Standing Inside the Eye

This 3-D virtual reality technology reveals clinical findings that would otherwise be inaccessible on 2-D, slice-based images.

AN INTERVIEW WITH SZILÁRD KISS, MD

Retina Today interviewed Szilárd Kiss, MD, of Weill Cornell Medical College to learn about how an interactive, 3-D virtual reality technology, is being used to better understand disease processes in the eye.

Q: What is the CAVE?

Szilárd Kiss, MD: CAVE, or Computer Assisted Virtual Environment (Christie Digital Systems USA, Inc., Cypress, CA) is a 3-D virtual reality room. Volumetric data sets can be viewed and manipulated in this fully immersive, interactive, 3-D virtual reality environment.

Q: Where is this technology being used for retinal applications?

Dr. Kiss: The Retina Service at Weill Cornell Medical College has teamed up with the David A. Cofrin Center for Biomedical Information at the HRH Prince Alwaleed Bin Talal Bin Abdulaziz Institute for Computational Biomedicine (also at Weill Cornell) to blend 3-D stereoscopic immersive technology with high-resolution, spectral-domain optical coherence tomography (SD-OCT).

Q: How does this technology work?

Dr. Kiss: The CAVE works by using a mathematical algorithm to render 2-D optical coherence tomography (OCT, Spectralis, Heidelberg, Inc.) data segments to create a 3-D volumetric object. It is powered by a supercomputer that controls eight overlapping high-definition projectors that project images onto four walls, creating 1920x1920 pixels of resolution per wall. Two off-axis stereoscopic image pairs rapidly and sequentially flicker back and forth as they are projected onto the screens. The viewers wear stereoscopic LCD shutter glasses. The glasses are synchronized with the display, allowing users to perceive images in full color with true depth perception. Ultrasound sensors track viewers’ glasses so that they can manipulate the perspective of the image through intuitive head and body movements. For example, stepping forward draws the image closer, and bending down allows the wearer to see underneath the 3-D object.

Q: How do viewers interact with the images?

Dr. Kiss: Viewers are surrounded by a high-definition reconstruction of their data sets (in front, to the left and to the right, as well as on the floor of the viewing room). A handheld remote control allows the viewer to move images six degrees of freedom. An image, which can be enlarged through body movements or with the handheld controller, is enlarged until the viewer is standing inside their data. Components of the data can be selectively subtracted, layered, and separated to uncover previously undiscovered relationships of various structures. Multiple users can simultaneously view, manipulate, interact with, and analyze the images.

Q: How are data imported to the CAVE?

Dr. Kiss: Raw data from 2-D, slice-based, high-resolution SD-OCT images are imported into visualization software using programs developed and custom-built at Weill Cornell. Once the data are imported, threshold-based computational algorithms can be used to segment...
and isolate specific retinal structures. These anatomic segmentations are used to create 3-D representations of various structures within the retina.

Q: How can data be analyzed in and outside of the CAVE?

Dr. Kiss: These 3-D structures can be analyzed in various qualitative and quantitative ways. For instance, volumes, surface areas, and distances can be instantaneously measured and converted to millimeter equivalents. Individual structures can be isolated for closer inspection or subtracted from the object to reveal other underlying structures of interest.

Viewing these objects within the virtual reality environment of the CAVE permits close inspection and appraisal of 3-D retinal structures from any angle, including within the retinal tissue itself. One can literally walk through the retina to closely inspect specific structures and how they interrelate.

These same high-resolution images can be viewed from any angle, manipulated in any direction, and analyzed on traditional 2-D desktop monitors (Figure 1). Still images and video sequences can be captured and exported for viewing on any personal computer. Furthermore, the 3-D objects can be exported in other commercially available formats (ie, Adobe Acrobat) for viewing, manipulation, and analysis.

Q: How has this technology modified your approach to treating patients?

Dr. Kiss: Although this technology is still in its infancy, we have begun to render various retinal pathologies (eg, central serous choroidopathy [CSR], age-related macular degeneration, Vogt-Koyanagi-Harada [VKH] syndrome) as well as specific retinal structures (eg, a cast of the choroidal vasculature) into 3-D volumetric objects. This has allowed us to quantify not just choroidal thickness, but also choroidal volume in patients with CSR and VKH and to monitor patients’ responses to treatment (Figure 2).

Q: What are some clinical situations in which you have used the CAVE, and has the technology revealed findings that you otherwise would not have discovered?

Dr. Kiss: When we rendered and viewed in 3-D a patient with a macular pucker, the edge of the epiretinal membrane that could be used to initiate the membrane pealing became obvious. I could explain to my retina fellow (who was inside the CAVE viewing this same patient with me) the best surgical approach before even entering the operating room. Looking simply at the 2-D slice-based images did not show the same relationships of the pathology to the retina as the 3-D interactive images.

Q: What has been the reaction in the retinal and medical community in general to the CAVE?

What are the criticisms of the technology?

Dr. Kiss: There is obviously the initial “wow” factor that any virtual reality environment generates. After presenting our work at conferences, I am often asked by other physicians if they can come and view images in the CAVE. The most common criticism is how this technology could add to or change the way in which we understand and treat our patients.

Q: Do you think the CAVE will gain widespread clinical use?

Dr. Kiss: Given the footprint and costs required for setup, this specific CAVE technology may not gain widespread clinical use. However, the newly expanding commercial availability of stereoscopic 3-D monitors may offer a more direct way to bring true 3-D retinal viewing into every day clinical practice.

Q: How do you think the CAVE will revolutionize the way retinal diseases are understood and treated?

Dr. Kiss: The CAVE offers a different way to examine the retina. It gives us more information than is currently available in most commercial OCT systems. Having more information has almost always resulted in better understanding and treatment of our patients. The CAVE definitely has the potential to further revolutionize our understanding and treatment of retinal diseases.

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