2005-08-15

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Kaufmann, Hannes; Rizzo, Skip; Kim, Gerard Jounghyun; Darken, Rudolph P.; Astur, Robert; Tendick, Frank

IEEE

Kaufmann, Hannes, et al. "Virtual reality and spatial ability." null. IEEE, 2005.
http://hdl.handle.net/10945/60926

Virtual Reality and Spatial Ability

Hannes Kaufmann (Chair)
Interactive Media Systems Group
Vienna Univ. of Technology, Austria.
kaufmann@ims.tuwien.ac.at

Skip Rizzo
Institute for Creative Technologies
Univ. of Southern California, USA.
arizzo@usc.edu

Gerard Jounghyun Kim
Pohang University of Science
and Technology, South Korea.
gkim@postech.ac.kr

Rudolph P. Darken
The MOVES Institute
Naval Postgraduate School, USA.
darken@nps.edu

Robert Astur
Department of Psychiatry
Yale Univ. School of Medicine, USA.
robert.astur@yale.edu

Frank Tendick
Department of Surgery
Univ. of CA San Francisco, USA.
frankt@itsa.ucsf.edu

ABSTRACT

VR technology provides unique assets for assessing, training and rehabilitating spatial abilities. Its capacity for creating, presenting, and manipulating dynamic three-dimensional (3D) objects and environments in a consistent manner enables the precise measurement of human interactive performance with these stimuli. VE spatial ability testing and training systems may provide ways to target cognitive processes beyond what exists with methods relying on 2D pencil and paper representations of 3D objects (or methods using actual real objects) that are typically found with traditional tools in this area. Traditional methods are often limited by poor depth, motion, and 3D cues needed for proper stimulus delivery. In addition they have limited capacity for the precise measurement of responses. VR offers the potential to address these variables in an ecologically valid manner (functional simulations) without the loss of experimental control common with naturalistic studies in this area relying on observational methods.

The following panelists will briefly describe their research in this area and will actively participate in a dialog with the audience on the status of VR relevant to user spatial ability:

Hannes Kaufmann will describe his efforts in developing Construct3D, an Augmented Reality (AR) application for geometry education, as a tool for training and improving students' spatial abilities. A brief overview of the potential of Construct3D for educating spatial abilities will be given. At VR 2005 he will also report about an ongoing evaluation with 250 students where pre-/post-tests of spatial abilities will be conducted before/after six hours of geometry education with Construct3D. A hands-on report about experiences and in-depth research on a series of standard spatial ability tests (MRT, MCT, DAT:SR, PSVT:R, OPT) will be given. Strategies of solving spatial tasks are also a matter of research in the ongoing project and findings will be summarized.

Skip Rizzo will discuss a series of research trials using both an Immersadesk and CRT monitor 3D VR system to deliver cognitive component-based scenarios that target hands-on assessment and training of visuospatial skills including spatial rotation, depth perception, 3D field dependency, static and dynamic manual target tracking in 3D space, and visual field-specific reaction time. This research has produced results demonstrating training improvements in both young and elderly subjects. One study on training produced enhanced performance levels in females relative to males as measured on a standard paper and pencil visuospatial test of mental rotation. A PC version of these applications has now been created that can deliver such 3D stereoscopic stimuli on a standard computer CRT monitor.

Gerard Jounghyun Kim will address the challenge of testing and comparing various 3D user interface devices and methods, using a standardized block rotation benchmarking scenario. This application focuses on the capture of human interaction performance on object selection and manipulation tasks using standardized and scalable block configurations that allow for measurement of speed and efficiency with any interaction device or method. It will be possible with this system to store performance data across different defined user groups (age/gender/years of computer experience/etc.) and build performance norms for future comparison purposes. As well, the block configurations that being used as benchmarking stimuli are accompanied by a pure mental rotation visuospatial assessment test. This feature will allow researchers to test users' existing spatial abilities and statistically parcel out the variability due to innate ability, from the actual hands-on performance metrics. This statistical approach could lead to a more pure analysis of the ergonomic features of interaction devices and methods separate from existing user abilities.

Rudy Darken has been studying the use of VEs for training spatial tasks, predominantly navigation or spatial knowledge acquisition over the past 10 years. While I originally thought I was just figuring out how to manage the limitations of the technology in order to get human performance and behavior that was characteristically similar to real performance and behavior, what I found was that the differences between VEs and the real world are so vast, that correlations are difficult if not impossible to isolate. We have struggled in the use of spatial abilities aptitude tests as predictors of spatial performance in a VE. Why is this? We believe it is because other factors inherent (but not obvious) in the technologies we use interfere with the task causing wide variation in performance. In short, good navigators in the field are not necessarily good navigators in VE. For this panel, I will briefly touch on a few of our experiments we have conducted over the years and how it applies to the human spatial abilities in natural and simulated environments.

Robert Astur will talk about using VR to study brain areas that are involved in spatial navigation. Moreover, he will discuss how this will provide insights into psychiatric illnesses such as Post-traumatic stress disorder, schizophrenia, and Alzheimer's disease.

Proceedings of the IEEE Virtual Reality 2005 (VR'05)
1087-8270/05 $20.00 © 2005 **IEEE**

Frank Tendick will discuss the importance of spatial cognition in surgical performance and the role of virtual environments in understanding spatial problem solving in surgery and improving surgical training. Although skilled surgeons are often said to have "good hands", in fact performance in surgery is strongly dependent on spatial skills. The surgeon must develop a mental image of three-dimensional anatomy based on a surface view or cross sections from CT, MRI, or ultrasound images. With the advent of minimally invasive techniques, the surgeon must rely on a video image of the internal anatomy and use instruments constrained by a fulcrum at their passage through the skin. Consequently, the performance of surgical tasks requires a broad range of spatial processes. The surgical skill Dr. Tendick has studied most extensively with virtual environments is the use of an angled laparoscope. There are large differences in initial performance, even among practicing surgeons. Novices successfully learn the skill in the virtual environment. Haptic guidance, in which the haptic interface constrains the user's motion to encourage a successful strategy, improves learning, particularly in low spatial individuals.

To provide a basis for a lively **discussion** between panelists and the audience some of these exemplary questions could be raised:

- Can spatial ability be improved through training, or are benefits task-specific?
- Can the effect of individual differences in spatial ability be overcome by training?
- What forms of interaction are necessary for spatial understanding?
- Can virtual environments produce spatial understanding equivalent to, or better than, real environments?

BIOGRAPHIES

Dr. Hannes Kaufmann is a postdoc researcher at the Interactive Media Systems Group at Vienna University of Technology. He attained a master's degree in mathematics and geometry in 1999 and a Ph.D. degree in computer science ('Geometry Education with Augmented Reality') in 2004. Dr. Kaufmann worked on several educational commercial projects and educational research projects. In 2003, he initiated an Austrian research project on 'Educating Spatial Intelligence with Augmented Reality' on which he is currently working. He is also working on an EU IST project (Lab@Future) in the area of eLearning. Publications at various conferences and journals reflect his research interests in virtual and augmented reality, human computer interaction, spatial abilities and education in collaborative VR/AR.

Gerard Jounghyun Kim, Ph.D. is an associate professor in computer science and engineering at the Pohang University of Science and Technology (POSTECH). Prior to joining POSTECH in 1995, he had worked as a computer scientist with support from the U.S. National Research Council Postdoctoral Fellowship for two years at the National Institute of Standards and Technology (NIST). He received a bachelor's degree in electrical and computer engineering at the Carnegie Mellon University (1987), and master's (computer engineering, 1989) and Ph.D. (computer science, 1994) degrees at the University of Southern California. His main research interests include various topics in virtual reality, human computer interaction, and computer music, and has written over 60 refereed technical papers.

Albert "Skip" Rizzo, Ph.D. is a Senior Research Scientist at the University of Southern California Institute for Creative Technologies (ICT) and a research asst. professor at the USC School of Gerontology. Dr. Rizzo conducts research on the design, development and evaluation of Virtual Reality systems targeting the assessment and rehabilitation of spatial abilities, attention, memory, and for various motor abilities. Additionally, he conducts research on VR applications that use 360-Degree Panoramic video and is also investigating the use of VR for pain distraction at LA Children's Hospital and for PTSD therapy in Iraq War veterans. He is the associate editor of the journal, CyberPsychology and Behavior; Senior Editor of the MIT Press journal, Presence: Teleoperators and Virtual Environments, is on a number of editorial boards for journals in the areas of cognition and computer technology (Presence; Cognitive Technology; Journal of Computer Animation and Virtual Worlds) and is the creator of the Virtual Reality Mental Health Email Listserver (VRPSYCH).

Rudolph Darken, D.Sc. is an Associate Professor of Computer Science and a Technical Director of the Modeling, Virtual Environments, and Simulation (MOVES) Institute at the Naval Postgraduate School in Monterey, California. He is the Chair of the MOVES Curriculum Committee and directs the Laboratory for Simulation and Training. He also directs modeling and simulation efforts for the Center for Homeland Defense and Security. His research has been primarily focused on human factors and training using virtual environments and computer gaming media with emphasis on navigation and wayfinding in large-scale virtual worlds. He is a Senior Editor of PRESENCE Journal, the MIT Press journal of teleoperators and virtual environments. He received his B.S. in Computer Science Engineering from the University of Illinois at Chicago in 1990 and his M.S. and D.Sc. degrees in Computer Science from The George Washington University in 1993 and 1995, respectively.

Dr. Robert Astur is Director of the Virtual Reality Laboratory at the Olin Neuropsychiatry Research Center at the Institute of Living in Hartford, Connecticut. He also is Assistant Professor in Psychiatry at Yale University. His background is in Neuroscience with particular emphasis on the neurobiology of memory. Accordingly, Dr. Astur has studied memory processes in monkeys, chimpanzees, orangutans, and rodents. His current work involves using VR to study memory processing in people with psychiatric illness such as schizophrenia, Alzheimer's disease, post-traumatic stress disorder, or drug abuse. Dr. Astur also uses functional brain imaging while people are navigating through virtual environments in order to determine brain areas involved in spatial navigation and how these brain areas differ between genders and psychiatric illnesses.

Frank Tendick, Ph.D. is interested in human-machine interfaces, teleoperation, and virtual environments, especially as applied to surgery. He received the bachelor's degree in Aeronautics and Astronautics from MIT, the master's degree in Mechanical Engineering from the University of California Berkeley, and the PhD in Bioengineering from the joint program at the University of California, San Francisco and Berkeley campuses. He is now Assistant Professor in the Department of Surgery at UCSF.