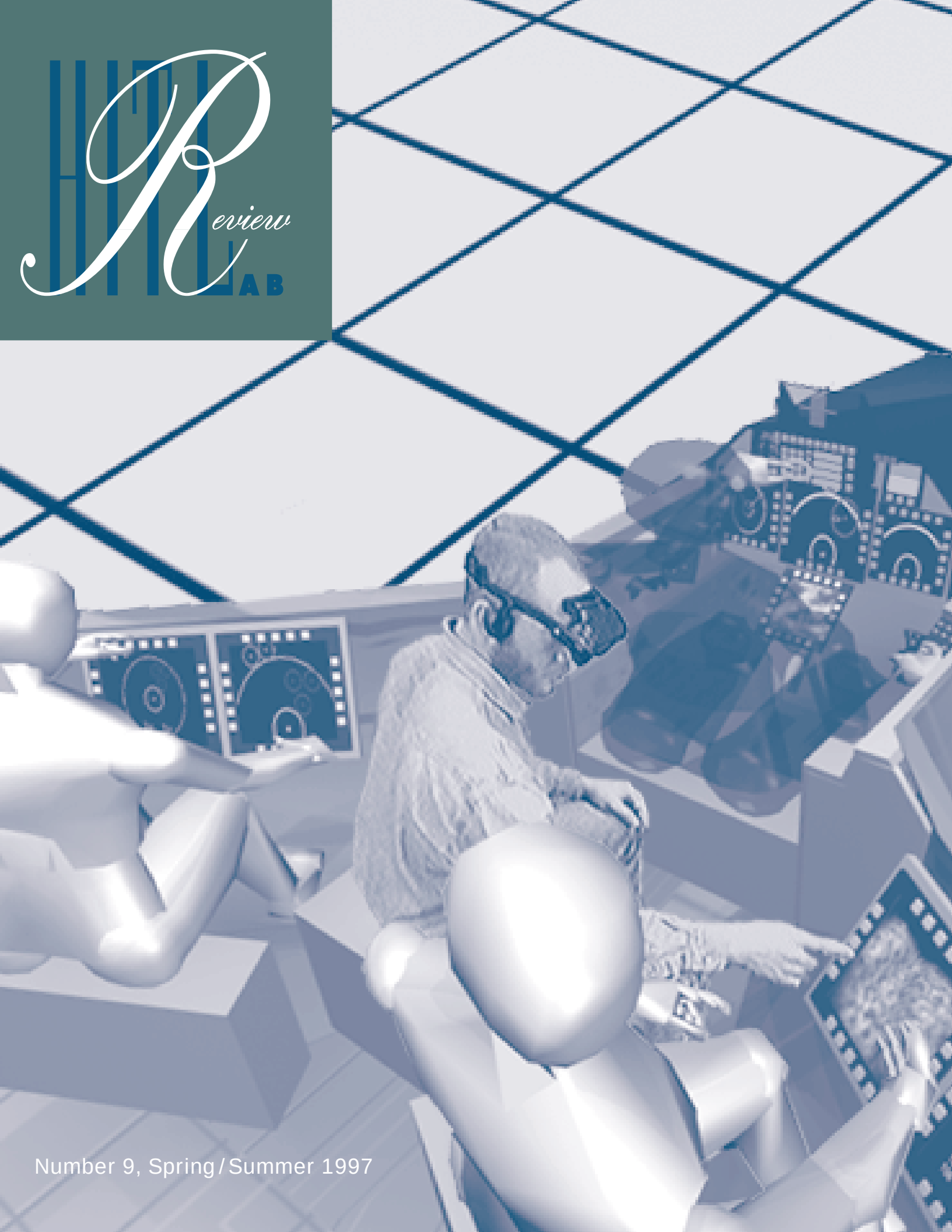
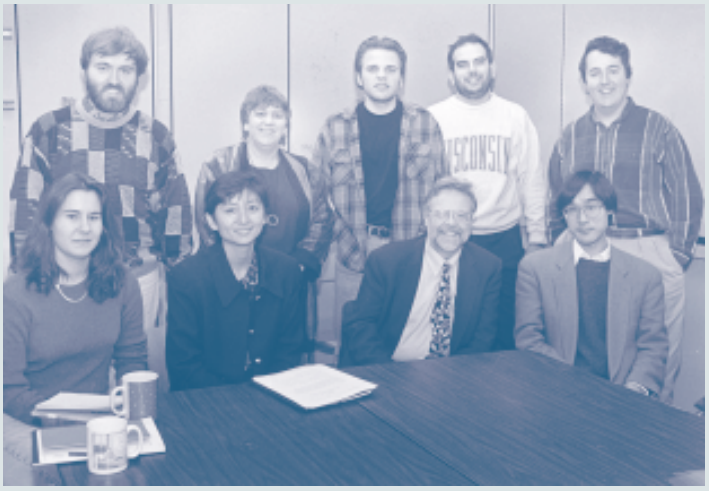
HITL Review



Number 9, Spring/Summer 1997

Director's Brief



Fujitsu visiting scholar Youji Kohda (lower right) presented current research on cyber-architecture to HITLab personnel (seated clockwise from Kohda's left) Tom Furness, Rose Yu, Jessica Foeste, Jerry Prothero, Suzanne Weghorst, Sisinio Baldis, Bruce Campbell, and Joey King.

Hello everyone!

As usual, the last six months have been full of activity and change. In this issue we feature progress on the Air Force Office of Scientific Research (AFOSR) grant. Several new theories and technologies have resulted from this project which enhance communication within complex information environments. Also included in this issue are updates on our medical, architectural, interface design, knowledge base and educational work, among others.

The HITL Learning Center recently completed the Virtual Reality Roving Vehicle (VRRV) project sponsored by the U S *WEST* Foundation. Through this program, over 8,000 students in Washington and Nebraska experienced virtual reality. Our research indicates these virtual experiences have had a positive impact on students' knowledge acquisition and retention. We are hoping to host a NSF workshop in the near future to explore the implications of our findings and to develop a strategy for future K-12 programs.

On the industry front, we welcome two new members to the Virtual Worlds Consortium: BHP and Sense8 Corporation (see page 18). Their participation brings the total number of Consortium sponsors to 37. We treasure our industry partners and the valuable insight, direction, services and support they generously contribute to our scientific and technical infrastructure.

Within the Lab, we are busy reconfiguring research space and upgrading equipment thanks to a Defense University Research Instrumentation Program grant. After the dust settles, we will have a state-of-the-art simulation "collaboratory" with multiparticipant and spatial sound capabilities.

As always, the most thrilling part of HITLab activity is the opportunity to work with such wonderful colleagues. Special congratulations to Jerry Prothero and to Mark Draper for successfully passing their Ph.D. general examinations. We especially extend our best wishes to Rich Johnston, David Melville, Heather Patrick and Steve White as they launch new careers. They leave a legacy of pioneering contributions to the virtual retinal display project for which we are tremendously grateful.

Your feedback on our research projects and this publication is welcome. We're considering "going paperless" and posting the newsletter exclusively to our Web site. Send us your thoughts on this alternative and any other comments to *Review* editor Alden Jones *alden@hitl.washington.edu*.

Thomas A. Furness III, Ph.D.
Professor and Director

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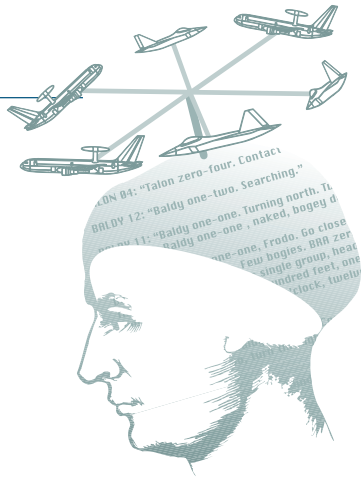

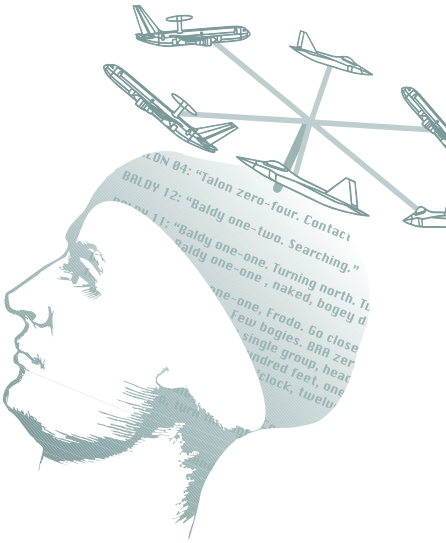

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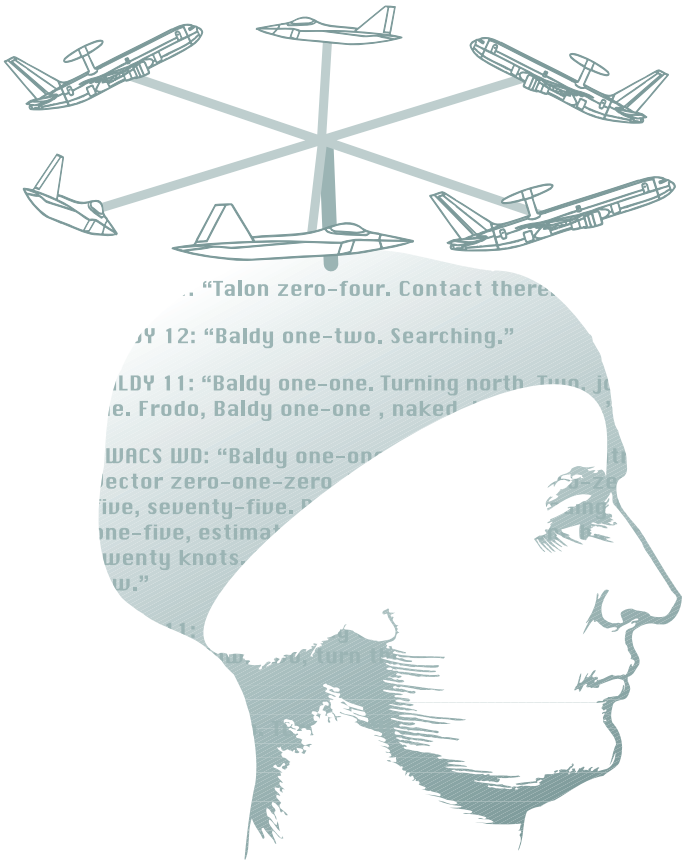
Page 2, 5, 6: Mary Levin, UW. Special thanks to Debra Sutey and Chief Steve Olson, Seattle Fire Department (p. 6).

Page 3: excerpt from AWACS-fighter transcript provided by Matt Dalyrmple and Linda Elliott (Brooks AFB). Boeing AWACS and F-22 drawings.

Page 9: center photo courtesy Lockheed-Martin, other images by Peter Oppenheimer.

Page 10: video stills by Wayne Taylor.

Page 19-21: images courtesy Virtual Vision, Division Ltd. and Insight.



The HITLab Review is a periodic publication of the Human Interface Technology Laboratory, a joint research unit of the University of Washington and the Washington Technology Center. Questions or comments regarding the Review can be sent to:

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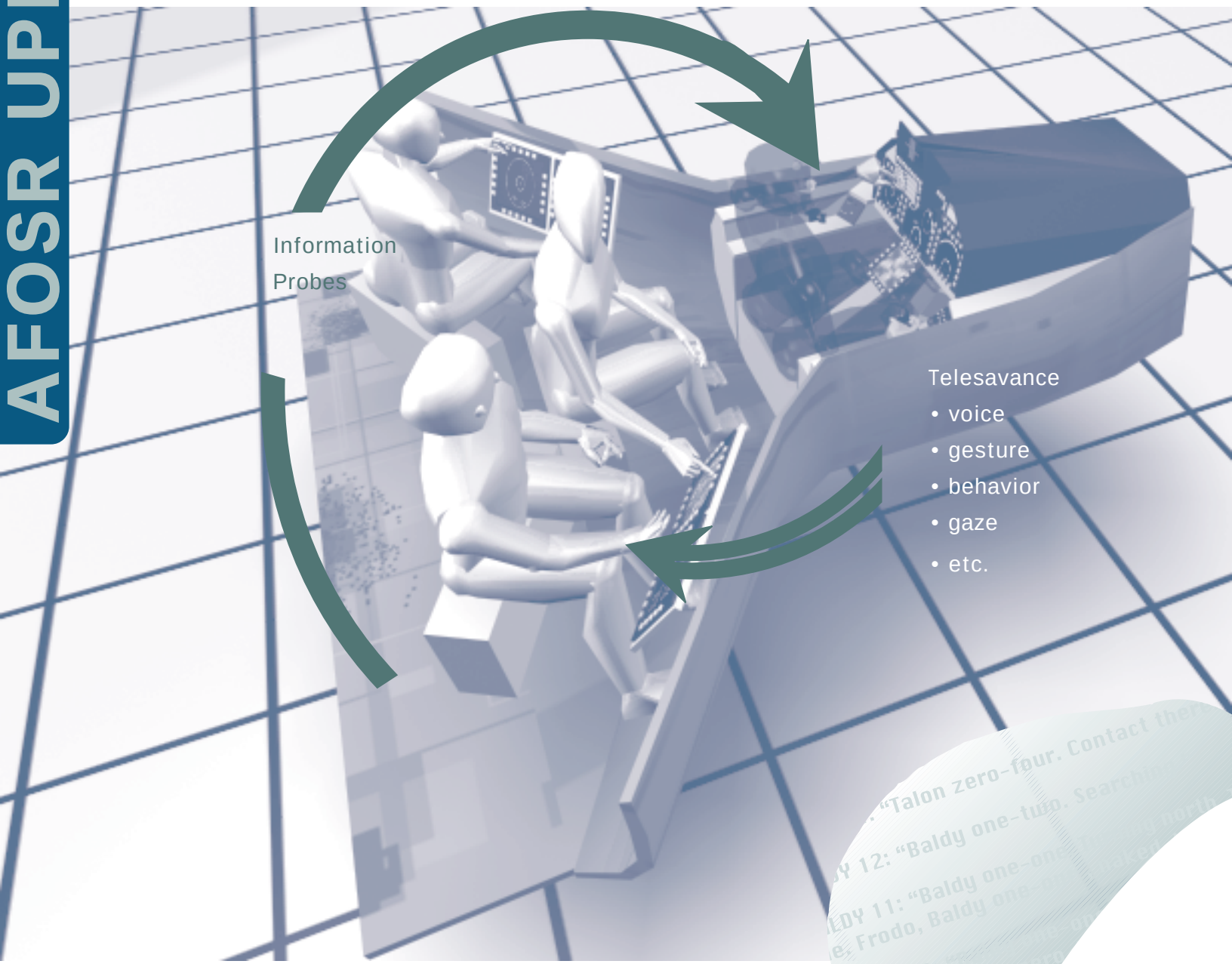

A shared virtual space with four participants in separate physical locations. In this scenario, the advisors can see and hear each other, but the pilot can only hear one advisor.

Telesavance

The term savance comes from the noun “savant” meaning a wise, learned or knowledgeable person. The term “telesavance” refers to the transmission of the state of a person’s “wisdom,” or situation awareness, using telecommunication techniques. The HITLab has been exploring the concept of telesavance as part of the evolution of the Virtual Pilot (ViP). The ViP was demonstrated in September 1996 and was described in the Fall/Winter 1996 HITLab *Review*. In the ViP demonstration two people played the role of pilot and copilot in a shared virtual cockpit. They communicated with voice and gesture as they collaborated on a demanding task. This concept has acquired some momentum in the form of telesavance. One embodiment of the concept is shown on the cover, and at left.

The scene depicted on the cover shows an advisor with a see-through HMD surrounded by a shared augmented reality consisting of displays and avatars. Each avatar is controlled by a real person. All four participants are in different locations and may represent, for example, a pilot in a single seat fighter being advised by an AWACS operator, a Forward Air Controller and a ground controller. A version of the shared virtual environment is present at each location, and is animated by gestural signals generated at the various sites. In addition to tracking movements of the hands and head, eye movements are also tracked and shown as a circle where the pilot is currently looking. Other physiological measures, such as galvanic skin response, electromyography, and electrocardiography could also be added.

Each advisor is attempting to impact the situation awareness of the pilot by transferring a mental model to the pilot. To do so, the advisors transmit information and probes to assess the state of the pilot’s knowledge. In face-to-face communication we use probes (e.g. “OK?” “Know what I mean?” “Yea?”) and look for verbal and gestural confirmation that the information being transmitted is understood. This is an important aspect of intelligent communication. It prevents the transfer of redundant information, it allows for changes in pacing and repetition when there is ambiguity or lack of understanding, and it builds confidence on the part of the transmitter and the receiver.

The concept of telesavance draws from a large body of literature on communication, from previous work at the HITLab on distributed virtual worlds (GreenSpace), from research at the HITLab and elsewhere on facial gesture recognition (e.g. Joey King’s work), and from ideas generated by the Virtual Pilot project. Telesavance represents a unifying construct with the following potential advantages:

• it emphasizes solutions based on the communication of situation awareness, rather than on the communication of data.

• it uses natural, intuitive communication techniques which may require less cognitive resources.

• it can serve as an interim development step to an intelligent assistant in the cockpit.

Some of the communication advantages represented by the ViP scenario could be achieved by placing a video camera in the cockpit. However, the advantages of using avatars include lower communication bandwidth (73,728,000 bits/second for video vs. 11,520 bits/second per sensor), the ability to manipulate gestural data (e.g. for machine recognition and to summate, exaggerate or filter), and the flexibility of information presentation (e.g. the see-through pilot shown on the cover and at left). The question of whether video is a sufficient solution needs to be answered empirically.

An experiment is being prepared to test the performance advantages which can accrue from the communication of situation awareness in virtual reality. This proof of concept study is being supported by Armstrong Laboratory at Wright Patterson Air Force Base and the Air Force Office of Scientific Research (AFOSR). Future directions for the program include the creation of design guidelines to identify domains in which telesavance can play a role, and expansion into other domains (e.g. ship borne, remotely piloted vehicles, and training).

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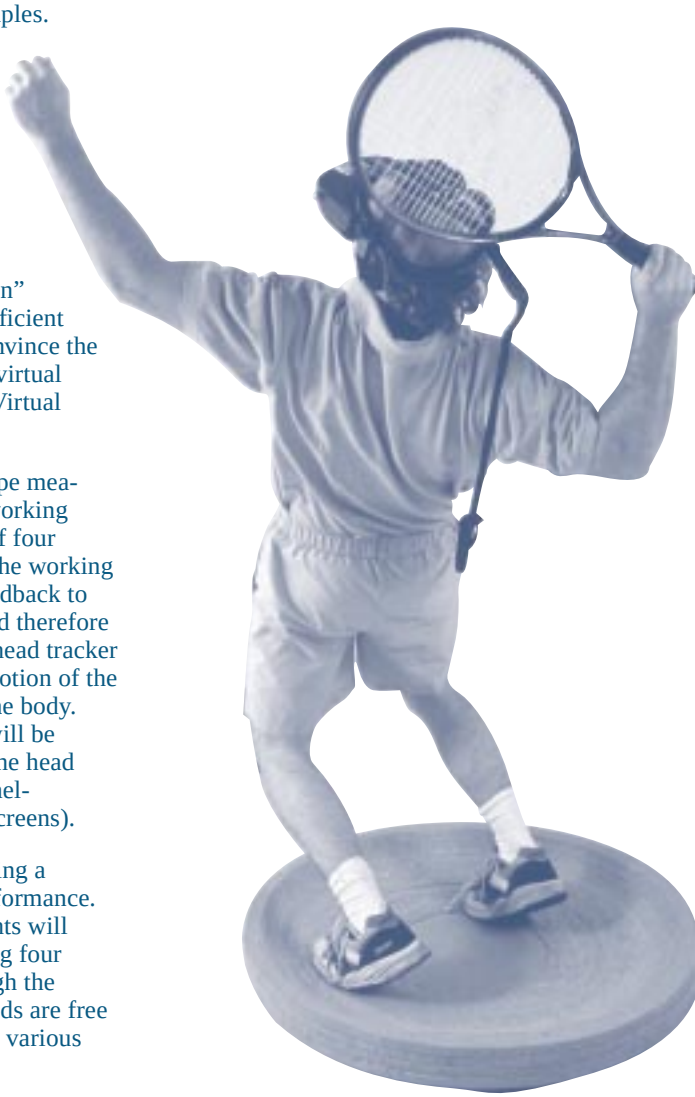
The Virtual Motion Controller

In some virtual training environments, movement is accomplished using vehicles ranging in complexity from a bicycle to an F15 aircraft. Typically, the purpose of these virtual environments is to train for competence in the control of the vehicle in the real world.

However, in many other instances, it is more appropriate for a trainee to walk through the virtual (and real) environment, and to focus on the task at hand rather than on a "vehicle" interface. For these applications, which often require a hands-free interface for holding tools and operating machinery, a body-operated walking simulator is ideal. Immersive environments to train firefighters, and to play VR games are good examples.

One solution to walking simulation is a 360 degree treadmill which would emulate real world kinesthetic motions in the virtual world. We call this approach a "full-motion" simulator. In contrast, the HITLab has been developing a "sufficient-motion" simulator in which there is sufficient motion in the real world to convince the user that she is moving in the virtual world. We call the device the Virtual Motion Controller (VMC).



HITL's VMC working prototype measures body position over the working surface with an arrangement of four weight sensors. The shape of the working surface provides important feedback to the user about her location, and therefore her input to the device; and a head tracker is used to measure yaw axis motion of the head, and by implication, of the body. Other conceptual prototypes will be capable of operating without the head sensor, and will work with panel-mounted screens (projection screens).

The HITLab is currently creating a virtual world to test VMC performance. In this environment, participants will perform a navigation task using four techniques to maneuver through the training world, while their hands are free to operate machinery and hold various tools.

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Direct "Class A" Measures for Presence

Presence is the term used to describe the sense of "being in" a virtual environment. HITLab researchers believe establishing a good metric of presence would be useful for measuring the goodness of virtual environments.

Existing measures for presence are generally based on questionnaires. It is thought that direct measurements of perception ("Class A" measures) are more reliable than measures which require conscious introspection of mental states (for instance, questionnaires).

HITL researchers have hypothesized that Class A measures for presence can be created by setting up experiments in which virtual and real cues conflict. The degree to which the virtual cues "beat" the real cues perceptually may be a Class A presence measure.

In the current experiments, a subject is placed in a rotating chair (at right) which oscillates in the horizontal plane. A virtual scene in a head-mounted display also oscillates with the same frequency but variable phase. Subjects are asked to indicate the perceived right and left extremes of the chair motion. (The frequency and amplitudes used in this experiment avoid motion sickness symptoms.)

At low amplitudes of chair motion, subjects inadvertently signal the visual motion, rather than the chair motion. At higher chair amplitudes, subjects are able to signal the chair motion correctly. Large differences (factor of 2-3) between conditions have been found for some subjects, but a correlation has not yet been established between the Class A measure and reported presence. A more sensitive experiment is currently being designed.

The rotating chair approach is intended as a proof of principle that Class A presence measures are possible. Subsequent experiments will use this metric of presence to explore the influence of variables such as field-of-view and resolution. A grant application has been submitted to investigate a potentially more useful Class A measure, suitable for interactive virtual environments. The measure, based on an illusion known as "induced motion," should impose only a minimal burden on subjects' normal actions in the virtual environment.

Jerry Prothero *prothero@hitl.washington.edu*

worth noting...

AFOSR researcher Jerry Prothero's abstract, "The Role of Rest Frames in Vection, Presence and Motion Sickness," has been accepted for inclusion in the forthcoming book entitled Psychological Issues in the Design and Use of Virtual Environments to be published by Lawrence Erlbaum Publishers in early 1998. Congrats Jerry!

AFOSR UPDATE

Stretching the LIMIT

Several recent innovations have enhanced the research capabilities of the HITLab's clinical simulation environment: the LIMIT (Laboratory for Integrated Medical Interface Technology), also known as the "Virtual ER."

During the autumn 1996 term, Dr. Stan Kaufman, HITL medical advisor and an experienced cardiologist and medical informatics fellow at Seattle's VA Hospital, led a team of programmers including Edward Miller and Ivan Poupyrev in the development of several novel spatial representations of electrocardiogram (ECG) data. Using the concepts of primary and secondary task loading developed for aviation display research, the team also implemented methods for immersively testing the effectiveness of new display objects and presentation styles. Results of Kaufman's studies were presented at the Medicine Meets Virtual Reality conference in January '97 and at the American College of Cardiology meeting in March.

With waveform data stream capability represented by the ECG, the LIMIT team is now focusing on immersive simulation of advanced interfaces for radiology tasks, incorporating the Lab's tablet-based "working surfaces" approach for image selection, processing and annotation. Dr. David Haynor, UW radiologist and a long-time HITLab medical advisor, is providing domain guidance and appropriate image data for this activity.

In addition to cardiology and radiology, data elements relevant to general surgery will also be incorporated into the LIMIT over the next six months, under a DARPA-sponsored project with Prof. Blake Hannaford (director of the UW Biorobotics Lab) and Dr. Mika Sinanan (director of the UW Center for Video-endoscopic Surgery).

The LIMIT testbed was featured in Olympia, WA this February at a legislative reception sponsored by the Washington Technology Center and the Association of Washington Business. Using Poupyrev's nonlinear "go-go" reaching metaphor, participants were able to grab and relocate clinical data objects, such as x-rays and Kaufman's spatial ECG model, in an immersive version of the Harborview Medical Center emergency room. The demonstration effectively conveyed the potential of VR as a medical interface prototyping environment.

Suzanne Weghorst *weghorst@u.washington.edu*

At left, "Virtual ER" with ECG data stream. This page, (below) virtual sinus cavity with endoscopic instrument, (center) Lockheed-Martin sinus surgery simulator, and (right) view of virtual sinus cavity alongside view of sinus CT image.

Surgery Simulator Evaluations Underway

As a challenging and potentially risky procedure, endoscopic sinus surgery (ESS) is a prime candidate for VR simulation training. Over the past two years the HITLab has been collaborating in the construction of an ESS simulator with a group from Lockheed-Martin (formerly Loral Training and Simulation), the Ohio Supercomputer Center, and Immersion Corp., under the direction of Major Chuck Edmond, an otolaryngologist at Madigan Army Medical Center and a HITLab medical advisor.

The Lockheed-Martin ESS simulator, which incorporates a force display interface and simulated (Visible Human) anatomy and instruments, made a successful public debut at the Medicine Meets Virtual Reality conference in San Diego in January. After a few changes to the haptic interface, the prototype system was relocated to the HITLab for shakedown and evaluation, and will be installed at Madigan for further testing and clinical use later in the spring.

During the next six months, the HITLab team (led by research scientist Suzanne Weghorst and professor Bill Winn) will take the leading role in evaluating the utility of the simulator as a training environment. Technical support will be provided by HITL software engineer Peter Oppenheimer and lab assistant Chris Airola.

Otolaryngologists typically learn sinus surgery procedures by observing an experienced surgeon and then practicing under the guidance of a mentor. Using the VR simulator, a trainee will progress from a simplified "novice" task aimed at training basic endoscope navigation and instrument skill, through a more complex anatomical model enhanced with visual and auditory cues (the "intermediate" level), to an unassisted simulated procedure (the "expert" level). All trials are automatically scored by the system and can be replayed for further feedback and instruction.

Aspects of the system to be evaluated by the HITLab team include the utility of the haptic display and of the visual and auditory training aids, the correlation between performance on the simulator and performance in the operating room, and the relative impact of experience with the simulator on various components of surgical skill. This systematic evaluation will provide a valuable conceptual framework for medical training simulator design.

Suzanne Weghorst *weghorst@u.washington.edu*

VR Treatment for Burn Pain

Because most pain receptors in the human body are located in the skin layer, severe skin burns are one of the most painful injuries possible. While morphine and similar drugs help enormously, frequent dressing changes, essential for healing and recovery, can still produce excruciating procedural pain. Since patients typically give the highest pain ratings during these procedures, new techniques used in conjunction with drug treatment are desperately needed.

One of the leading experts in this field, Dave Patterson, a UW associate professor in rehabilitative medicine, heads an NIH funded research team at the UW's Harborview Burn Center in Seattle. For several years, Patterson and his colleagues have been investigating new techniques (e.g., hypnosis, tranquilizers) for helping burn patients cope with pain. Toward this end, Patterson and his post-doctoral fellow Jason Doctor recently joined with Hunter Hoffman, Tom Furness and Suzanne Weghorst at the HITLab to explore whether immersive VR can help reduce severe burn pain.

The logic behind this treatment is straightforward. Pain requires conscious attention and VR is exceptionally attention grabbing—witness the successful use of HMDs to distract dental patients.

In a recent case study, an 11 year old boy named Michael, with third degree gasoline burns on his hand and leg, was immersed in Division's KitchenWorld demo as he lay in his hospital bed at the Harborview Burn Center. Wielding a 3-D wand with his good hand, he picked up a virtual teapot, opened cabinet doors, dropped toast in a virtual toaster, and finally, shot through a wall and traveled a great distance into the void of cyberblue.

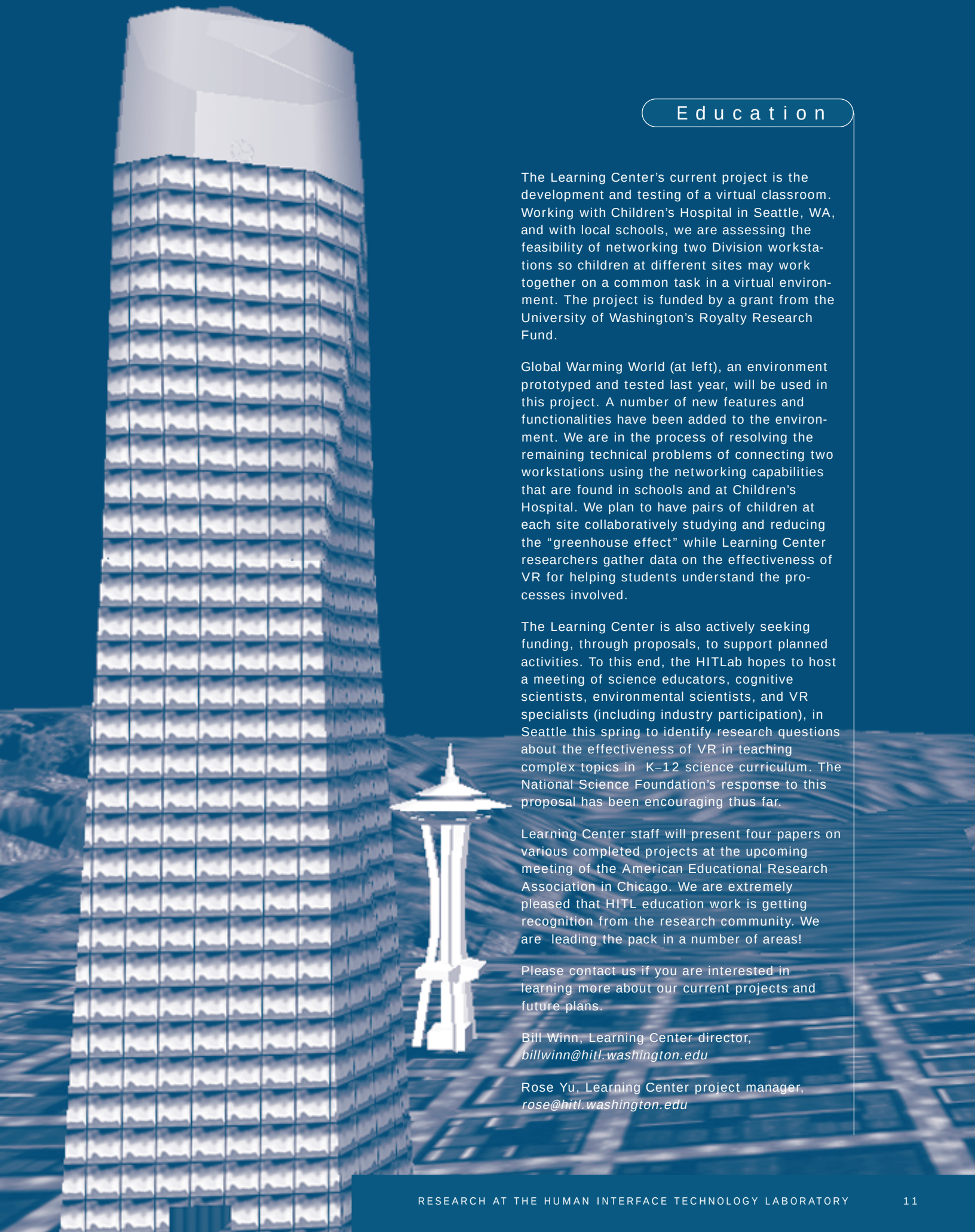
Compared to measurements of his resting pain taken immediately prior to VR treatment, pain ratings while in VR dropped dramatically. After removing his HMD, Michael realized with mild surprise that he had temporarily "forgotten" his discomfort while in VR. In the near future, the Harborview and HITLab research team will explore the relationship between a patient's sense of "presence" in the virtual environment and the patient's level of pain distraction.

A second patient, Ryan (in images above), experienced mixed results. Sometimes he showed significant pain reduction and sometimes he did not. For Ryan, facial and neck burns complicated HMD use. At one point Ryan craned his neck to see more of the virtual environment and stretched his skin, causing a painful but therapeutic motion (as noted by his nurse). After filling out his pain ratings in a session a week later (a session that did not involve neck movement), Ryan remarked with mild annoyance that our questions about his pain didn't make sense since he was focusing on the task!

Future case studies are under development in which young burn patients could (individually or with other participants) explore a sunken ship, build virtual atoms, or move through a virtual house. The use of tactile augmentation, which has been shown to increase presence in virtual environments, may also be built into these studies to help maximize pain reduction.

Although a large-scale, carefully controlled experiment with a relatively large number of burn patients co-sponsored by NIH is planned, and will be needed to verify the findings, the preliminary results of this initial case study are encouraging. Many thanks to Michael, Ryan, and the Harborview Burn Center staff for helping us pioneer these potentially beneficial techniques.

Hunter Hoffman *hunter@hitl.washington.edu*



Education

The Learning Center's current project is the development and testing of a virtual classroom. Working with Children's Hospital in Seattle, WA, and with local schools, we are assessing the feasibility of networking two Division workstations so children at different sites may work together on a common task in a virtual environment. The project is funded by a grant from the University of Washington's Royalty Research Fund.

Global Warming World (at left), an environment prototyped and tested last year, will be used in this project. A number of new features and functionalities have been added to the environment. We are in the process of resolving the remaining technical problems of connecting two workstations using the networking capabilities that are found in schools and at Children's Hospital. We plan to have pairs of children at each site collaboratively studying and reducing the "greenhouse effect" while Learning Center researchers gather data on the effectiveness of VR for helping students understand the processes involved.

The Learning Center is also actively seeking funding, through proposals, to support planned activities. To this end, the HITLab hopes to host a meeting of science educators, cognitive scientists, environmental scientists, and VR specialists (including industry participation), in Seattle this spring to identify research questions about the effectiveness of VR in teaching complex topics in K–12 science curriculum. The National Science Foundation's response to this proposal has been encouraging thus far.

Learning Center staff will present four papers on various completed projects at the upcoming meeting of the American Educational Research Association in Chicago. We are extremely pleased that HITL education work is getting recognition from the research community. We are leading the pack in a number of areas!

Please contact us if you are interested in learning more about our current projects and future plans.

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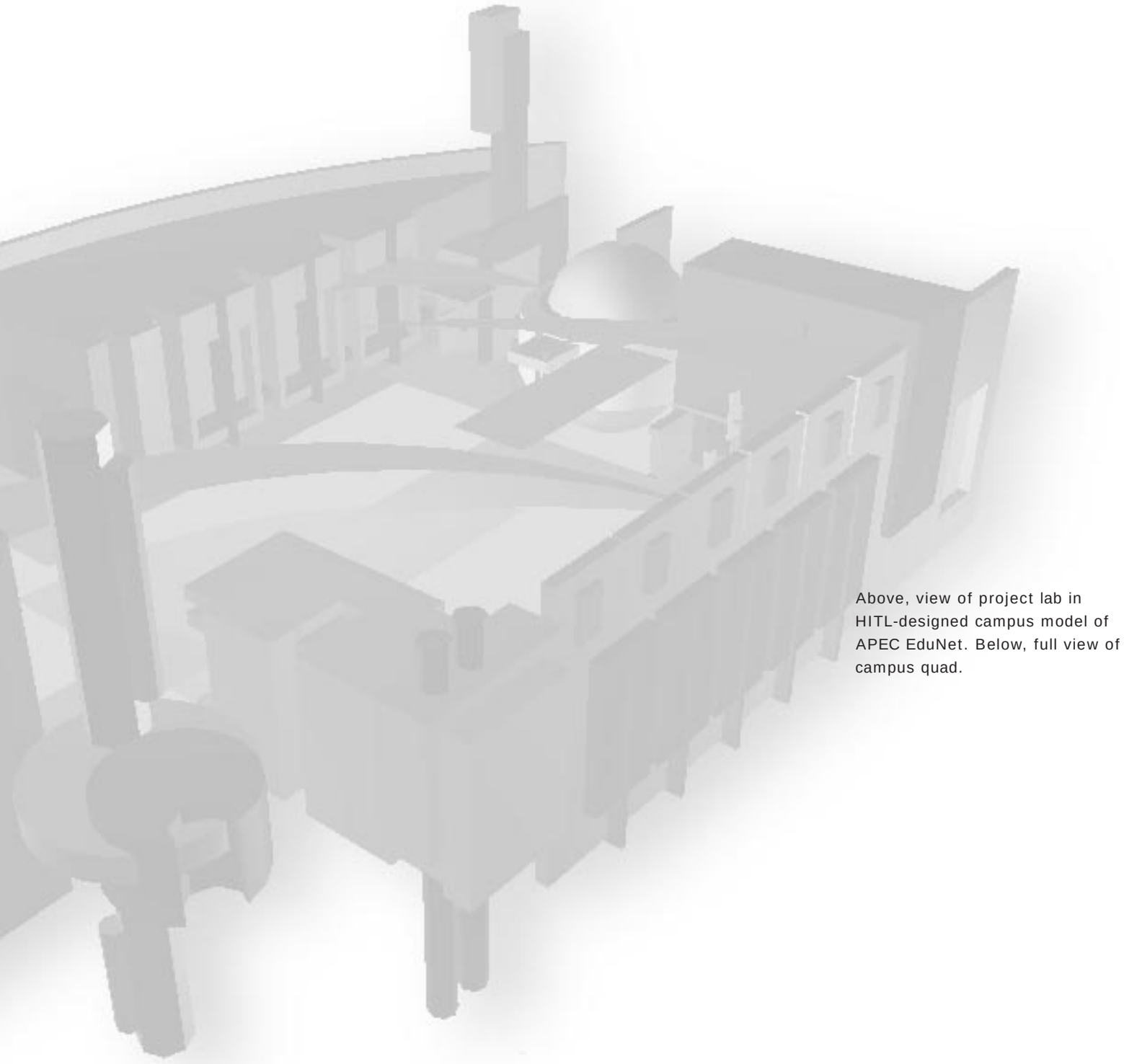
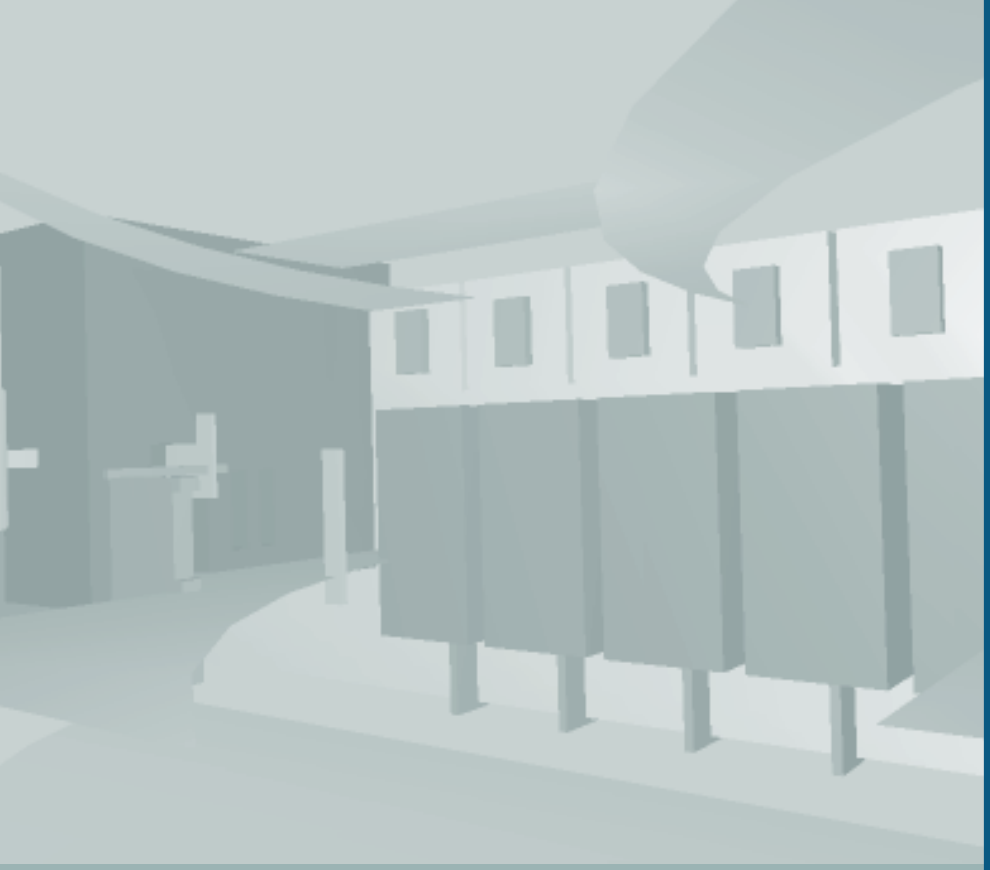


Above, view of project lab in HITL-designed campus model of APEC EduNet. Below, full view of campus quad.



CEDeS Lab Update

CEDeS Lab Update

The Community and Environment Design and Simulation Lab (CEDeS Lab), a multidisciplinary partnership between the HITLab and the UW College of Architecture and Urban Planning (CAUP), has been introducing design students to virtual interface technologies for a number of years, and has continued to do so recently in the context of classes, new equipment, demonstrations, and projects.

In the autumn of 1996, Jim Davidson, CAUP lecturer and CEDeS director, taught a class on building virtual environments. Students constructed virtual representations of proposed design studio projects and of existing spaces—such as the landscaped courtyard behind UW's Gould Hall. Environments were developed at CAUP on PCs and on four new SGI Indy workstations. Using Lightscape, students rendered still frames and animations, as well as real-time walkthroughs, to analyze the lighting and spatial elements of their designs. Davidson plans to teach another class at CAUP in the autumn of 1997.

Past projects created by CEDeS classes continue to be used for demonstrations. The "Virtual Venice" walkthrough was recently showcased at a grand opening celebration of an Italian maritime consulting and engineering company that has relocated to the Arsenale (HITLab *Review*, No. 6, Fall/Winter 1995, pp. 4-5).

CEDeS personnel have also continued to showcase the GreenSpace II application—demonstrating a networked, distributed, virtual environment complete with tools to facilitate long-distance design reviews between architects and clients (HITLab *Review*, No. 7, Spring/Summer 1996, pp. 11-12). Audiences have included architects from Virtual Worlds Consortium member NBBJ, as well as government officials from Wenatchee, WA who are interested in a virtual environment representing existing conditions and proposed urban renewal plans for downtown Wenatchee.

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For a complete overview of past, present and future CEDeS projects see www.hitl.washington.edu/projects/cedes/projects.html

Computer Image Generation Project

The HITLab is working with Silicon Reality, Inc. (SRI), Federal Way, WA, to develop algorithms and architectures for a new generation of computer image generation hardware. This work is being sponsored by the Washington Technology Center under a Research and Technology Development grant.

The project goal is to develop algorithms and architectures that can be implemented in high density application specific circuits (ASICs) for use in a wide range of platforms, including game consoles, PCs and midrange workstations. A major emphasis is the development of high performance, lost cost systems for entertainment, virtual reality and advanced simulation applications. It is imperative these systems be capable of synthesizing and rendering high quality images at real-time scene update rates.

Currently, HITL is working with SRI to develop and optimize the software interface to their TAZ architecture (Texture-mapped Anti-aliasing Z-buffer). Their first products in the TAZ line are scheduled to be available in the second half of 1997. The first generation TAZ design promises to define a new performance level in low cost rendering accelerators. It is capable of 1 million tri-linear MIP mapped, perspective corrected, textured, transparent and anti-aliased polygons per second and can maintain a peak pixel fill rate of 75 million pixels per second with all rendering options enabled.

Silicon Reality, founded in 1994, specializes in computer graphics and multimedia solutions. One of the company's aims is to "help bring high performance 3-D graphics to the masses." SRI founders and a majority of SRI personnel have extensive backgrounds in flight simulation graphics and sub-micron silicon architecture.

For more information, contact project lead Jon Mandeville *jrman@hitl.washington.edu* or visit the SRI Web site: *http://www.sireal.com*

Understanding Immersive Object Manipulation

Manipulation of objects in virtual environments is often awkward and inconvenient. Lack of tactile feedback, limited depth cues, tracker noise, and other factors can make the simple task of grabbing and moving a virtual object a frustrating experience. Developing virtual environments which allow users to perform actual work over a longer duration requires optimization of the most basic interactions, such as object manipulation, so that the immersed participant can concentrate on higher-level tasks rather than on low-level motor activities.

Recognizing this problem, HITL researchers Ivan Poupyrev and Suzanne Weghorst have developed a conceptual and practical framework for experimental studies of immersive manipulation techniques. One obstacle in developing such a framework is the lack of a comprehensive understanding of the immersive manipulation task and how it differs from physical object manipulation. The HITL-developed framework provides a detailed task analysis of immersive manipulation, suggests a user-specific non-Euclidean system for the measurement of distances and sizes in the virtual world, and categorizes immersive manipulation techniques according to their underlying metaphors.

The framework is implemented as a manipulation research testbed using Poupyrev's X3-D toolkit, and pilot studies have been conducted under the auspices of the AFOSR project on Situation Awareness (see page 4). Systematic comparison of user performance with ray-casting, direct interaction, and Poupyrev's nonlinear "go-go" technique have helped to characterize the costs and benefits of each metaphor.

There are several practical implications of this work. First, the framework provides a systematic view of immersive manipulation which can guide developers in constructing immersive interaction dialogs. Second, using the experimental testbed, developers can systematically optimize existing manipulation interaction techniques to achieve the best user performance. Third, optimization of immersive manipulation techniques can be a first step toward developing more generic principles of immersive interaction which better utilize the potential of VR.

The long-term goal of this research is to establish a set of guidelines for immersive interaction which would facilitate the creation of unified, cross-platform virtual reality interface development tools. A technical report and extended conference presentation abstracts are available at:

www.hitl.washington.edu/projects/advanced

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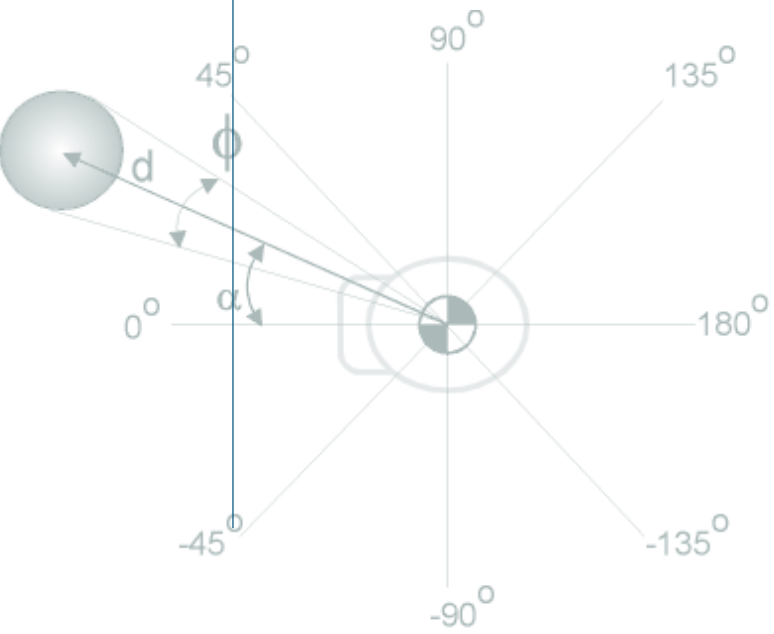
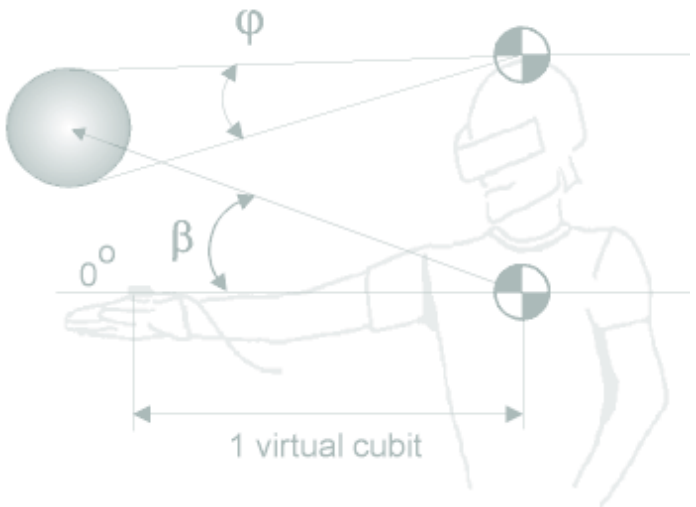
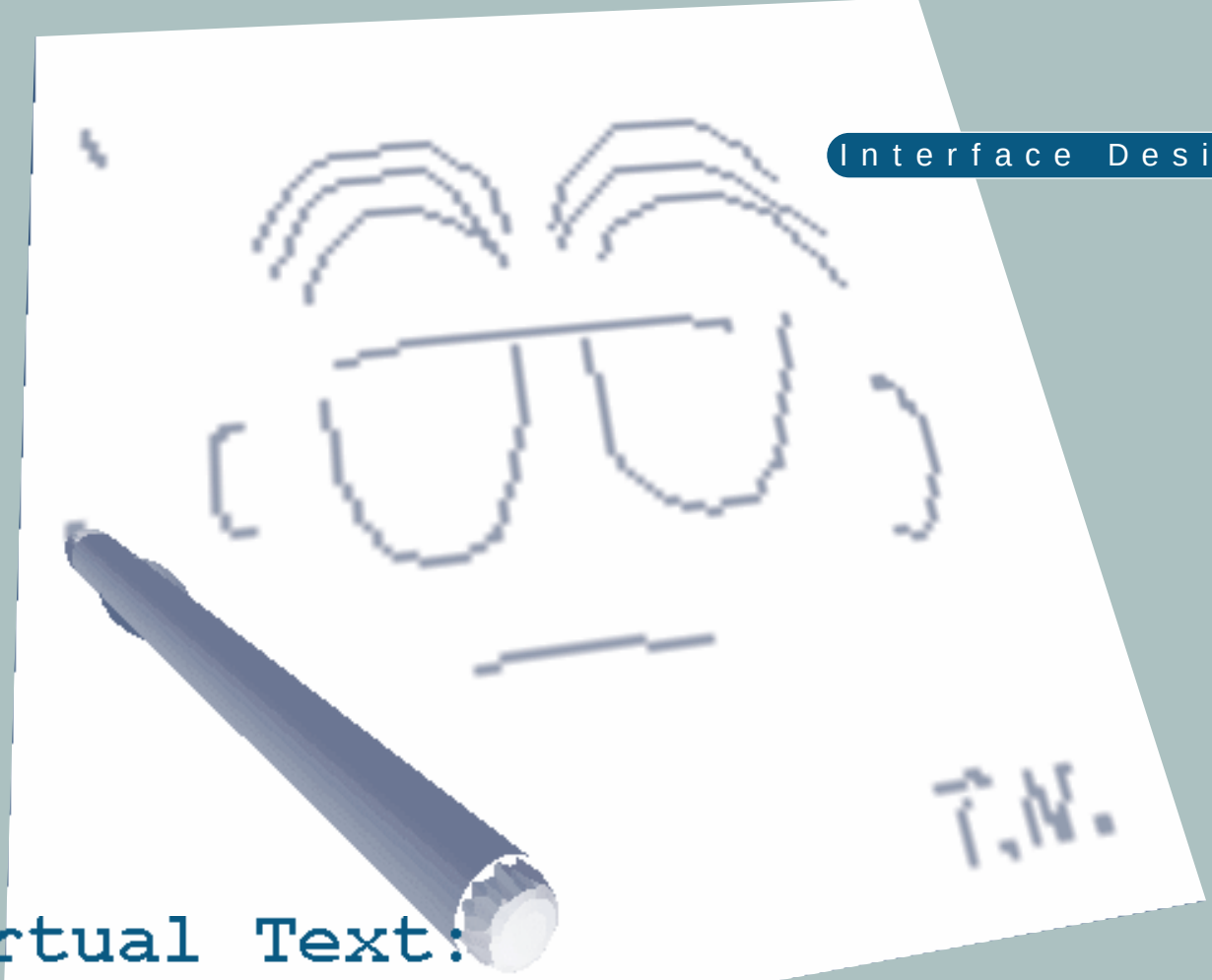






Virtual Text: Handwriting in VR

Text input is almost impossible in immersive VR, since participants are visually cut off from the real world and cannot easily access conventional text input devices such as keyboards. Although speech recognition provides some capability for text input, text manipulation and editing are difficult to accomplish with voice alone, and current voice recognition technology suffers from poor performance in noisy environments, limited sensitivity to differences in speaker voice and accent, and other limitations (such as the need for silent interaction) in operational environments.

In the Virtual Text project, HITLab researchers hope to solve this problem by investigating the use of handwriting as a source of text input in immersive VR. Using a spatially-tracked pressure-sensitive graphics tablet from Wacom Technology Corp. and a handwriting recognition engine from ParaGraph International, Inc. we are investigating various approaches to immersive handwriting input. Sensory feedback is provided by registering a virtual tablet with the real one—so the user can feel the tablet, and see the pen trajectory and the interpreted text stream. We are currently exploring the utility of off-tablet display of the visual feedback for various simulated tasks.

This research is being conducted in close collaboration with Hiroshima University's Information Systems Laboratory (Japan), and with Hiroshima University graduate student Numada Tomakazu. The project leverages the HITLab's ongoing "working surfaces" research and is tightly integrated with the Lab's multi-modal interface project and the LIMIT simulation testbed for advanced medical interfaces.

Ivan Poupyrev
poup@hitl.washington.edu

The Shared Space Project

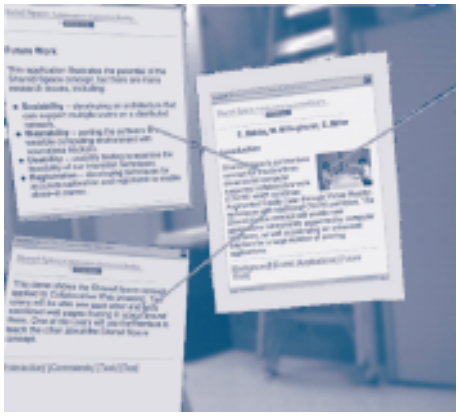
Virtual reality appears a natural medium for three-dimensional computer supported collaborative work (CSCW). However, the current trend in CSCW is toward the "open shared workspace" in which the computer is adapted to work with the user's traditional tools, rather than separating the user from them as is the case with immersive VR. One solution is augmented reality–the overlaying of virtual objects on the real world–which combines the advantages of virtual reality with the open workspace paradigm. The HITLab's Shared Space project explores the use of augmented reality for CSCW.

Several demonstration applications showing the shared space concept have been developed. One application is illustrated here: a collaborative Web browser in which users can see each other and virtual Web pages simultaneously (image at right). Using a see-through display, participants are naturally aware of each other's facial expressions, body language, gestures and gaze.

This ability to see the real world and the virtual world at the same time facilitates high bandwidth communication and enhances collaboration. In a recent study, HITL researchers compared performance in a two-player game, in a shared space condition and in a fully immersive virtual world with virtual bodies. While subjects enjoyed the immersive virtual world condition the most, they correctly perceived that they performed better in the shared space condition.

Current research involves further usability studies to validate the shared space approach and the development of an interface for collaboration between workstation and head mounted display users. HITL researchers involved in this project include: Sisinio Baldis, Mark Billinghurst, Edward Miller, and Suzanne Weghorst.

See *www.hitl.washington.edu/projects/shared_space* or contact Mark Billinghurst *grof@hitl.washington.edu*



Below, Jerry Prothero and Ivan Poupyrev collaborate on a "shared space" Web browser application. Above, the view through the HMD. Both users can easily interact with the real and virtual world simultaneously.

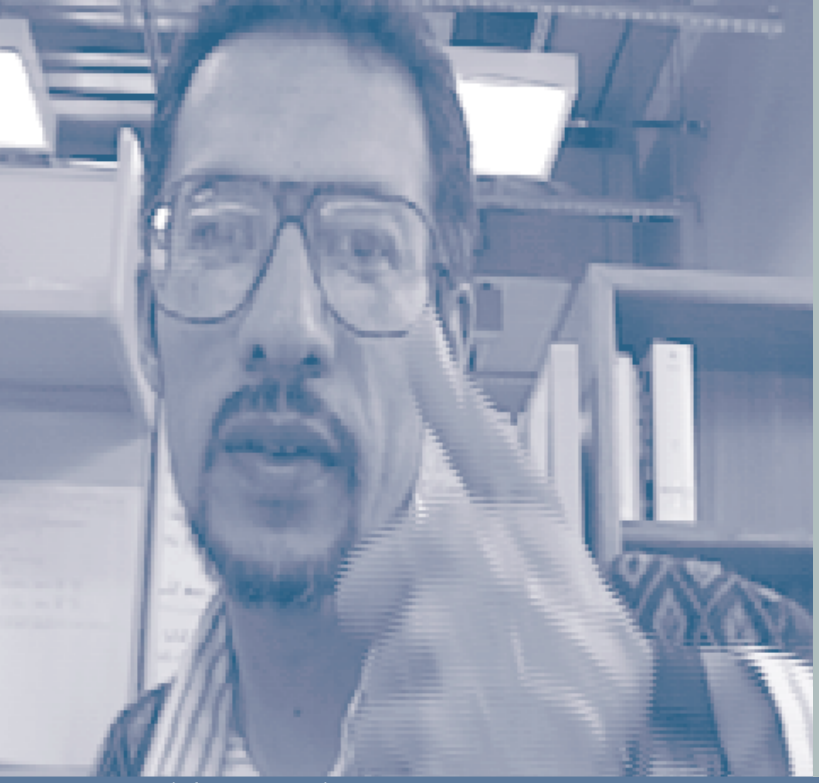
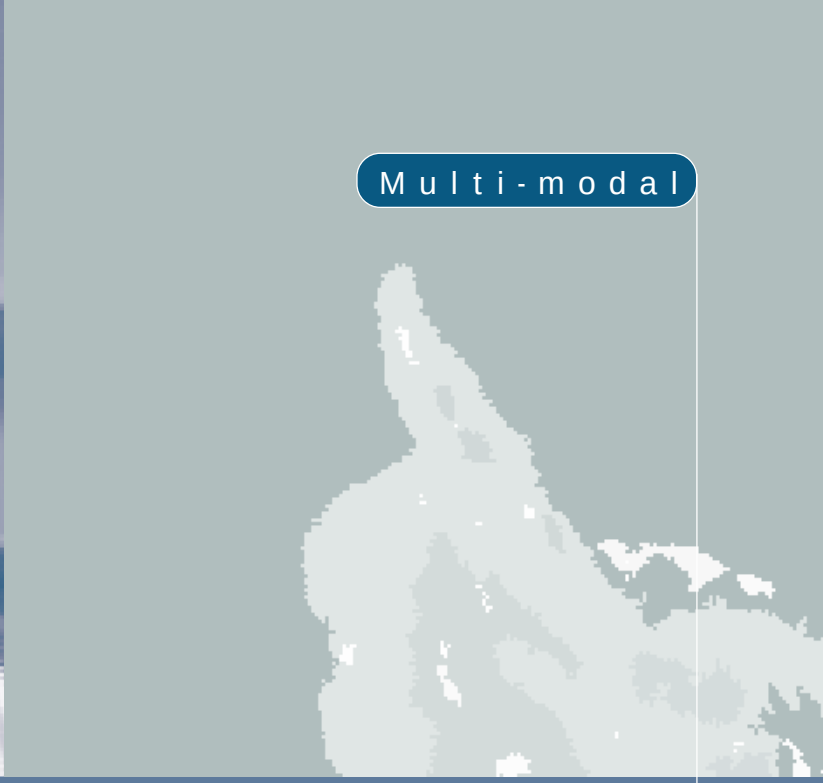


Image before segmentation



Moving hand segmented out of image

Moving Object Segmentation for Hand Gesture Recognition

As a first step in the development of hand gesture recognition, the HITLab is working on several approaches for segmenting moving objects from digital image sequences.

Our main algorithm works in two steps. First we compute a dense motion estimation vector field using pel-recursive methods. Second, since we are using Markov Random Fields for modeling, we use this vector field to separate an image into regions.

After these steps, the object motion information may still be incorrect—especially at movement discontinuities. In this case, we may also include the following data sources to improve the final solution:

- image intensity
- non-compensated pixels
- intensity edges that favor the coincidence of motion boundaries and strong spatial gradients (0=edge absence, 1=edge presence)

Furthermore, we can also add the following physical properties to the model:

- a motion model for each region in the scene to be segmented
- spatial continuity for segmentation
- motion boundaries only when strong intensity changes occur
- expected geometrical shapes for region boundaries

Preliminary results using these techniques have been very encouraging. We are currently working on classifying segmented objects for use as gestural input for communicating with a virtual robot.

HITLab researchers involved in this project include: Francisco Garcia-Ugalde, Jesus Savage-Carmona, and Mark Billinghurst.

Mark Billinghurst
grof@hitl.washington.edu

Publication News

Research scientist Suzanne Weghorst and HITLab director Tom Furness are serving as guest editors of a special issue of the *Journal of Visual Languages and Computing*, to be published by Academic Press in August 1998. Suitable manuscripts on the topic "User Interfaces and Interaction in Virtual Reality" should be received by October 1, 1997. For further information, contact Suzanne via *weghorst@u.washington.edu*

Welcome New Members

SENSE8

Founded in 1990 with the mission to bring VR technology from research labs to a broader commercial audience, Sense8 Corporation is the world's leader in viable 3-D virtual reality solutions for business. As part of its solutions-oriented focus, Sense8 also provides system integration, training, and customer application development.

Sense8's first product, WorldToolKit, was originally released on the PC and supported the Intel DVI technology. The next release of WorldToolKit supported Silicon Graphics' systems making Sense8 the first company to offer a cross-platform, development and deployment VR software tool. Support for additional hardware platforms has been added over the years as customer needs have evolved.

While demand continued to grow for WorldToolKit, the company also received requests to deliver this same functionality in a much easier to use environment. In response to this demand, Sense8 developed the world's first interactive IDE (integrated development environment): World Up. First released in 1995, Sense8 recently announced an updated 3.0 version with new features such as enhanced functionality; faster download times; more flexible navigation bars; improved integration of site links; easier incorporation of complex behavior and interaction; and more versatile tools to help developers create compelling, life-like 3-D applications for delivery over the Internet and intranets. World Up is now available for use on Windows NT, Windows 95 and Silicon Graphics workstations. The recommended minimum system configuration includes a 90 MHz processor, 24 MB RAM and an OpenGL-based graphics accelerator board.

Since 1990, Sense8 has doubled in size and revenue every year. In 1995, the company moved from Sausalito, CA to larger offices in Mill Valley, CA. In addition to allowing for more employee growth, this change in location also allowed the company to add the industry's first VR training center.

In 1996, Sense8 opened its first wholly-owned subsidiary in Nyon, Switzerland in order to better serve the company's European resellers. In addition, Sense8 opened a second U.S. office in Bethesda, Maryland to better service East Coast and government customers.

Sense8 provides the University of Washington with a site license for their popular WorldToolKit and World Up software.

To contact Sense8 call (415) 331–6318 or email *info@sense8.com*

http://www.sense8.com

BHP

The Broken Hill Proprietary Company Limited (BHP) is Australia's largest company. BHP was incorporated in Melbourne, Australia, in 1885, and began operation as a miner of silver, lead and zinc at Broken Hill in New South Wales, Australia.

Today, BHP is one of the world's largest diversified resources companies, with operations in more than 20 countries and over 100 years of experience in the resources industry. BHP has four main businesses: steel, petroleum, minerals and copper—and specialist support businesses including transport, engineering, information technology, power generation and insurance.

BHP has assets of more than $30 billion and more than 239,000 shareholders in 80 countries. Its shares are listed in Australia, Germany, Japan, New Zealand, Switzerland, the United Kingdom and the United States.

For more information on BHP see *http://www.bhp.com.au/*

What is the Virtual Worlds Consortium?

Established in September 1990, the Virtual Worlds Consortium (VWC) serves as a nexus for the investigation and commercialization of advanced human interface technology in the global virtual reality market, and as an educational and professional resource for participating company representatives. The VWC is the primary mechanism through which strategic projects and partnerships are formed between the HITLab and industry, government and academia. The membership fee in the Consortium is $50,000 per year. For further information contact Consortium business manager Art Kerr: phone (206) 616–1477 *adkerr@hitl.washington.edu*

HUGHES RESEARCH LAB

In conjunction with Seagull Technologies and the State University of New York (Stony Brook), Hughes Research Lab (HRL) has developed a sophisticated conflict processing and visualization system and free flight scenario for air traffic control. The free flight scenario was constructed after consultation with experts at the Fremont (Oakland) Center and with others and simulates a realistic volume of air traffic in the Coaldale region east of San Francisco.

In a one hour period, approximately 100 aircraft were placed on direct routes with cruise descending and ascending traffic, creating a complex interwoven free flight transition region. The decision support system employed spatial and temporal visualization of the airspace, view control, zooming, tethering, visualization of protected airspace and alert zones. Two displays, a plan view and an auxiliary perspective display, enabled a user to understand the complex conflicts in the most appropriate visualization. Conflict detection and resolution software were used to automatically detect problems and suggest resolutions which were communicated to the user via spatial visualization of the options. The system and scenario were demonstrated at the largest international air traffic control conference sponsored by the Air Traffic Control Association.

Another HRL project involving Hughes Training, Inc. and the University of Houston Virtual Environment Technology Lab (UH VETL), has resulted in the development of the infrastructure and the models to support a three way distributed virtual environment for training astronauts in the International Space Station. This system uses a dedicated ISDN network to communicate state changes in each human model between the sites. The UH VETL developed a high fidelity model of the space station and human models to support the collaboration. Hughes constructed infrastructure supporting CAVE to CAVE collaboration between the sites in a standard software environment (Sense8 WorldToolKit). A three way distributed VE with simulation of the training activities was demonstrated in March 1997.

HRL has also developed a prototype "collaborative command center of the future" for Navy command and control. This capability incorporates real-time texture mapping of video input on polygonal models of large screens inside the command center model. Ongoing development will enable use of the command center model for collaboration and visualization concept evaluation during 1997.

Mike Daily *daily@isl.hrl.hac.com*

VIRTUAL VISION

Virtual Vision of Redmond, Washington has had a busy and productive year marketed by product releases, trade shows, and field testing. The V-Cap line of HMDs was launched in late 1996 and is now in initial production. The V-Cap (at right) presents visual information on patented optics, which are see-through when not in use. Images from the VGA 640x480 pixel, monochrome display can be focused over the work plane, making them easy to reference. Spoken commands are entered through a noise-canceling microphone, and system feedback is presented on a wide bandwidth speaker. The electronics are mounted on a display visor and worn on a replaceable neoprene cap. The result is a comfortable, durable, and easy-to-use interface that is unobtrusive when not in use.

Fourth quarter 1996 saw the release of the OEM Evaluation Kit, which includes a V-Cap HMD, advanced speech recognition system, and software demonstrations supporting voice activation. With the kit, developers can assess the potential for a Distributed Information Delivery System (DIDS) in a particular application, and test the functionality of speech-driven command and control of system resources. The speech system delivers speaker-independent, continuous-speech performance, and incorporates hardware to diminish the memory footprint on system resources.

Virtual Vision has been very active demonstrating its HMD technology at trade shows and conferences, such as Comdex, Scantech, and the National Retailer's Federation conference and expo. Field testing and development have also continued with the ARPA Technology Reinvestment Program (TRP).

Through the TRP, Virtual Vision is collaborating with the Boeing wireshop on an augmented reality project which pairs a Virtual Vision HMD with an inertial, ultrasonic spatial-

tracker to create a wire bundle fabrication application. Using this system, workers will be able to see the wire routing information change as they move. Because the appropriate information is constantly displayed on the work plane, eyes and hands are left free to work on the wire harness.

Another client, McClellan Air Force Base, recently wrapped up a successful Multimedia Development Initiative with Virtual Vision. In this project the company's HMD was integrated with a body-worn computer, speech recognition system, and application specific software for an improved inspection procedure of KC 135 tanker planes. The program successfully reduced aircraft inspection from five days to one day, and grew from a prototypical system to a reliable productivity tool.

Virtual Vision, a member of the Telxon Corp. Technical Subsidiaries Group, continues to expand the frontiers of nomadic computing by integrating HMD technology with speech recognition systems, body-worn computers, and wireless communications. For further information about Virtual Vision, contact Sandra D'Adam (206) 882.7878
sdadam@virtualvision.com
www.virtualvision.com/

DIVISION

Division and Electronic Data Systems (EDS) recently collaborated on an elaborate and extensive virtual reality training environment for Southwestern Bell field technicians.

The training application, SBC Town, is a virtual city with major streets, residential and commercial buildings, and telephone-circuit facilities familiar to Southwestern Bell technicians. Within the city limits are aerial terminals, buried pedestals, manholes, and crossboxes that look and behave like the real thing.

In a typical scenario, a technician in the central office receives a simulated work ticket describing a customer problem. Armed with a virtual toolbox, the technician uses a computer mouse to "drive" through SBC Town to any terminal identified by a Southwestern Bell logo. Clicking on the logo causes a menu to appear revealing options for troubleshooting.

Once the technician locates the fault, he enters the information into the system, which tells him if he is correct or not. While the technician is searching for the fault, Division's dVISE software collects information on the time spent performing different tasks and the resources used. This information is used to generate a report on time and costs associated with the job.

Safety is also a part SBC Town's training curriculum. For example, when a technician descends a virtual telephone pole he must watch for animated vehicles passing by on the street; and when the technician opens a manhole cover, gas might escape, signaling he should properly ventilate the manhole.

Southwestern Bell expects virtual training will lead to better-prepared, more-efficient technicians and to higher-quality customer service. Cost savings are a factor as well. The virtual environment could eliminate some training conducted at remote sites and could simulate situations that would be impossible to duplicate in a normal classroom.

For more information on Division, contact Nazita Fadakar, director of marketing, *nazita@division.com*

Above, SBC Town, the Division and EDS virtual training environment developed for Southwestern Bell.

INSIGHT

Insight, Inc., Port Townsend, WA, a world leader in the design of head mounted and eyeware HUD displays, has announced a new patented technology that automatically calls a 911-type base station and transmits digital images along with GPS and other salient information in real time. This "robotic witness" is an embedded system that is about the size of a pocket pager. The device has applications in law enforcement, fire fighting, military operations and other situations where immediate response and high quality evidence are critical.

Insight continues to pursue product development in the racing and sport motorcycle market. Dominic Dobson, lead driver for the Chrysler touring team, is testing Insight's heads-up racing helmet which will be available to consumers this year.

Another industry partner, Cochran Consulting, Inc., Richardson, TX, a leading manufacturer of undersea technology products used by the Navy and sport divers around the world, is integrating Insight technology into their "Spectacle" heads-up display dive mask (image at right). The Spectacle received rave reviews at this year's DEMA dive show in Orlando, FL and industry leaders believe this product will take over the dive computer market within three years.

For more information contact Peter Purdy (360) 379–5740.

Cochran's "Spectacle" dive mask featuring Insight display technology.

www.hitl.washington.edu

Knowledge Base

Web Site

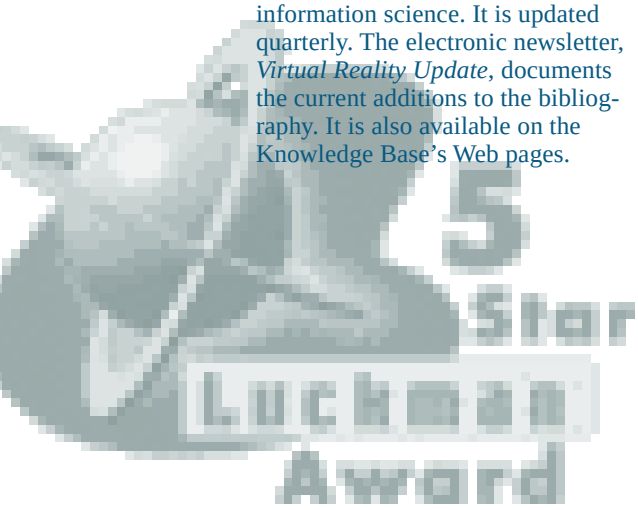
http://www.netguide.com

The HITLab WWW site recently received two awards: the NetGuide Gold and a five-star Luckman award. The NetGuide Gold Award recognizes Web sites that meet NetGuide's stringent criteria for overall excellence. NetGuide has screened over 100,000 URLs and reviewed more than 50,000 sites and the Gold Award goes to only 15,000 of the Web's best sites. The HITLab's Knowledge Base (KB) Project was described by NetGuide as a "well-presented collection" and to "get thee hither" if you're looking for information on VR. Luckman's CD-ROM reviews, rates, and recommends 10,000 of the best sites on the Web.

SEARCHABLE DATABASE

This month the KB Project is beta testing a searchable database of the **Virtual Interface Technology Bibliography.** You can search for particular authors and/or keywords in the title field. The results will be a page with your relevant citations. The bibliography project is at: *www.hitl.washington.edu/projects/knowledge_base/meta/*

The Virtual Interface Technology Bibliography was originally created in 1993 as a part of Toni Emerson's master's work in library and information science. It is updated quarterly. The electronic newsletter, *Virtual Reality Update*, documents the current additions to the bibliography. It is also available on the Knowledge Base's Web pages.



SCI.VIRTUAL-WORLDS

Sci.virtual-worlds now has its own page at the HITLab site *http://www.hitl.washington.edu/scivw/*

There are quite a few FAQs (Frequently Asked Questions) available there as well as an archive of postings. The Visual Display FAQ is the newest addition to sci.virtual-worlds. This new FAQ lists vendors and products divided into head based displays, stationary displays, shutterglasses and alternative displays (such as hand held). Included in the FAQ are on-line resources, recommended conferences, and a citation list.

At its inception, the sci.virtual-worlds ftp site was a repository of VR related papers. Now with the Web, papers are usually kept at the place of business, research center, etc. However, there are times when a site isn't available. For example when sci.virtual-worlds' moderator, Toni Emerson, read the **Review of Virtual Environment Interface Technology** by Youngblut, C., Johnson, R.E., Nash, S.E., Wienclaw, and Will, C.A. (1996) and published by the Institute of Defense Analyses, she contacted them and asked if it was available on the Web. Discovering it was not available, Toni received permission to archive the technical paper at the HITL site: (available in Adobe Acrobat PDF files) *http://www.hitl.washington.edu/scivw/IDA/*

This is an excellent review of the technology covering visual, tracking, auditory, primary user input, tactile, kinesthetic, full-body motion, and olfactory interface technologies.

NEW BOOKS

A couple of new titles have been purchased for the HITLab library.

Melzer, James E. and Moffitt, Kirk W. (1997) **Head-Mounted Displays: Designing for the User.** New York, NY: McGraw-Hill.

Melzer posted an announcement regarding the publication on sci.virtual-worlds. Melzer is a senior project engineer at Kaiser Electro-Optics and Kirk Moffitt, Ph.D., is a human factors consultant with extensive background in the human-centered design of VR, medical and military systems. Their book provides new information and perspectives such as:

- Replacing the traditional engineering design approach with a user-centered model.
- An unique compilation of HMD optical requirements and lens designs.
- Cybersickness and eye strain: causes and solutions.
- How head and neck anatomy drive HMD head-supported weight requirements.
- Mapping the needs of the human visual system into a successful HMD design.
- A novel model for HMD stereoscopic imagery.
- Testing HMDs for utility and user acceptance.
- How brain-actuated control can replace clumsy manual interfaces.

The second 1997 title, **Designing Digital Space: An Architect's Guide to Virtual Reality,** by Bertol, Daniela (Ed.) and published by John Wiley & Sons, is a good book for architecture students and professionals looking for a solid introduction to the field of virtual architecture. The authors address the history of three-dimensionality (Part I) and the basics of digital architecture and virtual reality (Part II). Part III, "Who is Doing What?" is written by guest authors who discuss particular projects and VR architecture applications. HITL's Dace Campbell and Jim Davidson wrote a chapter on the CEDeS Lab, see: *http://www.hitl.washington.edu/people/dace/portfoli/cedes.html*. The final chapters cover technology predictions.

Toni Emerson
diderot@hitl.washington.edu

Personnel Additions

Chris Airola, Lab Associate. Chris received his bachelor's degree in biomedical engineering from Marquette University in May of 1996 and is now working with HITLab medical team researchers Suzanne Weghorst and Peter Oppenheimer on the sinus surgery simulator project. Chris is also providing part time hardware tech support in the Lab. Other research interests include arthropometric studies, medical instrumentation and surgical simulation with virtual reality. In his off hours, Chris enjoys mountain biking, hiking, snowboarding, performance art and creating.

Rachel Ennis, Student Aide. Rachel returned to Seattle a year and a half ago to pursue a philosophy degree at the UW. Her dream is to study librarianship and be an elementary school librarian. To pay the bills in the meantime, she is working at the HITLab and studying legal assistantship.

Jessica Foeste, Research Assistant. Jessica, a graduate student in the industrial engineering department, hails from the University of Wisconsin at Madison where she double majored in psychology and anthropology. Jessica spent five years involved in primate research at the Harlow Center for Biological Psychology. During her stay at the Harlow Center, she spent four months with the Caribbean Primate Research Center in Puerto Rico, working on a study of mate selection in rhesus macaques. She is currently interested in the human factors involved with communication and collaboration in virtual and augmented environments.

Lamont Granquist, Student Aide. Lamont joined the HITLab in the summer of 1996. He is a senior at the UW with a double major in physics and astronomy. Currently, Lamont helps keep HITL computers secure and operational—no small task. Academically, Lamont is working on reducing data on variable stars and photometric binaries in M15.

Prof. Diane Gromala, Director New Media Research Lab. Diane directs the New Media Research Lab at the UW, where she teaches courses in new and virtual media. Gromala's area of expertise is the critical analysis of visual media, in both theoretical writings and in the creation of critical artwork. Gromala frequently lectures on these issues at international conferences and symposia. She is the recipient of a Fulbright Fellowship and is Chair of the Art and Design Sketches for SIGGRAPH '97. Gromala's critical artwork focuses on the creation and dissemination of virtual environments, including museum exhibits, video, and performances. Along with choreographer Yacov Sharir, Gromala developed a virtual environment at the Banff Centre for the Arts in Canada. "Dancing with the Virtual Dervish: Virtual Bodies" was performed and presented at venues in Canada, the US, Europe, the Middle East, and aired on the Discovery Channel. Throughout the 1980s, Gromala worked as a designer and art director, most recently at Apple Computer, Inc. Her graduate and undergraduate degrees are from Yale University and the University of Michigan, Ann Arbor.

Kristi Hatch, Student Aide. Kristi is a UW sophomore majoring in psychology with a focus on child psychology. She hopes to get her master's in education and become an elementary school teacher. Kristi recently got engaged and will be married this summer.

Michael Herbert, Visiting Scholar. Michael holds a bachelor's degree in music education from DePaul University, a master's degree in educational technology from the UW, and has studied filmmaking at Columbia College. Michael has extensive and diverse experience in music, education, and media, and he currently provides free-lance instructional and multimedia design/production services for businesses. Extending his work as a teacher for hospitalized children at the Children's Hospital in Seattle, Michael is assisting the Lab's Learning Center with the Virtual Classroom project, linking hospitalized students with a community- based classroom through VR. He is also working with the Virtual Worlds Society to develop an educational and therapeutic virtual environment for young cancer patients. Among a wide range of interests, Michael enjoys sailing and being with his family.

Aaron Jones, Knowledge Base Assistant. Aaron is a UW sophomore in pre-engineering. He is part of the Knowledge Base team, and is currently working on HITL's Web site. Aaron has spent time at Intel working on Viscape and other multimedia projects. Aaron is excited to be expanding his knowledge of and involvement with new VR technologies at the Lab.

Stan Kaufman, M.D., Medical Advisor. Kaufman received his AB from Bethel College, North Newton, Kansas; his M.D. from the University of Kansas; and his post-doctoral training at the UW and the University of Minnesota. Kaufman is a board certified internist and cardiologist and a member of the Information Technology Committee for the American College of Cardiology. Currently, he is finishing a medical informatics research fellowship through the Veteran's Administration Hospital in Seattle. At the HITLab, Kaufman is developing new interface metaphors for medical information in augmented reality environments. He presented an ECG monitor object prototype as part of this work at the MMVR meetings in January 1997. In addition, Kaufman is also working on Java applications for Web-based clinical research.

John Kelly, Research Scientist. John received his B.A. in psychology from Fort Lewis College in Durango, Colorado, where he learned science and the art of skiing. His scientific endeavors progressed at Brown University, where he studied eye movements and human electrophysiological recording. He completed his M.A. and Ph.D. in biopsychology at the State University of New York, Stony Brook, studying the development of color vision and the effects of glaucoma on color vision. After a three year post-doctoral fellowship at the UW with Prof. Davida Teller, he now works at the Department of Ophthalmology at Children's Hospital and Medical Center in Seattle. His interest in the HITLab has brought him closer to his goal of providing scanning laser opthalmoscopes to the practice of pediatric ophthalmology.

Sonja Max, Lab Associate. Sonja is working with Toni Emerson on animating the HITL home page. She is also working on illustrations for the VRD and motion sickness research projects with Dr. Erik Viirre. Sonja is completing her last quarter at the UW and will receive a BFA in Graphic Design in June.

Linda Mayhugh, Research Assistant. Linda is working in the HITL library for Toni Emerson while pursuing a master's in library and information science at the UW. She has an AA degree from the University of Cincinnati and a bachelor's degree in natural sciences from The Evergreen State College. She is a bibliophile, which is why she is in library school, but has no plans to ever work again in a public library. Future plans involve doing research in one form or another.

Brian Michalowski, Lab Associate. Brian is a second-year grad student in computer science who completed his undergraduate education at the University of Maryland at College Park. Brian is working with Alistair Holden on a natural language project to automatically interpret airline maintenance records.

Debra Revere, Laboratory Associate. As part of her exploration of the field of library and information science, Debra is volunteering in the HITLab library on a variety of projects. Debra's professional background consists of an integration of psychology, education and research while her extracurricular background consists of a variety of artistic endeavors, including weaving, writing and playing the cello. Currently Debra holds an adjunct faculty position in the psychology department of Seattle Central Community College and an adjunct faculty position in the education department of Antioch University. Her professional history also includes ten years of work as a mental health therapist in both private practice and the community mental health delivery system.

Susan Tanney, CEDeS Lab Research Associate. Susan holds a bachelor's in interior architecture from Cornell University and is now a graduate student in interengineering at the UW. Previously she was a facility planner and designed/managed projects for the University of Rochester and Strong Memorial Hospital. Through study and research she plans to strengthen the bridge between architecture and human environment relations within virtual/augmented environments.

Farewell

Sadly, since the last issue, we said good-bye to four incredible colleagues. They have departed to plow new fields and advance their careers with the following enterprises: Rich Johnston (Information Optics Corp.), David Melville (Microvision, Inc.),Heather Patrick (Intermec Corp.), and Steve White (currently job hunting in New Hampshire). As some of the founding members of the virtual retinal display "braintrust," they are greatly missed and fortunate are those employers who now, or will soon, count them in their midst.

Alumni News

We recently caught up with Mark Cygnus who is now a senior programmer analyst with Enterprise Systems, Inc. in Wheeling, IL. The Cygnus family welcomed Christian Daniel Cygnus into the world February 22. For baby pics and more *www.mcs.com/~mcygnus*

Congrats as well to Daniel and Sabine Henry on the November 29th arrival of Salomé. Daniel predicts she'll follow her dad's footsteps to the HITLab in 20 years. Her desk is saved!

Mary McGough left the Lab in January 1996 to pursue teaching and her Ph.D. full-time. Recent classroom posts have included a public speaking class at Central Washington's Lynnwood Center, and a critical thinking and writing course at the Art Institute of Seattle. Her travels for academia have also found her in Rio de Janeiro to present her master's thesis and in Boston to savor her first lobster. For more information see her Web site *http://weber.u.washington.edu/~mocha/*

ATTENTION PROSPECTIVE STUDENTS

The HITLab has positions available for graduate students during the 1997–1998 academic year.

Students wishing to pursue graduate studies in the field of VR and virtual interface design must first obtain admission to a University of Washington academic department, for example:

- College of Engineering (e.g. electrical engineering, mechanical engineering, bioengineering, computer science and engineering, technical communication, industrial engineering)
- College of Arts and Sciences (e.g. psychology, art, communications, physics)
- College of Architecture and Urban Planning
- College of Education

Students may then apply to the HITLab for graduate project work and for economic support. A limited number of master's level graduate research assistantships are available for 1997-1998. Funded support is highly competitive.

To apply, after admission to the UW, please fax or mail a resume and cover letter to:

HITLab/University of Washington
Attn: Student Position
Box 352142
Seattle, WA 98195–2142
(206) 543–5380 fax

65-6344

HUMAN INTERFACE TECHNOLOGY LABORATORY
http://www.hitl.washington.edu
University of Washington
Box 352142
Seattle, WA 98195–2142

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