imagine a cardiac device engineering team viewing a volume visualization and asking, "Can we see a relationship between blood pressure and flow patterns in this 3D region". While defining "this 3D region" in a medical imaging dataset could take several hours using a keyboard and mouse, complex 3D selections can be made in real time with this interface by moving one's fingers on top of the imaging data. Head-tracked stereoscopic projection makes 3D renderings of data (the small

* keefe@cs.umn.edu

red heart) appear to float in the air above the table. By touching the shadow of the 3D data, which is projected onto the table, engineers can slice through the imaging data, plot 3D curves, and measure volumes in virtual space.

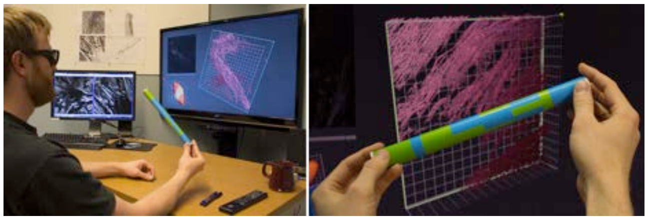

Figure 2: Physical props and depth cameras for the scientist's desktop.

Figure 2 illustrates a complementary user interface project, a tool for scientists to use as they explore data at a 3D desktop. We were motivated in this work by observations of our own discussions of the 3D fiber datasets. When discussing these data with a colleague, it is natural to pick up the pen on your desk and gesture into the screen, "see the fibers going in this direction; now, notice how the fibers down here run perpendicular". This type of "lightweight" 3D gesturing can provide a much more direct interface for 3D tasks than a mouse and keyboard. Unlike most current uses of low-cost depth cameras and 3D displays, we create a stereoscopic fish-tank virtual reality system at the scientists' desk that supports tracking of small-scale gestures with objects already found in the office. The tangible prop is simply a rolled up piece of paper, but because it gives users something to touch, this simple physical device facilitates control when performing 3D tasks, such as pointing, rotating the volume, and setting scalar values.

Figure 3: Virtual reconstruction of the architecture and assembly at the Pnyx in Ancient Athens.

Figure 3 shows work from an ongoing digital humanities project. Working with a scholar of ancient rhetoric, we have developed a VR environment that recreates the experience of speech giving at the Pnyx in Ancient Athens, a hillside regarded as the birthplace of democracy. The work involves research on crowd simulation, navigation in large virtual environments, acoustic simulation, and comparative visualization of large-scale architectural structures and crowds. The Pnyx underwent three major phases of reconstruction, and understanding these changes over time and how they impacted speech giving and receiving is a major research question for our collaborators.

Figure 4 shows some of the work for which our lab is most well known. CavePainting (originally developed at Brown University) is a 3D user interface for virtual sculpture created in the style of loose, organic 3D brush strokes. 3D user interfaces for creative design and artistic modeling in VR remain a key research topic for our lab. Our recent work in this area (not yet published) includes new user interfaces for creating artistic sheet metal sculptures in VR.

Figure 4: CavePainting and follow-on 3D user interfaces for virtual sculpture and modeling.

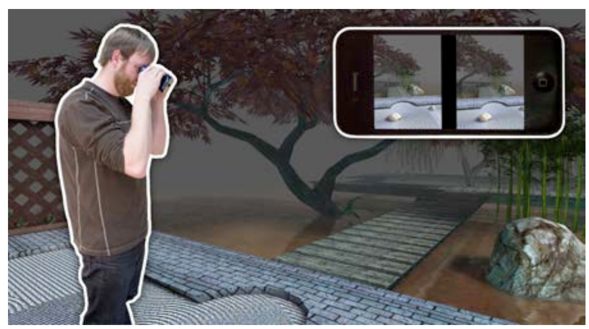

Figure 5: iPhone VR for treating patients with chronic pain.

Figure 5 illustrates one of our recent efforts to get VR and 3D user interfaces out of the lab and into the real world by using smart phones as VR displays. We believe one of the most promising applications for this new technology is in delivering mobile treatments. Although VR has been known for a long time to be effective for treating acute pain (e.g., burn victims in a hospital), the high cost and low mobility of the technology has until now limited applications to chronic pain patients. We believe that all this is about to change, and we view mobile VR as one of the key research methods we can use to move our research results out of the lab and into the broader community.

References

[1] Daniel F. Keefe and Tobias Isenberg, 2013. Reimagining the Scientific Visualization Interaction Paradigm. *IEEE Computer (Special Issue on Cutting-Edge Research Challenges in Visualization) 46(5)*, 51-57.

[2] Interactive Visualization Lab, 2014. http://ivlab.cs.umn.edu.