

Using Sensor Inputs to Affect Virtual and Real Environments

Eolus One, Green Phosphor, and the Parsec voice controller use sensor technology to transmit data from real-world environments to virtual ones. This article focuses on the design principles these three projects apply at the experimental stage of cross-reality design.

Cross-reality (also known as x-reality) is an informational or media exchange between real- and virtual-world systems. Specifically, x-reality affects worlds both real and virtual to the point that its platforms have a meaningful and discernable effect upon that particular world. Current x-reality projects from different fields point to an unprecedented emergence of synchronous communication applications and information visualization design. The technical design of Eolus One, Green Phosphor, and the Parsec voice controller, for example, represent valuable additions to the architecture, protocols, and standards of x-reality.

Their most important innovation, however, is a conceptual shift in design paradigms from asynchronous and single-direction information flows to synchronous and multidirectional engagement.

Because technical standards haven't yet been established, the fundamental work of x-reality systems is to extend collaborative tools into networked spaces and augment user engagement in the experience of virtual presence (copresence). The movement toward advanced visualization, design communication, and collaborative environments extends to such diverse research fields as engineering design, knowledge management, and virtual enterprise.¹ The three projects in this article are sensor based, creating information flows

from real to virtual (R-V) or feedback loops of real-virtual-real (R-V-R). All address real-time processes and real-time data flow formatted to work in 3D graphical interfaces.

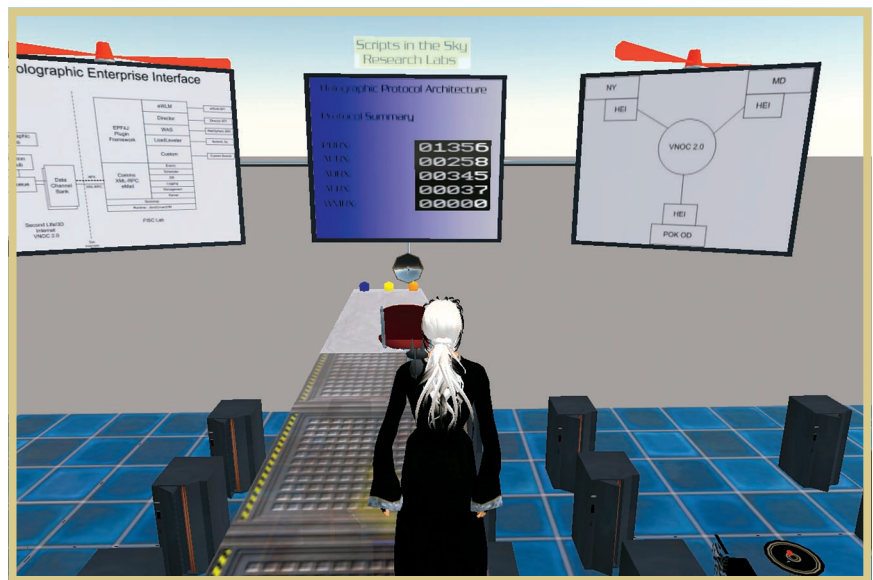
As a group, the projects represent early 21st century experiments in x-reality design and aren't yet statistically meaningful enough to provide quantitative analysis. However, they do engage social networks as powerful collaborative tools and leverage 3D visualization for enhanced communication. Collaborative design networks, such as the open source code culture of the 1990s, set an important precedent for the media technology innovations we see today. Even if general protocols and standards don't yet exist, x-reality platforms already share a clearly defined set of design principles:

- The networked information must be available synchronously among all users.
- Users can more easily visualize data, particularly complex data, in 3D graphical form.
- Collaborative network tools support greater experiences of virtual presence (copresence).

X-reality design brings together aspects of different historical fields such as virtual reality (VR), shared virtual environments (SVEs), human-computer interaction (HCI), and, importantly for the works under consideration, real-time networks that influence social media use. The Eolus building management system, Green Phosphor 3D software, and the Parsec SVE sound space all engage a social use of VR and HCI applications

Beth Coleman
Massachusetts Institute
of Technology

Figure 1. IBM's holographic enterprise interface (HEI). Chief 3D architect for IBM's IT Optimization Business Unit, Michael Osias worked with Eolus to provide the middleware for the experiment.



as well as new aspects of networked (ubiquitous) media that create the conditions for x-reality design.

A growing body of research addresses lab-based x-reality experiments, including issues of presence, copresence, and “sensible” objects.^{2–6} The three projects in this article address fields of interest from building and management to musical composition, yet they all share broad, horizontal, real-time participation. They model emergent behavior in x-reality design for a general user experience (UX) that includes participants outside of an exclusively academic- or research-based community. This orientation is important in addressing ubiquitous users in relation to ubiquitous computing. Each product’s actual content isn’t the central concern here. Rather, in discussing concept, design, and application, I demonstrate how these projects address collaborative real-time applications.

Eolus One: Real-Estate Management and Virtual Controllers

Researchers and developers have focused on smart buildings—structures with sensor networks and degrees of automation—for more than a decade.⁷ Since 2005, test applications engaging Internet protocols (IP) have accelerated toward the goal of making building management more efficient or “smarter.”^{8,9} Going online in 2006, the Eolus One project tested building sensor technology that used a networked 3D graphical interface to exploit the possibilities of real-time data collection and distributed control mechanisms. Initiated by Swiss engineer Oliver Goh at Implenia, Zurich, the two-year ex-

periment connected real-world events in actual buildings with a centralized virtual command center where users could monitor and affect building systems remotely. I conducted a personal interview with Goh on 28 November 2008 to learn more about this project.

Based physically in Switzerland and virtually on the OpenSim platform, Eolus One took advantage of third-party application development (the open source OpenSim and the proprietary Second Life platforms developed by Linden Labs) to run a secure 3D intranet operation. Eolus used collaborative methods to solve technical and human communication issues, combining in-house hardware and software development with existing media technologies to make their experiment in networked management possible. By using virtual-world platforms as the system simulation engine, the project explored two emergent terms of x-reality design: the centralized yet nongeographic control station and information rendering as a 3D interactive simulation.

Eolus One also tested the hypothesis of whether a virtual network could create greater efficiencies in real-estate, including systems maintenance and worker time. The project’s mission was to implement industry goals of building automation systems (BAS) to control heat, air

conditioning, lighting, and other systems in a unified IT infrastructure.¹⁰ To create a secure link between real- and virtual-world information systems (building sensors and the virtual control room), Goh and his team designed the Eolus Virtual Worlds Communications Interface in collaboration with Michael Osias, chief 3D architect for IBM’s IT Optimization Business Unit, whose work on holographic enterprise interfaces (HEIs) provided the middleware for the experiment (www.marketwire.com/mw/release.do?id=823627).

Implementation

The first implementation began with using virtual control capabilities to turn lights on and off in dollhouses at Coventry University’s Serious Games Institute, an IT fair in Berlin, and other real-world sites. In the next stage, the Eolus development team created a system of templates to unify all the information a building system provides. The team surveyed the operations systems of 4,500 buildings to create 27 reference points or building primitives. It then simulated the reference buildings’ management systems (HVAC, elevators, light, safety, and so on) as 3D objects for visual identification in the virtual command center (VCC; see Figure 1). The Eolus team created low-power

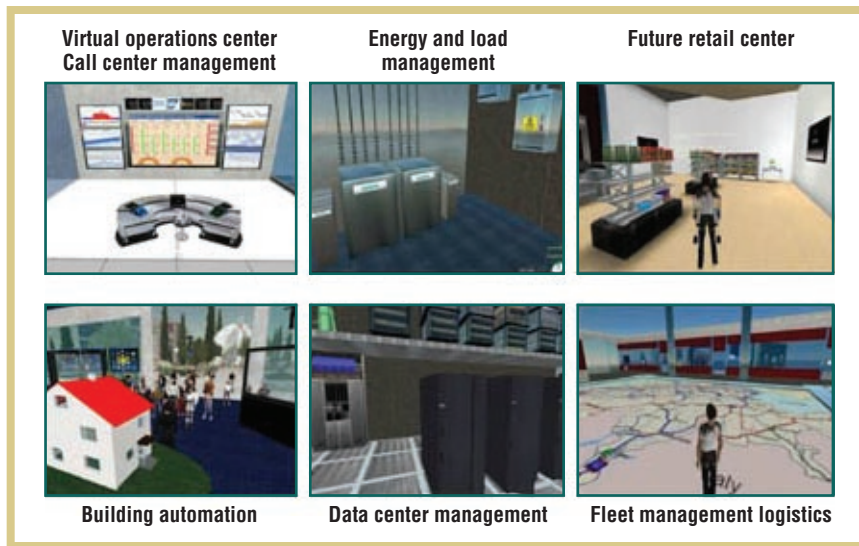


Figure 2. Eolus One Park. Real world viewers of the Eolus One greeting station on Second Life platform, Eolus One.

network-sensor hardware that sat in 25 real-world facilities. After identifying the kind of devices a building used, the hardware box translated building data into virtual objects. Once the hardware configured a virtual object for each relevant building system, a virtual simulation effectively managed the building.

The VCC exists on a network: operators have immediate access to everything they need to run the system. The control room staff appears as 3D avatars to show who's virtually present, supporting a greater experience of copresence.¹¹ Anyone online can visit the project's public face, as you would an actual headquarters, by accessing the Eolus One Park in Second Life (see Figure 2). Those with proper authorization can access the actual systems data from behind the Eolus firewall on the OpenSim platform.

The simulation's goal was to create an intuitive method for understanding a company's architecture, monitor live systems, and run scenarios on a distributed network. In using the VCC, the buildings' physical locations became less relevant to their efficient engineering maintenance. Yet, by creating a "smart" system around building management, the VCC implemented greater

efficiency in the local administration of actual buildings (see Figure 3). For example, an engineer in Mumbai could monitor a building in Zurich, then dispatch the appropriate locally based person to fix the problem.

Collaboration

The project showcased a unique collaborative method for developing x-reality technology. The Eolus team invited virtual-world users on the Second Life and OpenSim platforms to help solve interface issues and design challenges. A network of interested researchers provided the project's building test sites on a volunteer basis. Much in the model of open source code development efforts, such as Apache or Linux, Goh and his team created the Eolus x-reality interface in collaboration with a network of virtual-world participants, not a proprietary group of developers.

Goh claims that Eolus can reduce energy use by 20 to 27 percent, depending on the building, which is within the established projections for BAS. Yet, the Eolus efficiency number can't be verified because, as Goh explained in his personal interview that the collected data isn't statistically meaningful.

Working with the ideas of cost, time,

and carbon footprint reduction, the Eolus vision, in applying distributed real-time management to global data centers, aligns with current trends in "globally integrated enterprise."¹² It's not just the building that's smarter, but the whole system. Reorganizing how the traditional real-estate industry manages buildings already presents a radical change. Nonetheless, Eolus stops short of invoking the most powerful network it could gather. Although the project experimented with engineering design and virtual enterprise extensions, Eolus remained within the traditional thinking of command control: its knowledge network only addressed designers and engineers. A major innovation would engage the networked building's occupants in the information flow. Goh indicates that the next project will bring UX as part of collaborative networks to the fore.

Belgium-based VRcontext (www.vrcontext.com) provides an additional model for real-world systems management with x-reality design. As Eolus uses VR technologies, SVE, and real-time network connections in building management to improve efficiencies, VRcontext runs a similar type of operation for industries such as oil and gas, energy, and architecture/engineering/construction (AEC). VRcontext uses its 3D applications Walkinside and ProcessLife to augment workflows in engineering and human communication, by, respectively, creating a virtual model of a facility and managing its assets. (However, VRcontext hasn't yet made public client data supporting its claim of greater efficiency and seamless communication via its platform.)

Both Eolus and VRcontext demonstrate a progression in media design from visualization technologies, such as AEC-applied CAD models, to integrated real-time graphical applications that allow for dynamic use of materials across a network. Eolus uses avatars to enhance copresence in the virtual control room, whereas VRcontext creates high-level graphics to simulate

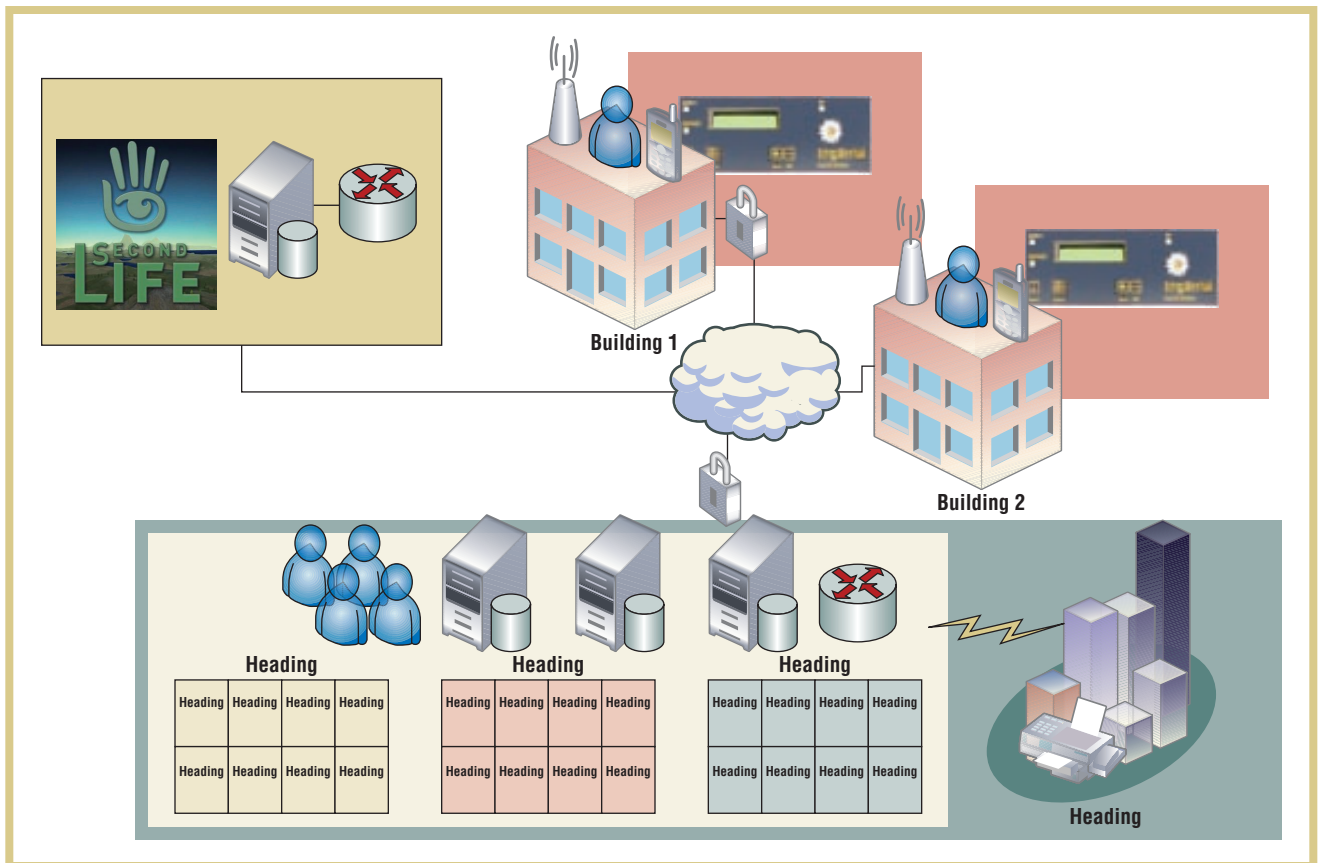


Figure 3. Eolus One/Shaspa Virtual Control Center (VCC). The diagram shows a cross-reality information flow, illustrating real-world-to-virtual exchange.

objects, light, motion, and so on. VRcontext features a media-rich platform that can include laser scans, photography, digital terrain models (DTMs), and CAD data. Eolus doesn't offer the same degree of graphical realism, media diversity, or event simulation. In development, VRcontext created its own 3D software whereas Eolus leveraged existing properties to rapidly prototype an x-reality exchange. Despite their differences, both projects demonstrate that immersive VR simulation produces a distinctive x-reality effect: networked real-time media platforms creating an intuitive aid to operations management.

Green Phosphor: 3D Interface Design

Since 2006, Ben Lindquist, CEO of Green Phosphor, has focused on de-

veloping 3D software that translates data into real-time interactive visual systems. Green Phosphor has created applications for the Sun Microsystems Wonderland virtual world as well as 3D simulations for other clients that are accessible via Second Life. Over the past few years of 3D application development, Lindquist has grown adverse to the term *data visualization* to describe rendering *n*-dimensional information into interactive 3D programs. Instead, in a personal interview, Lindquist told me that he prefers the term *user interface* to describe both what Green Phosphor makes and to discuss the larger field of emerging 3D Web applications.

Lindquist sees the change that a 3D Web promises as a shift in user interactivity that's deep and increasingly complex. If data visualization has historically represented finite and inaccessible

data sets, the 3D Web offers real-time data feeds that users can parse with increased granularity as well as an efficiency of scale in distributing the information. In his practice, Lindquist sees that 3D interfaces invite users to engage with the material. 3D isn't simply a mode of graphically representing information, rather, it invites a UX that heightens engagement; it's a mode of designing interactivity.

Green Phosphor created a 3D world-oil map in 2006 that models the company's concept of increased interactivity with 3D graphical information design. The map charts global oil use from the 1970s to the present day as a blue Lego-like village, in which users can zoom in on particular silos of information in a manner similar to Google Earth or other 3D maps that allow for granular display. In this case, each part

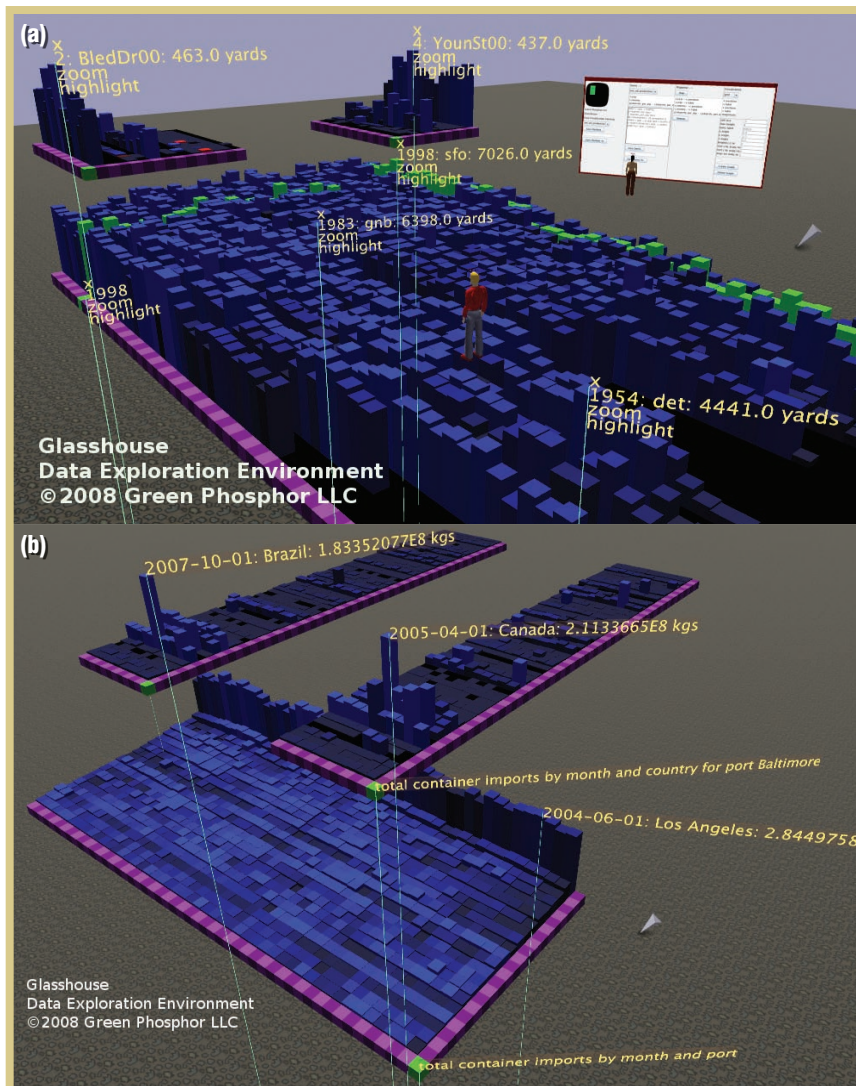


Figure 4. Green Phosphor. (a) The Green Phosphor data exploration environment with avatars uses a blue Lego-like structure in which users can zoom in on particular silos of information in a manner similar other 3D maps that allow for granular display. (b) Each part of the Green Phosphor 3D Interactive oil map represents time-based and geographically oriented consumption of oil per barrel drilled globally from 1970 to present, Green Phosphor.

of the map represents time-based and geographically oriented consumption of oil per barrel drilled (see Figures 4a and 4b). Users can track the information as a whole or see it broken down to national striations. Avatars fly over the oil map and metatag the information (provide metadata over a network); user groups can add their metatags to the map, creating a shared data pool of annotations.

3D Interactive Design Principles

Green Phosphor bases its design principles on the idea that 3D rendered information is easy to comprehend, particularly when the data is complex and pattern recognition is highly valued. The company designs along two axes of 3D engagement: user comprehension of data and user interaction with data. Additionally, Green Phosphor focuses on real-time networked environ-

ment design, where data interaction is synchronous. Its goal is to move away from static information sources and toward greater degrees of dynamic design solutions.

The company begins with the premise that to see information in 3D is to see it differently—for example, its oil map project includes in its data set historical, contextual, and political shifts in oil trading and consuming that aren't as easily implied by the static presentation of the same data. Lindquist suggests that by making such data accessible in a commons-based (open access) networked environment and designing a dynamic interface, users will find multiple and collective ways to activate the information for their own purposes. Green Phosphor sees virtual-world or 3D platform engagement much like that of real-world engagement, in which sensory information in shared space-time is the basis of the exchange.

Lindquist explained in his interview with me that genomics and proteomics researchers in particular are faced with unprecedented amounts of data. Green Phosphor's efforts in computational information design seek to create visual languages conducive to summarizing complex and voluminous data. By putting cancer diagnostics into a seamless 3D configuration, the company creates a system in which scientists can more easily identify data patterns—for example, researchers were able to identify new proteins on the cancerous side of the visual simulation that hadn't been apparent in other data iterations. Green Phosphor employs strategies in networked information design that speak to a powerful emergent trend. At the forefront of this new direction for designer and computer scientists, Ben Fry's work in the Processing language (<http://benfry.com/genetics>), an open-source code often used for interactive graphic representation, offers another current example of 3D interactive design moving into the biological sciences.¹³

Open Source and 3D standards

In its software design, Green Phosphor uses a geometric primitive system that can be adapted to any 3D platform. For the Wonderland application, which is all Java, Sun added a cell to the code base that reads and directs a Green Phosphor scene graph that in turn users can manipulate in the Open Graphics Library (OpenGL) standard. A scene graph is one object, so within that object users can exploit the same files on any platform. Green Phosphor found a solution for design within each platform; the same logic can be applied to Forterra in C++ or Second Life in Linden Scripting Language (LSL).

Although Green Phosphor has well-articulated design principles, critical technical issues remain in implementing its brand of UX. For networked 3D software, Lindquist says the core technical issue is the number of geometrical primitives that can be supported on a graphics card. If research groups continue to assemble in labs with access to supercomputers, then information rendering isn't an issue. But when information needs to be shared across a broader network, distributed graphical simulation problems can become profound. If the goal with Green Phosphor applications is a live stream of data and real-time interaction shared across a network of collaborators, then computing capacity becomes an issue. Additionally, data in particular product forms (for example, Excel) must be mapped appropriately to the particular 3D format. As Lindquist pointed out in our discussion, data storage varies greatly, which presents data integration problems.

The issue of 3D Web architecture, protocols, and standards becomes even more pressing as 3D applications such as Green Phosphor's are adopted within—and increasingly between—simulation platforms. To a large extent, groups willing to share their code will determine the standards and, from there, which protocols present best practice. Because collaborative networks thrive

on open source information, companies both large and small continue to struggle with degrees of transparency and sharing.

Green Phosphor addresses its own approach to 3D protocols with a multilayered strategy. The company works with both a GNU Public License (GPL), which is open source, as well as proprietary licensing for its various projects. In general, though, the Green Phosphor code and provisional patent for creating

Designed specifically for the Second Life platform and launched in January 2008, it represents the collaboration of sound artist Robert Thomas (Dizzy Banjo in Second Life), visual artist Eshi Otawara, and script developer Chase Marellan. The project links Second Life's voice over Internet Protocol (VoIP) system with additions to the LSL to create an interface for users to move virtual objects with their voices. The Parsec system deserves to

Insert pull quote here! Insert pull quote here!

Insert pull quote here! Insert pull quote here!

ALIGN THE TOP BAR WITH BASELINE.

a 3D interface within any virtual-world platform is GPL. The company's application design for a gateway between database and virtual-world implementation (portability of data and seamless translation) remains proprietary.

It's currently impossible for anyone working in the medium to port data across platforms, which makes interoperability central to the larger debate around 3D Web design standards. Second Life, OpenSim, and IBM staged an experiment in July 2008 in which they teleported an avatar from the SL environment to the OS itself, but none of the avatar's inventory (collected data) transferred with the figure (<http://blog.secondlife.com/2008/07/08/ibm-lindenlab-interoperability-announcement>). In such a case, you could argue that the collected information surrounding the avatar is far more important than its appearance. Lindquist is currently collaborating on the Metaverse Exchange Protocol (MXP) with an international group to determine technical solutions for a virtual-world/3D architecture (www.bubblecloud.org/wiki).

Parsec: Controlling Virtual Environments

The Parsec system lets users control a virtual environment with their voices.

be included in an x-reality design discussion for several reasons. The interface controller is voice based, allowing for a heightened experience of copresence, which represents a development in HCI but not in x-reality per se. Instead, the system's x-reality event is the nature of its SVE, which is collaborative by design, engaging multiple real-time inputs from diverse sources to create a virtual composition: real-world information (voice) creates a virtual event. Parsec's design affordances speak to an x-reality engagement that has VR, HCI, and real-time collaborative structures in place. Additionally, unlike proprietary x-reality systems, anyone can use Parsec, which makes it an easily accessible x-reality prototype for professionals, researchers, and general users alike.

Its designers created Parsec to look and behave like a virtual performance space. A user begins in a black antechamber that outlines instructions on how to set voice control parameters and other user details (see Figure 5a). After the briefing, the user enters an all white spherical chamber in which voice prompts move sound objects through the space (see Figure 5b; black spheres represent the sound objects). The voice input's volume and pitch control

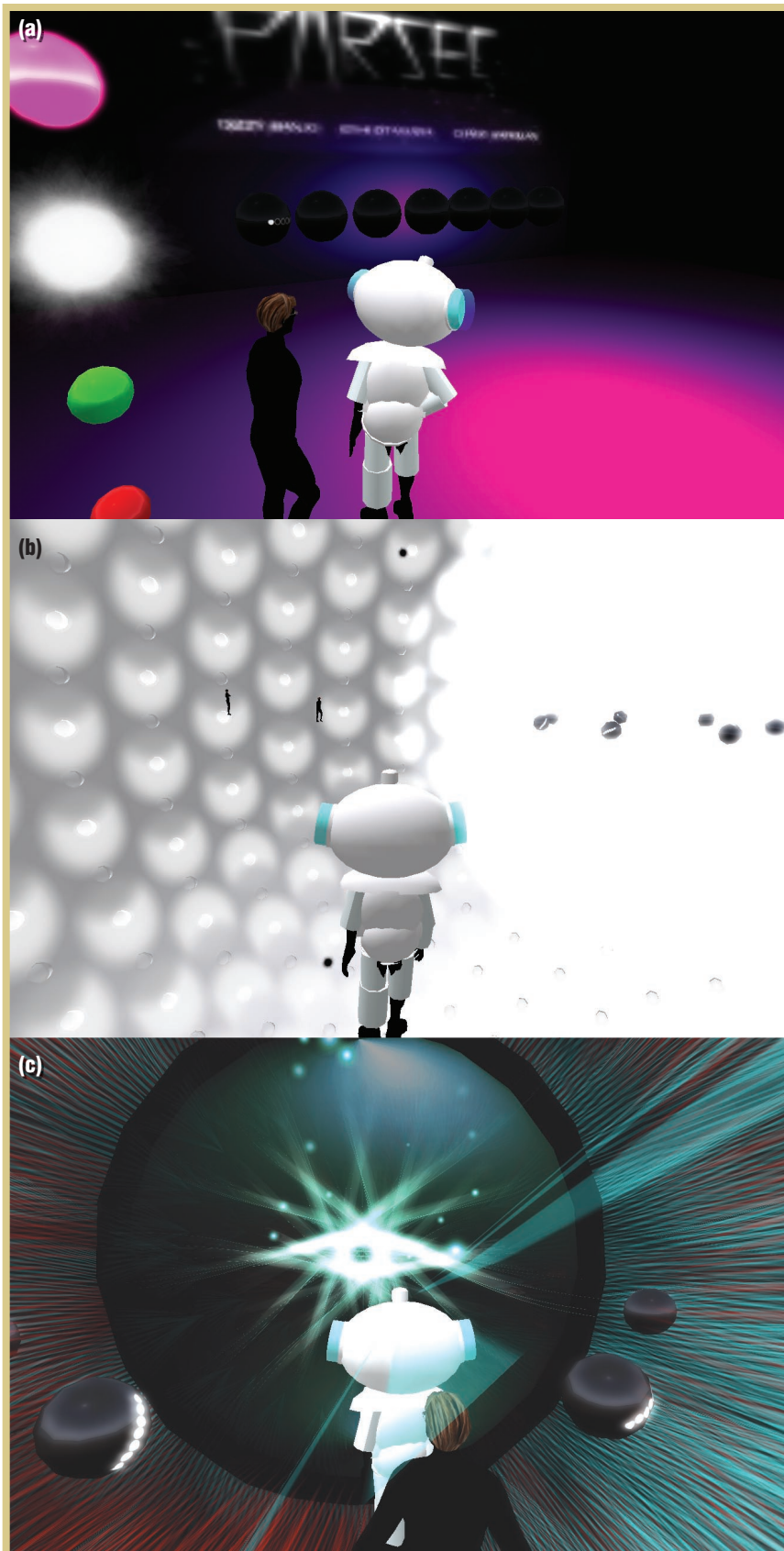


Figure 5. Parsec multiplayer environment.

(a) Parsec multiplayer environment antechamber where avatars select virtual instrument (black sphere). (b) Parsec multiplayer environment, three avatars using voice controlled instruments. (c) Parsec multiplayer environment, sonic input triggering virtual light show.

the velocity and other aspects of the sound objects. Made for seven players, the Parsec instrument harmonizes the various sound objects put in motion; it also contains an audio puzzle that resolves in a light show (see Figure 5c). When users play a particular audio sequence, the Parsec virtual chamber explodes into a kaleidoscopic array. // again, these figures seem to have the same caption—consolidate them into one figure, three parts?//

In terms of its technical design, the Second Life platform autonomously hosts Parsec, using just the code and media available within the platform—the system needs no additional hardware or servers. The Parsec group worked collaboratively with Linden Labs' developers to create the project. In particular, Parsec runs its voice dynamics information through a modified version of Second Life speech gestures (code that links animation to VoIP; http://wiki.secondlife.com/wiki/Voice_FAQ). By using this preexisting speech gesture system, the Parsec group could design voice input to directly communicate dynamic information to virtual objects.

Collaborative Environment Design

Parsec's designers created the instrument to facilitate multiplayer composition in a collaborative environment—in fact, the best way to play the instrument is to create some kind of group or choral participation. A powerful aspect of the collaborative design is the sound-input (voice) controller, which facilitates a full-bodied, or at least full-throated, enthusiasm from its users.

Unlike the keyboard-and-mouse interface, Parsec's users must physically throw themselves into the experience. Recent success with gesture-based controllers, such as the Wii interface, points to similar ways that users can affect virtual space including a hands-free virtual world controller (www.handsfree3d.com) and virtual interface design.¹⁴ Beyond the visual presence of avatars, the new possibilities for sensor controllers include bodily affect such as touch, sound, and gesture to activate virtual events.

Parsec connects aspects of human physicality (voice) to the virtual, simulating the feeling of greater proximity as well as creating a necessity out of collaboration: to trigger the light event, the instrument needs multiple players. Its designers describe the project's effect as allowing people to feel closer to each other—an enhanced sense of copresence—when they use the voice-based controller. Beyond the instrument's compositional aspects, the Parsec group's design includes aspects of a user's real-world persona in the virtual realm, which could prove a crucial aspect of x-reality experiences. Creating a more emotive virtual space increases the social aspect of collaboration and copresence.

The three x-reality projects discussed in this article demonstrate emerging key principles for design: synchronously shared information, complex real-time visualization, and collaborative tools. Eolus engages x-reality applications to create a VCC for buildings. Green Phosphor creates applications that allow for the portability of data from n-dimensional and multistorage formats into a 3D interactive form. The Parsec multiuser virtual instrument lets vocal input control virtual objects.

These projects forecast the future of x-reality in the way they design their knowledge networks. The particular

Need new
author photo

Beth Coleman is an assistant professor in the Comparative Media Studies and Program in Writing and Humanistic Studies at the Massachusetts Institute of Technology. Her research interests include new media user experience, shared virtual environments, and cross-reality design. Coleman has a PhD in comparative literature from New York University. Contact her at bcoleman@mit.edu.

silos of real-estate or genomic data aren't the issue at hand as much as are the shared methods of solving problems with new tools. Current x-reality use, nascent as it might be, predicts the growth of interoperable systems of data as well as a UX that nimbly crosses platforms. X-reality design aspires to dynamic, collaborative systems that can be applied to unique projects with an efficiency of scale and granularity. Graphical simulation and real-time distributed networks are critical to this endeavor. ■

REFERENCES

1. I. Horváth, S.M.J. Vergeest, and Z. Rusák, "Six Ingredients of Collaborative Virtual Design Environments," *Proc. 7th Int'l Design Conference (Design 02)*, 2002, pp. 67–74.
2. J. Blascovich et al., "Immersive Virtual Environment Technology as a Methodological Tool for Social Psychology," *Psychological Inquiry*, vol. 13, no. 2, 2002, pp. 103–124.
3. B. Friedman, ed., *Human Values the Design of Computer Technology*, Cambridge Univ. Press, 1997, pp. 191–200.
4. F. Kaplan et al., "Growing Virtual Communities in 3D Meeting Spaces," *LNAI vol. 1434*, J.-C. Heudin, ed., Springer-Verlag, 1998, pp. 286–297.
5. T. Koda and P. Maes, "Agents with Faces: The Effect of Personification," *Proc. 5th IEEE Int'l Workshop on Robot and Human Communication (RO-MAN 96)*, IEEE CS Press, 1996, pp. 189–194.
6. Y. Ohta and H. Tamura, *Mixed Reality: Merging Real and Virtual Worlds*, Springer-Verlag, 1999.
7. D. Snoonian, "Smart Buildings," *IEEE Spectrum*, Aug. 2003, pp. 18–23.
8. C. Waltner, "Smart Buildings Offering Clever Ways to Reduce Energy Consumption," June 2008; http://newsroom.cisco.com/dlls/2008/ts_072108.html.
9. R.C. Shah and J. Rabaey, "Energy Aware Routing for Low Energy Ad Hoc Sensor Networks," *Proc. IEEE Wireless Communications and Networking Conference (WCNC 02)*, vol. 1, IEEE CS Press, 2002, pp. 350–355.
10. *Data Communication Protocol for Building Automation and Control Networks*, ASHRAE Standard Project Committee 135, Am. Soc. Heating, Refrigerating and Air-Conditioning Engineers, 2003, p. 1–11.
11. J. Bailenson et al., "The Effect of Behavioral Realism and Form Realism of Real-Time Avatar Faces on Verbal Disclosure, Nonverbal Disclosure, Emotion Recognition, and Copresence in Dyadic Interaction," *Presence*, vol. 15, no. 4, Mass. Inst. Tech. Press, 2006, pp. 359–372.
12. S. Palmisano, "The Globally Integrated Enterprise," *Foreign Affairs*, vol. 85, no. 3, 2006, pp. 127–136.
13. M. Clamp et al., "Distinguishing Protein-Coding and Noncoding Genes in the Human Genome," *Proc. Nat'l Academy of Science, U.S.A.*, vol. 104, no. 49, 2007, pp. 19428–19433.
14. D.E. Stone and C.L. Koskinen, *Planning and Design for High-Tech Web-Based*, Artech House, 2002.

For more information on this or any other computing topic, please visit our Digital Library at www.computer.org/csdl.