An Introduction to Holographic Television

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Today’s Guest Speaker

V. Michael Bove, Jr.
MIT Media Lab
An Introduction to Holographic Television

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Thanks to James Barabas, Sundeep Jolly, Daniel Smalley, and the late Stephen Benton.

What’s this really all about?

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What’s this really all about?

Well, besides that...

- Realism
- Viewer comfort
- For professional applications like visualization or teleoperation, precision of depth judgment
6 primary 3D perceptual cues

- Ordinary 2D TV provides occlusion and perspective
- Stereoscopic TV adds binocular fusion and convergence
  - But focus (“accommodation”) isn’t consistent with them (viewer is always focused at the screen)
  - No motion parallax (unless there’s eye tracking)
- For maximum realism and minimal unpleasant physiological effects, all cues should be provided and be consistent with one another (holograms and volumetric displays try to do that)

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Even if the problem isn’t this bad...

- Viewing TV using the 3D function
- If you experience any of the following symptoms, immediately stop watching 3D pictures and consult a medical specialist: (1) altered vision; (2) lightheadedness; (3) dizziness; (4) involuntary movements such as eye or muscle twitching; (5) confusion; (6) nausea; (7) loss of awareness; (8) convulsions; (9) cramps, and/or (10) disorientation. Parents should monitor and ask their children about the above symptoms as children and teenagers may be more likely to experience these symptoms than adults.
- Viewing in 3D mode may also cause motion sickness, perceptual after effects, disorientation, eye strain, and decreased postural stability. It is recommended that users take frequent breaks to lessen the likelihood of these effects. If you have any of the above symptoms, immediately discontinue use of this device and do not resume until the symptoms have subsided.
- We do not recommend watching 3D if you are in bad physical condition, need sleep or have been drinking alcohol.
...it’s still agreed among researchers...

- Comfort is increased when there’s no vergence/accommodation conflict
- Stereoacuity is increased as well
- Motion parallax can increase understanding of the 3D space

3D cinema ≠ 3D living room ≠ 3D desktop ≠ 3D handheld

- Simple trigonometry tells us that “disparity budgets”, accommodation, and lookaround (motion parallax) situations are different at different viewing distances
When do we actually need 3D?

Experiments

- Find tasks that are easy when a viewer has binocular fusion but difficult otherwise
- Measure time-to-fuse (by presenting images for a range of short intervals) under different display circumstances
- Results will be presented as part of a PhD thesis in a few weeks
The ultimate 3D display is the hologram. But what’s a hologram?

Holograms

- Medium that uses diffraction of light to reconstruct light wavefronts identical to (or at least closely approximating) those that come from a real object
- Holograms can independently control light intensity, direction, and wavefront curvature (apparent distance from which it is emitted), and thus can provide autostereoscopic 3-D with no mismatch between convergence and accommodation, as well as making smooth motion parallax
Diffraction

- A sinusoidal “intensity” (variation in transmittance) or “phase” (index of refraction) grating can bend light through an angle.
- Change spacing of grating (spatial frequency) to change angle, change amplitude to change brightness.
- Wavelength-dependent, so monochromatic illumination is needed.

Diffractive TV (2D) is not a new idea (Scophony, 1938)
And the idea of doing 3D TV holographically has been around for a long time, too

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How to think of a hologram

• A window that can remember light wavefronts and reconstruct them later

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But most things called “holograms” aren’t

Ceci n’est pas un hologramme.

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Jessica Yellin is definitely not a hologram

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Tupac, Al Gore, Prince Charles, et al. aren’t even 3D

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The “Pepper’s Ghost” is a really old idea made new again

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Graphic by Raffaella Nofaro for the International Business Times
(Our group has, incidentally, developed a multiview Pepper’s Ghost)

And then there’s the “mythical hologram”...

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...which is physically impossible (sorry, Princess)

- It must be possible to draw a line from the viewer’s eye to each point in the reconstructed scene and hit the hologram creating it

BTW, this life-size Bob Marley at the MIT Museum really is a hologram (but he’s printed and static)
So why aren’t there more real moving holograms?

- It’s all physics’ fault!
  - To get a useful view angle, the pixels that make up the diffraction pattern need to be less than a half-micron in size (about the size of the light wavelength)
  - That means 2 million pixels per scan line per meter of screen width!

...and that’s just too many pixels to manage

- It’s possible to capture holograms of real moving scenes using coherent light (lasers) and interference but it requires a really short exposure time since the scene can’t move more than a fraction of a wavelength during the exposure
- And it also requires a ridiculously high-resolution image sensor
- And even if one manages to make it all work, transmitting that many pixels in real time is impractical
So what do we do?

• Capture the scene information a different way and compute the hologram at the display
  – Parallax array of ordinary cameras
  – Light field camera
  – CGI model (could be a point cloud from a rangefinding camera)
• Advantage: holographic displays can co-exist with other 3D display technologies

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Computing the hologram at the display

• A computed hologram can be a mathematical simulation of the physics, or for speed it can be built up by superposing smaller patterns (“hogels”) that direct light in desired directions (if we do that correctly, in the spatial and angular sampling limit it converges to the physically-correct Fresnel hologram)
• In the latter case, the computation can be done in real time on a high-end GPU (at least if we make the hologram horizontal-parallax-only)

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Holographic stereograms

- Analogous to other kinds of stereograms: approximates continuous 3D scene by projecting 2D images into their corresponding view directions either in one dimension (“HPO”) or in two (full parallax)
- Segment hologram into regions called hogels, each of which contains a set of diffractive basis functions corresponding to directions, modulated by intensities of views in those directions
- Imagery can originate as 3D model or array of 2D views
- Like other kinds of stereograms, all the directions have the same wavefront curvature (and thus accommodation cue is incorrect)

Holographic stereogram (left) vs. Diffraction-specific coherent panoramagram (DSCP) (right)
Finally, we need a display technology

- We need a lot of little pixels, and R/G/B laser light source
- Most light modulators (like LCOS and DLP chips) provide too few, too big pixels, though there are some tricks to get around the limitations (tiling, eye tracking, etc.)
- Multiple groups around the world working on solutions

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~$500 desktop monitor

Making live holo-TV using a Kinect


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(Image courtesy University of Arizona College of Optical Sciences)

One additional complication:
Real cameras aren’t orthographic

• Using incrementally shearing orthographic cameras (with perspective projection vertically for HPO holograms), rays crossing the hologram plane can be sampled uniformly in position and angle

• Uniform sampling of rays allows the hologram function to be computed independently at each hologram pixel enabling efficient GPU parallelization

• Current rangefinding cameras tend to have short focal lengths and thus don’t approximate orthographic cameras, so we have to resample the rays they collect (in real time!)

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Conclusions

• Good 3D is desirable for technical reasons and popular culture seems to demand it, too
• One ultimate goal is holo-video, which is more practical than many people think
• Can co-exist with other 3D display technologies
• Scale-up is the sticking point
• So it’s likely to be in your pocket or on your desktop in the relatively near future, but living-room-sized displays will take a bit longer and theatrical displays will require a few breakthroughs

If you want to know a lot more:

Q & A

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