The technology that facilitates the operation of complex systems, consuming information and turning it into knowledge (that most valuable of human resources), is the realm of virtual reality. This special issue of *IEEE Computer Graphics and Applications* brings together articles describing virtual reality technology and applications being pursued worldwide. We felt the time was right for a peer-reviewed special issue because the field has produced an enormous amount of hype. This can damage credibility and obscure the real industry achievements and the extraordinarily important work being done.

**What is VR?**

Although the terms cyberspace and virtual reality have been around for years, virtual reality as an industry is in its infancy. (Evans and Sutherland demonstrated the first head-mounted stereo display in 1965.) The term “virtual reality” is credited to Jaron Lanier, founder of VPL Research; earlier experimenters, like Myron Krueger in the mid-1970s, used phrases like “artificial reality.” William Gibson coined “cyberspace” in his 1984 science fiction novel, *Neuromancer*.

Few technologies in recent years have evoked such fiery discussions in the technical community, and fewer still have sparked such passionate involvement of the humanities and the cultural sector. Maybe the humanities community reacts because the VR interaction is so tightly coupled to the human senses. Perhaps the cultural sector clamors for a role in the evolution of VR because the technology is finally interfacing with the human, rather than the human interfacing with the technology. Whatever the reasons, VR is more a convergence of previously disparate disciplines than a whole new branch of technology. It simply takes a fresh look at human interaction. Evolving from user interface design, flight and visual simulation, and telepresence technologies, VR is unique in its emphasis on the experience of the human participant. VR focuses the user’s attention on the experience while suspending disbelief about the method of creating it. We feel that neither the devices used nor the level of interactiveness or fidelity determine whether a system is “VR.”

The quality of the experience is crucial. To stimulate creativity and productivity, the virtual experience must be credible. The “reality” must both react to the human participants in physically and perceptually appropriate ways, and conform to their personal cognitive representations of the microworld in which they are engrossed. The experience does not necessarily have to be realistic—just consistent. Articles by Stephen Ellis and by John Latta and David Oberg consider the frequently forgotten human side of VR systems.

**VR today**

Virtual reality today bears a striking resemblance to the early stages of computer graphics in the mid-1960s to the early 1970s. The products seem to be “a solution in search of a problem.” As with early computer graphics products, the entry-level costs are relatively prohibitive. A complete VR environment, including workstations, goggles, body suits, and software, is in the range of $50,000 to $100,000. In an attempt to suggest low-cost methods, a new magazine called *PCVR: Virtual Reality and the IBM Personal Computer* (Gradecki Publishing, Laramie, Wyoming) publishes articles such as how to build a head-mounted display for under $500.

The serious limitations of the technology give rise to a number of apologists. At one VR meeting in 1992, the general attitude was, “Although the pictures aren’t very good, we really don’t need great pictures to achieve our objectives. They don’t have to be in real time, and they don’t need to be terribly realistic.” We see a strong analog to the early days of computer graphics, when all that was affordable was a fairly static, monochrome, storage tube display. The early rationalization was that we didn’t need color or dynamics. Time has shown that once the technology became affordable, color and realism were much preferred. We believe the VR community will reach the same conclusion as the technology progresses.

Much research into the various elements of VR technology remains to be done, for example, control and navigation metaphors for HMD point-of-view applications. We need to find a comfortable way for a user to move a POV while attempting to interact with objects and simultaneously control and gather information. Mark Bolas’ article discusses these issues. To accommodate both “immersive/inclusive” experiences and multi-serial users, Bolas suggests the headcoupled boom-supported stereoscopic display. Many application areas require this type of capability to integrate a VR system into the work environment. As the price comes down, these systems will surely see success in many fields.

**Distractions and progress**

Currently, we as developers, critics, and early adopters are distracted by measuring the fidelity of various technologies used in today’s VR systems. This preoccupation, while important, disguises the real issues that effective VR implementation highlights—to wit, the advances possible for some applications, even with crude component performance. The problem analysis and system design (in some cases, redesign) processes driven by VR application development can turn the entire human-machine interface on its ear. There lies the greatest benefit to the user. Like corporations “reengineered” to be workflow- and service-based, new logic and functional architectures will be developed to satisfy VR’s optimized human use requirements. The performance levels of the component technologies will catch up with our expectations and ideally will plug in to already well-designed systems.

VR is growing at annual rates on the order of 60 percent, about twice the growth rate experienced 25 years ago. We estimate that about $250 million worth of VR products and services will be shipped in 1994, with the revenue growing to...
about a billion dollars by 1997. This could be attributed to the “superfunctional” nature of VR technology. For example, computer graphics is just one of the component technologies upon which VR relies heavily for visual stimulus. As computer graphics and other component technologies advance, VR advances with a multiplier effect, due to great overall system performance attained from relatively small component technology gains.

The architecture of the “player system” (which plays the games or applications) and the networking component is in many cases the linchpin for high-performance VR applications. To produce the desired experience for a specific application, the player system must support the entire range of possible experiences for the user, yet maintain minimums dictated by human factors requirements. Ken Pimentel’s article sheds light on some of these multiuser network-related architecture issues. W. Dean McCarty et al. discuss developing new systems using multiuser system networking protocols such as SimNet and DIS. Standards such as these are of paramount importance, not only for linking dissimilar player nodes, but also for content definition and human interaction such as Apple used for the Macintosh. All applications carry the same core tools and commands, permitting easy use of different applications. The McCarty article also discusses an important set of concepts in scene complexity management to allow player systems to maintain their minimum required response time and update rate.

**Topics covered**

The articles in this issue cover a broad variety of topics. In addition to those mentioned above, Yannick L. Kergosien, Hiroshu Gotoda, and Toshiyasu L. Kuni describe a unique VR application in “Folding and Creasing Virtual Paper.”

Virtual reality is a worldwide effort, as two special reports show. Larry Rosenblum, Martin Göbel, and José Encarnação present an overview of VR activities in Europe, while David Kanhaner discusses the progress of virtual reality in Japan.

The coeditors recognize the lack of time and space to consider a number of equally important issues. For future special (or regular) issues of *CG&A*, we encourage authors to submit papers on the following topics:

- quantitative testing of VR navigation and control metaphors for various applications,
- common core competencies for systems of various types (HMD, boom-mounted displays, cabs, and so on),
- authoring and test systems,
- human factors issues that promote experience, believability (or realism),
- specific applications not possible without VR techniques, and
- applications enhanced by VR, plus their metrics.

This introduction includes a very brief bibliography of some of the books published about VR. Books appear so rapidly that unless the bibliography was online, it would be almost immediately out of date. Therefore, we list some of the books published in the last three years.

**Acknowledgments**

We extend our warmest thanks to the issue’s authors, who responded so enthusiastically to the initial call for papers, then spent additional effort modifying their articles to reflect the reviewers’ perceptive comments. Thanks also to the reviewers who helped make excellent papers even better. We are also most appreciative of the extraordinarily cooperative and professional editing and other assistance and encouragement given to us by Nancy Hays, *CG&A* managing editor, staff editor Linda World, and editorial assistant Karen Whitehouse. Thanks, Nancy and crew! Finally, Steve Tice adapted some of the ideas discussed here from the descriptive material he co-developed with Gary Beirne of the University of Toronto for the 1991 Siggraph Tomorrow’s Reality Gallery, one of the first comprehensive VR and multimedia interactive exhibits.

**Further reading**


**Carl Machover** is president of Machover Associates. He is also an adjunct professor of computer graphics at Rensselaer Polytechnic Institute and past president of NCGA. He serves on the editorial advisory boards of numerous industry publications, including *IEEE CGAA*. In 1988 he received the North Carolina State University Orthogonal Award and was inducted into the FAMLI Computer Graphics Hall of Fame. In 1993 he was the first recipient of the NCGA Vanguard Award.

Machover graduated as an electrical engineer from Rensselaer Polytechnic Institute. He is a Fellow of the Society for Information Display (and a former national president) and a member of the Computer Graphics Pioneers (and former Chief Oldtimer), ACM Siggraph, IEEE, the American Institute of Design and Drafting, NCGA, and CASA.

Readers may contact Machover at Machover Associates Corp., 152A Longiew Ave., Box 308, White Plains, NY 10605. His e-mail address is machover@egs.mcc.com.

**Steve E. Tice** is president of S.E. Tice Consulting, Inc. He was formerly chairman of the board, president, CEO, chief technology officer, and founder of SimGraphics (in 1985). He was responsible for product direction, focusing on using interactive real-time graphics in system solutions for engineering and entertainment applications. He cochaired the Tomorrow’s Realities Gallery for the 1991 Siggraph.

Tice obtained degrees from Rensselaer Polytechnic Institute, an ME and a BS in aeronautics, with minor concentrations in computer graphics and management.

Readers may contact Tice at S.E. Tice Consulting, 15860 Dartford Way, Sherman Oaks, CA 91403-4712.