JOHN SADOWSKY

GUEST EDITOR'S INTRODUCTION

For never shall this be proved, that things that are not are.
—Parmenides

Virtual reality—the term conjures up images of people wearing strange devices on their heads, hands, and bodies, experiencing another world created by computers, totally immersed and unaware of the artificiality of their environment. The devices intercept all signals and images from the real world and process them, with a generous mixture of computer graphical representation of data and virtual worlds, to control completely the stimuli to the human participants' visual, aural, tactile, and somatosensory systems. Virtual reality will revolutionize entertainment and recreation, education and training, industry and manufacturing, and all human endeavors, now and into the twenty-first century, so the hyperbole goes.

Yet those of us who have ever donned a head-mounted display, grabbed a force-feedback arm or bat (i.e., flying mouse), and navigated our way through a virtual environment have not failed to feel a certain disappointment: there is no true experience of immersion in another world—the graphics have an unnatural, computer-like sense to them, the "world" moves like a camera panning and is not stationary to our motions, and the most compelling feeling is that of sitting a bit too close to a television screen. Reality has never been like that.

We can, however, experience a wondrous sense of the potential of a virtual reality system. It is only a matter of time until the enabling technologies are developed to the requisite high performance and low cost to permit the design of immersive synthetic environments that will achieve some of the promise invoked in our imaginations by the term "virtual reality." It is this promise and a intuitive feeling for this potential that pervade the current literature (see the suggested reading list at the end of this editorial).

Investigators at APL and at other divisions of The Johns Hopkins University have been actively involved in research and development of the technology to enable synthetic environment systems. The articles in this issue of the *Johns Hopkins APL Technical Digest* define the science and technology, discuss the development of tools and applications, and investigate basic problems whose solutions are required to realize the promises. Before we begin, however, it would be helpful to cull the science and engineering from the science fiction and fantasy and define the goals of the technology.

In its simplest terms, the science of synthetic environments is the study of new methods for computer interfaces. This may seem to be a trivialization of the entire endeavor—from major technological revolution down to building better mice—but the nature of the interface and the challenges that the nature implies will indicate just how revolutionary the field is. I will review the evolution of computer interfaces, from my perspective, to establish a context for this claim.

Those of us who have been around computers for some length of time have seen the rapid growth of the means for communication with computers. When I was but a fledgling programmer, running my jobs on the IBM 7094 that occupied the entire fourth level of the Eisenhower Library at Hopkins, my only method for communication was via decks of Hollerith cards. The major advance of my undergraduate days was the introduction of teletype machines with paper tape readers and a time-sharing operating system that allowed direct and somewhat parallel communication with the system.

Over the past twenty-some years, I have experienced major changes in the way in which I communicate with computers. Teletypes gave way to display monitors, and operating systems evolved from IBM JCL to somewhat more natural language systems. Graphical User Interfaces such as pioneered by Xerox Parc, the Apple Lisa and Macintosh computers, and various windows environments were a major advance in computer interfaces. Pictures and icons that could be manipulated in intuitive ways gave a much wider audience access to computers with a natural form of computer interface.

We are now at the point where we have learned that graphics and pictures are natural and intuitive methods for organizing and understanding information and for communicating ideas with computers. Although this realization is a major accomplishment in the history of computer interface design, it is dwarfed by what is to come. Current methods of interface separate the human operator from the computer. We see information on the monitor as information on a monitor; we communicate with the computer by typing on a keyboard and by manipulating a mouse, joystick, or wand. The interfaces are very easy to use; however, the computer remains a separate object in the environment, and we are aware of this situation.

In a synthetic environment, the objective is to remove this separation altogether by having the computer become the interface between ourselves and our data. We are able to interact directly with a world constructed from the data because all of our senses and behavior are in direct contact with the computer; ideally, we are no longer aware of a separate computer moderating the interchanges between ourselves and this virtual world. Such an interface requires a tremendous leap in technology. Not only must we understand the nature of software, hardware, and some human factors, but we must explore the very nature of how we sense and understand reality. Effective synthetic environments require deep understanding not only of computer science and engineering, but also of biological sensory processing, the psychology of perception, epistemology, and the philosophy of reality.

Before we can reach these rather ambitious goals, however, much can be done with the current and near-term technology to produce manageable and useful systems. With an accommodation for the imperfect nature of current virtual reality experiences, we can now employ such systems to achieve very compelling entertainment experiences, effective simulators for training and education, distributed networks for teleconferencing and teleoperation, and visualization workstations for obtaining deep and unexpected understanding from data.

Articles in this issue of the *Technical Digest* describe some of the work in progress at APL and in other divisions of Hopkins in synthetic environments and the science of virtual reality. In the article that I coauthored with Robert Massof of the Johns Hopkins School of Medicine, the field of sensory engineering is defined and described. In a sense, this is a homegrown product—the term "sensory engineering" was coined at Hopkins to describe an evolving multidivisional program to study the sciences and engineering disciplines necessary for synthetic environments—that will act as a catalyst for some wonderful collaborations among researchers and developers over a wide range of diverse interests.

The article by Dennehy, Nesbitt, and Sumey describes a real-time, three-dimensional graphics display system that has been developed in the Fleet Systems Department for commander support in command and control. This system creates a virtual workstation to integrate sensor data and create an intuitive and compelling representation of the state of the warfare. In developing the system, the authors solved many of the difficult problems of real-time, three-dimensional graphics and created more general-purpose graphics tools and architectures.

Massof, Rickman, and Lalle describe an application of the concept of sensory enhancement to low vision rehabilitation in their article about the Low Vision Enhancement System. The primary device in their system is a head-mounted display that can interject image processing algorithms between the visual environment and the eyes of a patient with a visual impairment. The Low Vision Enhancement System is an important medical treatment system and can easily be adapted to use as the display device in other synthetic environment systems.

Data visualization is an important application for synthetic environments. An interactive world constructed from three-dimensional graphical representations of data is a natural setting for understanding complicated numerical relationships in outputs from models and simulations, in sensor data and measurements, and in time series interrelated in subtle ways. Two articles present experiences with data visualization in synthetic environments.

Geckle and Raul have been investigating the simulation and visualization of blood flow. Their model of a virtual artery requires not only computer graphics with which to visualize the flow, but also accurate mathematical models of the fluid dynamics of the blood flow and physical properties of the blood and arteries. In particular, they were faced with new problems and challenges, essentially of high-fidelity descriptive models of what the phenomena look like. These are similar to challenges facing designers of distributed interactive simulation systems and virtual prototyping systems: to develop accurate terrain dynamics models that will produce a realistic look and feel.

The article by Dolecek describes his experiences with stereoscopic displays for data visualization and, in particular, the nature of and techniques for achieving stereopsis, or solid seeing. Because a synthetic environment is inherently three-dimensional, the problem of creating a convincing illusion of a solid world is important to solve.

Within the science of synthetic environments, perhaps no problems are more important than those of the nature of perception and attention. A virtual reality product creates a realistic illusion in direct proportion to its users' interest and willful suspension of disbelief. Virtual reality games have enjoyed the most success because game players can become so absorbed into the created environment as to forgive unconsciously the limitations in the graphics and equipment. The final two papers present some of the fundamental psychological and pyschophysical investigations that further define the science of synthetic environments.

The article by Hamill presents some intriguing and difficult considerations about the way in which humans perceive reality and maintain these perceptual processes in a synthetic environment, despite the limitations of the technology. Many factors influence our perceptions, and the context of our virtual reality experiences affects the extent to which we are willing to perceive artificial signals as real. Hamill's article considers applications of synthetic environments as a function of these factors.

Finally, Powell presents a thought-provoking model of visual perception—as a cognitive simulation with which we interpret visual experiences—in his interesting and speculative article. He finds himself at times at the crossroads of science and philosophy, facing difficult problems that further demonstrate the deep and revolutionary nature of the engineering of synthetic environments.

SUGGESTED READING

1. Aukstakalnis, S., and Blatner, D., *Silicon Mirage,* Peachpit Press, Berkeley, Calif. (1992).
2. Heim, M., *The Metaphysics of Virtual Reality,* Oxford University Press (1993).
3. Kalawsky, R., *The Science of Virtual Reality and Virtual Environments*, Addison-Wesley, Reading, Mass. (May 1993).
4. Pimentel, K., *Virtual Reality: Through the New Looking Glass*, Intel/ Windcrest, New York (1993).
5. Rheingold, H., *Virtual Reality*, Summit Books, New York (1991).

THE AUTHOR

JOHN SADOWSKY received a B.A. in mathematics from The Johns Hopkins University and a Ph.D. in mathematics with specialty in number theory from the University of Maryland. Before joining APL, he worked as supervisor and principal scientist for the Systems Engineering and Development Corporation and as a mathematician for the Social Security Administration and the Census Bureau. He joined APL's Research Center in 1989 and is currently the assistant supervisor of the Mathematics and Information Science Group. In addition, since 1981 he has served on the adjunct faculty for the computer science program of the G.W.C. Whiting School of Engineering. Dr. Sadowsky's current interests include signal processing, applied algebra and number theory, computational complexity, the design of algorithms, and sensory engineering.