Making VR More Usable : The State of Effectiveness in Virtual Reality

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1. Introduction

Within the virtual reality (VR) research community, the past decade has seen a marked trend towards making VR systems more usable. After moving past the initial hype in the early part of the 1990s about how VR was going to influence all aspects of our lives, including how we learn, heal, entertain ourselves, conduct business, and socialize, VR researchers began to focus on the more-fundamental questions involved in evaluating and improving the effectiveness of such systems [1]. Several threads of work can be identified, each making its own contribution to the overall fabric of where we currently are in identifying, understanding, and utilizing techniques for improving the effectiveness of VR applications. This paper highlights some of the important work done in the U.S. aimed at improving the state of effectives of VR systems. We are by no means attempting to perform a comprehensive survey of all the important work, as such an exercise, while helpful, is beyond the scope of this article. Here we focus more on general trends, and cite specific research activities to illustrate these trends. Furthermore, while very little research can be classified as emanating from a single country, here we focus on efforts that are primarily U.S. based, as other articles in this issue in turn focus on the important contributions of other regions. We will close by discussing the important contributions made by research groups in Japan over the last decade, and where future work might be focused.

2. Moving Virtual Reality into the Mainstream

Some of the main issues that have been impeding the general growth and acceptance of VR systems into the mainstream include a *lack of a general mental metaphor*, such as the desktop metaphor used in 2D systems, the *complexity* inherent in systems, where having one person immersed in a virtual environment (VE) typically requires at least one other person on the “outside” to handle system controls, a *lack of effective, basic interaction techniques* that can be used in a wide range of application domains, and an understanding of effective psychophysical approaches to *building and maintaining a sense of presence*. Finally, there have been only a few examples of applications that are unquestionably better done in VR than when using other methods. This is typically called the search for a *Killer Application* for VR. Are there applications that can still claim a compelling reason for them to be performed in VR in the face of all the issues outlined above? Some important headway has been made in all of these areas at research labs in the U.S.

In terms of improving the ability of users to affect change within virtual environments, of particular note is the work being done at the 3D Interaction (3DI) group at Virginia Polytechnic Institute and State University (Virginia Tech), headed by Doug Bowman. The seeds for the work done in the 3DI group were planted while Bowman was a student at the Graphics, Visualization and Usability (GVU) Center at Georgia Tech, an early hotbed of important work on usability in VR. One contribution by the 3DI group that has had a significant impact on framing the research efforts of many other groups around the world is the identification of four main interaction tasks in VR: navigation, selection, manipulation, and system control [2]. The system control aspect of this framework also helps reduce the need for someone to be on the outside of the VE while an individual is immersed. Using this classification scheme, researchers in the field have been able to place interaction techniques within a larger framework, thereby focusing on optimizing a particular technique, while keeping in mind the other tasks that might also need to be performed. The group has done empirical studies incorporating many types of 3D input methods, including the use of pen-and-tablet interfaces [3], finger-based menu display and selection [4], and methods for displaying information about objects in information-rich settings [5].

In 1998, a research group was established at the University of North Carolina at Chapel Hill to focus on the issue of effectiveness in VR. This group, called the Effective Virtual Environments (EVE) project, is headed by Fredrick P. Brooks, Jr. and Mary Whitton, and is focusing on several important, related issues. These range from work aimed at improving VR technology, such as reducing system latency, psychophysical issues influencing the sense of presence [6], and interaction techniques, including locomotion [7] and object manipulation [8]. Building on the significant work done to produce their compelling "Pit" demo, this group has worked on adding improved fidelity in interesting ways, including the use of passive surfaces registered with virtual walls and gangways, using the hand as an interaction surface, and measuring presence using physiological measures. Each of these projects aims to handle one aspect of effectiveness, be it locomotion, object manipulation, or presence issues.

One of the main areas we have been focusing on in our own lab has to do with addressing the lack of support for multiple sensory modalities beyond the visual and auditory cues typically incorporated into VR systems. The use of tactile cues, for example, can have a significant impact on improving situational awareness [9], as well as providing an improved sense of contact with virtual objects [10]. The study of how to combine multiple modalities in effective ways has yet to be addressed in a systematic way for VR. The aspects of multimodal interfaces that make them interesting for VR are that there are both *technical and psychophysical* issues that must be addressed. On the technical side, one of the main questions is how best to design software and hardware frameworks that treat the different modalities in a unified manner, in order to ease integration by system designers, yet still maintain adequate display speeds. In addition, VR researchers must also address the aspects of how user perception is affected by the use of multiple modalities, given that we cannot yet produce systems that can generate and deliver stimuli with the same fidelity as we receive in real life. Addressing these issues will have impacts on both the effectiveness of user interfaces, as well as the presence experienced by users. Improving the ease of system integration will also help make VR systems move from the lab into the mainstream.

3. Can Video Games Provide Some Answers?

In the U.S., the past several years have seen a dramatic increase in the popularity of video games. This has affected the field of VR research in several important ways. First, it has led to a significant decrease in cost of the hardware necessary for generating realistic visual environments at interactive frame rates, greatly reducing the initial investment costs necessary to set up a laboratory to perform research in VR, and improving support for deploying such systems. In addition, several open-source and low-cost software packages, such as game engines and modeling packages, have emerged, and can be employed to form a solid basis for building more-complex systems.

The video-game boom has also led to an explosion of educational programs that hope to teach the technical, artistic, and project-management skills necessary for success in the game industry [11]. This skill set matches fairly well with skills necessary for supporting research in VR. While the rise in video-game popularity is undoubtedly a worldwide phenomenon, the relatively flexible structure of the educational system in the U.S. has led to the rapid deployment of game development programs at all levels (e.g., certificate, associate, undergraduate, and graduate). Because of the large number of these programs, their graduates will provide a work force with the skills and interests that could lead to greater and more-rapid innovation within the VR field.

4. The Japanese Horizon

I have had the privilege of working at research laboratories in Japan for five out of the last ten summers, one in 1997 at the National Institute of Bioscience and Human-Technology, AIST in Tsukuba, and four (2002-2005) in the Department of Sensory Media of the Media Information Science Lab of ATR International, in Kyoto. In addition, I have visited many government, university, and commercial VR laboratories in Japan, where I have been exposed to interesting and innovative work. Prior to visiting Japan the first time, I had read several seminal works describing Japanese VR research. What always struck me about the work done in Japan was how a significant portion of it seemed to explore approaches that did not follow what might be considered "more-traditional" lines of thought. In America, we would call this "thinking outside the box," able to conceive of, design, build, and test fresh ideas. This is particularly apparent in the works of Hiroo Iwata at the University of Tsukuba, Michitaka Hirose at the University of Tokyo, and Susumu Tachi at the University of Tokyo. The influence these VR researchers have had on the field of VR in Japan is probably best illustrated by the achievements of students who have worked with them over the past decade, many of whom now have their own labs, and continue to innovate.

In looking at the process of Japanese innovation in VR, some interesting characteristics appear. The first is the ***speed*** with which Japanese researchers develop their ideas to the prototype stage. There does not seem to be much hesitation or trepidation about moving from the conceptual level to the implementation level in rapid succession. This approach to rapid prototyping allows researchers to "play" with actual devices much earlier, leading to emergent behavior and use cases. This is not to say that the ideas have not been thought through enough; quite the opposite is true! One of the reasons for being able to move so quickly has to do with the second characteristic commonly found in Japanese research labs: a very thorough ***understanding of the fundamentals of engineering, science, and mathematics***. I would argue that this trait is much more widespread in Japan than in the U.S., and allows Japan to move along more quickly to apply these basic principles in novel ways. The final trait is the aforementioned ***ability to think outside the box***, to come up with novel ways of combining basic building blocks into interesting and potentially useful solutions to many of the problems we face as VR researchers. Even after spending so much time in Japan, it is still not clear to me what causes these sparks of intuition to occur. One can only assume, like the ideas themselves, that there is something in the basic building blocks of Japanese *culture* that fosters it.

As far as the future of VR research in Japan, I would like to see a renewed effort at trying to achieve the integration of VR into our everyday lives that we put aside a decade ago. Where Japanese VR researchers could have the greatest success is by marrying their ability to innovate with a focus on moving to the next level of online virtual worlds. If we consider the rapid growth of video game technology described above (in which Japan is already the world leader), along with advances in input/output devices and techniques, and the dramatic drop in cost of broadband network connections, the ground is ripe for Japan to become a leading innovator in the area of ***online, persistent virtual worlds with high levels of immersion.*** Many researchers of my generation first got involved in VR because of visions of just such an online experience [12-13]. I believe Japan has the right combination of existing telecommunications infrastructure, foundational knowledge in engineering, science, and mathematics, innovative thinking ability, geographic size, culture of group thinking, and government and commercial funding opportunities to make such visions become reality. By layering such a system on top of existing and emerging Internet infrastructure, Japan could define what this next level of online world looks like, providing the infrastructure for people to use to learn, heal, entertain, *etc.*

With government funding of high-risk research being reduced worldwide, because of prevailing economic conditions, it is attractive to forgo investment in research that has ill-defined immediate impact (economic, societal, *etc*.) in lieu of "safer" directions. It has been said that while many of us spend our time working to improve virtual worlds, we must find worth for our efforts in the real world. I would turn this statement on its head, and say it is time to better leverage what we have done in the real world over the past ten years, in terms of the VR research, Internetworking, interaction techniques, *etc*., to improve the online *virtual* world experience. In the end, such an investment will pay off in the real world by improving shopping experiences, patient diagnoses, collaborative design sessions, caregiver access for the elderly, entertainment, and even face-to-face international political, economic, and environmental conferencing possibilities.

5. Conclusion

In this article, I have outlined what I consider to be the major strengths of current research into VR effectiveness in the U.S., giving examples of places of particular importance. It should be stressed that there are numerous places where significant work is being performed, and that I have in no way attempted to produce an exhaustive list.

I also gave examples of Japanese researchers who have had significant impact over the past ten years. Again, this is not an exhaustive list, and does not cover any of the "second generation" of VR researchers in Japan who are quite active. I also gave my optimistic view of the possibilities that Japan has for focusing its VR research on highly immersive, online virtual worlds.

The final hope and plea that I have for all VR researchers, regardless of geographic location, is that we all continue to pay attention to training the next generation of VR researchers. Only by passing on our own excitement and experience in the field can we hope to continue making the steady progress we have made over the last decade. *Ganbatte kudasai!*

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Biography

Robert W. Lindeman joined the Department of Computer Science at the Worcester Polytechnic Institute as an Assistant Professor in Fall 2005. Prior to joining WPI, he was an Assistant Professor in the Department of Computer Science in the School of Engineering and Applied Science at The George Washington University from 1999-2005. He did his doctoral work in the same department from 1993 to 1999, earning the Doctor of Science in 1999. He also holds a B.A. degree (cum laude) in Computer Science from Brandeis University, and a M.S. degree in Systems Management from the University of Southern California. He is director of the Human Interaction in Virtual Environments (HIVE) lab at WPI, and teaches in the new undergraduate major in Interactive Media and Game Development. Dr. Lindeman is a member of ACM, IEEE, and UPE. Funding for his work has come from NSF, DARPA, ONR, and AOL. He has been a Visiting Researcher in the Department of Sensory Media of the Media Information Sciences Lab of ATR International in Kyoto, Japan, for the summers of 2002, 2003, 2004, and 2005.