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WHERE IS MY DIGITAL HOLOGRAPHIC DISPLAY?

By Joel E. Tohline

Are high-resolution digital holographic displays just around the corner? In the 1990s, two hurdles seemed to be preventing the practical implementation of computational holography techniques: computational workload and hardware projection capabilities. Are these hurdles still in place?

As I mentioned in the Nov./Dec. 2007 Visualization Corner ("Scientific Visualization: A Necessary Chore"), I'm looking forward to seeing an accelerated development of digital holographic techniques over the coming decade. I should confess, however, that I've been making this same statement to students in my physics and astronomy classes for more than 10 years. So what I want to know is, where is my digital holographic display?

Workload and Hardware Limitations

I'm interested in computer-generated (or computational) holography (CGH) because my astrophysics research group relies heavily on animation sequences of complex volume-rendered images when interpreting the results of our large-scale computational fluid dynamic (CFD) simulations (see Figure 1). I'm always looking for more effective ways to display and examine simulation results.

In the early 1990s, I had the impression that researchers knew quite well *how* to create digital holograms from computer-generated, virtual 3D surfaces. (From the perspective of a computational scientist with relatively little background in Fourier optics, I found the article by A.E. Macgregor to be an enlightening tutorial.[1]) But, at that time, two technical hurdles seemed to be preventing the implementation of CGH techniques.[2] First, the computational workload required to generate even one high-resolution digital hologram was prohibitive. Second, hardware capable of transforming digital holograms into virtual 3D scenes—that is, a practical digital holographic display—had not yet been developed.

Are these Hurdles Still in Place?

I can't accept that the computational workload required to generate high-resolution digital holograms remains prohibitive. My own brief excursion into this research arena[3] has convinced me that the necessary computational tasks can be completed in a brute force, if not elegant, fashion by the recursive execution of two-dimensional fast Fourier transforms.

It's therefore easy for me to imagine programming today's affordable parallel arrays of general-purpose graphics processing units (GPGPUs) to efficiently convert a wire-frame model of any 3D surface into a digital hologram that stores all of that surface's essential features. With the aid of GPGPUs, it should be straightforward to convert even quite intricate 3D scenes from video games—not to mention scenes from scientific visualizations—into digital holograms.

And we shouldn't have to settle for low-resolution 3D scenes. Researchers at Zebra Imaging (www.zebraimaging.com) have demonstrated that we can use digital techniques to generate large-scale, static white-light holograms of magnificent quality. I would love to have a laptop whose digital screen could display virtual 3D scenes that have a quality comparable to the scenes that are derived from Zebra Imaging's holograms.

I am less confident about critiquing the lack of progress that has been made over the past decade in surmounting the second hurdle I identified. This is a hardware—rather than a software—issue. How do we *dynamically* project or encode a high-resolution, digital hologram across a 2D surface in such a way that the holographic image serves as a diffraction pattern for light that is either passing through or reflecting off of that 2D surface?

Although different groups worldwide are pursuing various display strategies, I have been particularly intrigued by the experimental projection strategy being pursued in Skip Garner's research group at The University of Texas Southwestern Medical Center at Dallas.[4,5] In this group's prototype holographic projector, the digital micro-mirror device (DMD) found in one of Texas Instruments' DLP chips (www.dlp.com/includes/demo_flash.aspx) serves as a dynamically controllable array of square dif-

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fraction apertures. Diffraction of light occurs off the edges of each approximately 16 μm × 16 μm mirror with a 1 μm gap separating each row and column in the micro-mirror array. This group has demonstrated that it can construct time-varying, virtual 3D scenes at video rates from a sequence of pre-calculated 2D digital holograms. Because the DMD contains a relatively small (in this case, 1,024 × 768) array of mirrors, and the spacing between mirror centers is relatively large (17 μm), this prototype projection system can only generate small and relatively low-resolution 3D scenes. But the principle has been clearly demonstrated. So, where is my digital holographic display?

Okay, I see the practical obstruction. Although a projection system designed around a DMD could work in principle, its practical (and affordable) implementation remains a significant challenge. To dynamically project a 3D scene that has a size and quality comparable to the 3D scenes produced by one of Zebra Imaging's static holograms, we must shrink each micro-mirror array by an order of magnitude so that the distance between mirror centers is on the order of 2 μm (rather than 17 μm), and the spacing between mirrors is considerably less than 0.5 μm. In addition, constructing a laptop-sized display would require assembling an approximately 300 × 300 array of these miniaturized DMDs. Is Texas Instruments, or any other company, pursing such a roadmap? Or is there a more promising route to a practical and affordable digital holographic projection system?

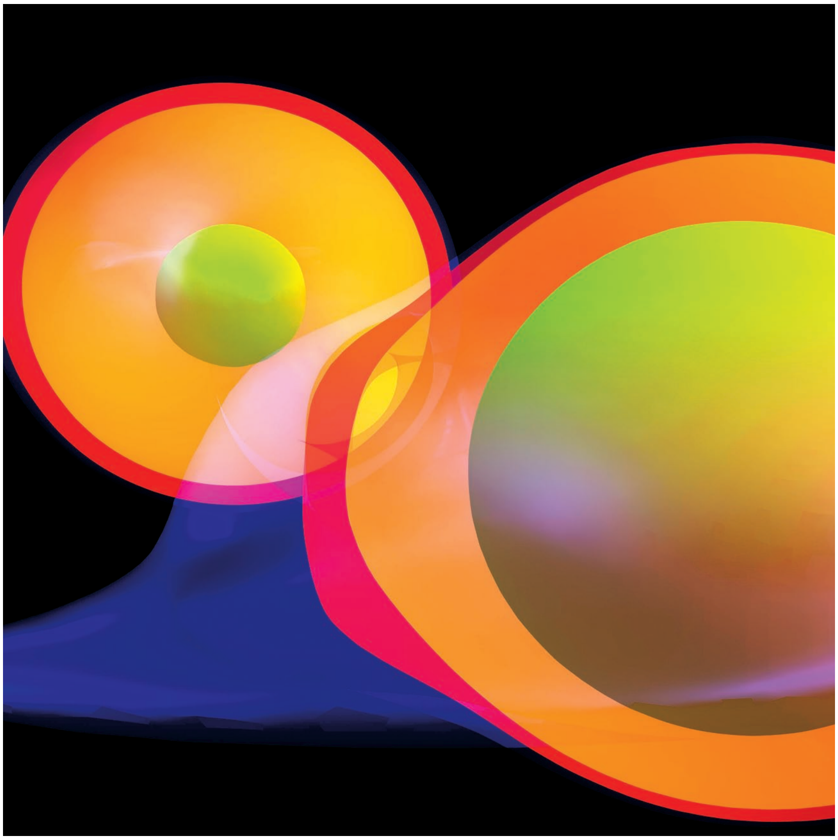

Figure 1. Four nested isodensity surfaces. This image illustrates the spatial distribution of material at one instant in time during a 3D, time-dependent computational fluid dynamic simulation of a mass-transferring double white dwarf binary star system. Lighting, texture mapping, and ray-tracing were performed using the Maya computer software package (version 7). An opaque, green surface identifies the region of highest density, whereas translucent yellow, red, and blue surfaces locate successively lower density regions of the flow. (Image created by Patrick Motl)

I invite readers to send me their thoughts on the issues I've raised regarding the near-future prospects for digital holographic displays. What should I be telling my students? Will I be able to acquire such a display within the coming decade? I hope the answer is yes.

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