The Ultimate Display: What Will It Be?

Moderator
Oliver Bimber (Bauhaus-Universität Weimar)

Panelists
Neil Dodgson (University of Cambridge Computer Laboratory)
Gregg Favalora (Actuality Systems, Inc.)
David Luebke (University of Virginia)
Ramesh Raskar (Mitsubishi Electric Research Laboratories (MERL))
Chris Slinger (QinetiQ)

The invention of television radically shaped the 20th century. Today we view most of our visual entertainment on new and innovative displays. This panel examines future trends in display technology, ranging from stereoscopic and autostereoscopic techniques, holography, and 3DTV to projector-based concepts. Leading experts from science and industry discuss possibilities, developments, and limitations of tomorrow's displays; fundamental facts; and emerging trends and applications in entertainment, science, and education.

Position Statement: Neil Dodgson

There will be no such thing as "The Ultimate Display," able to handle everything that we want to do. We will, instead, see a range of display technologies addressing a range of applications.

3DTV is not the way forward. Stereoscopic displays, whether glasses, autostereo, 3DTV or holographic, have limited practical use. Their two key applications are in the visualisation of complex 3D data, scientific and medical, and in remote manipulation, where a robot in a dangerous environment can be controlled more carefully and more quickly when the controller has a stereoscopic view. Beyond these two applications, stereoscopy is a gimmick. It adds a little extra buzz to entertainment products, especially 3D games and movies, but is not essential.

Stereoscopy will be used in its key applications and may penetrate other markets if users perceive a benefit. Elsewhere we will see wall-sized displays, displays on the physical desktop, paper-like displays, tiny projection displays and, possibly, direct stimulation of the brain.

UNC (Chapel Hill) did early experiments with wall-sized displays: users loved the experience and did not want to return to conventional monitors. The University of Cambridge and Xerox EuroPARC pioneered the idea of turning the physical desktop into a display device using projectors and cameras. Light Blue Optics is developing a projection display no bigger than a pack of cards, which can display onto any flat surface. All of these technologies will change the way we think about displays.

Paper is one of the best display devices: portable, flexible, high contrast and easy to annotate. Its drawback is that it is a write-once technology. This will change: we will see dynamically updatable displays with all these affordances of paper.

Direct visual stimulation of the brain is still the stuff of science fiction, but it is a tantalising possibility for the future.

Biographic Sketch: Neil Dodgson

Dr Dodgson is a Senior Lecturer in the Graphics & Interaction Research Group (Rainbow Group) at the University of Cambridge Computer Laboratory.

He has worked on autostereoscopic display technologies since 1991 and has a broad and deep view of research in the area. Since 2001, he has been on the programme committee of the primary conference for 3D display technology: Stereoscopic Displays & Applications (SPIE/IS&T) [www.stereoscopic.org]. In 2006 he is one of the three chairs of the conference. Dr Dodgson says: "I have seen a host of technologies presented as "the next big thing": this makes me sceptical of claims that "3DTV is the future"!"

In addition to his work in stereoscopy, Dr Dodgson's research group pioneered work on desktop displays with the "Digital Desk" (Pierre Wellner & Peter Robinson) and continues to work in novel display technologies, including the Escritoire, a foveal Digital Desk-like display (Mark Ashdown & Peter Robinson).

Dr Dodgson is a Fellow of Emmanuel College, Cambridge, and a member of the IEE, Eurographics, and ACM SIGGRAPH.

Position Statement: Gregg Favalora

The Pixel is Dead — Long Live the Hogel

There's a "data glut"— CAT scanners produce 2,000 slices of the body; seismic shots generate many GBytes of petroleum data; and military strikes are a multidimensional problem in time- and data-space. Even though this data glut increases exponentially, 2-D displays are reaching a plateau in pixel count. We must transition from the picture element (pixel) to the holographic element (hogel), and fast.

What's a viable autostereoscopic 3-D image? The visual field should be presented with at least XGA resolution and minimal interview aliasing artifacts for a reasonable viewing angle and distance. Quantitatively, at least one view per degree is required. Within a, say, 60-degree horizontal field-of-view, that corresponds to a 60-view display.

Customers need compelling application software. This suggests that legacy 2 1/2-D applications be compatible with the 3-D display platform.

Also, volumetric and quasi-holographic 3-D displays have staggering electro-optical bandwidth requirements. A swept-screen volumetric display with 768 x 768 x 198-slice resolution running at 30 Hz consumes over 1 GB/s to feed the embedded projector components. Few spatial light modulators, such as the Texas Instruments Digital Light Processing™ technology, satisfy this requirement.

One commercially-viable approach is the multiplanar volumetric display, such as our Perspecta® product. Others are time-multiplexed quasi-holographic displays, such as those which use diffractive or other optics to reconstruct light fields whose scenes are composed of a multitude of horizontal-parallax-only angle-dependent emitting surfaces. Displays in that family are capable of viewer-position-dependent effects such as occlusion.

In the next 2 years, "aerial" 3-D displays will have XGA resolution, 6"-12" diagonal image size, and 3"-6" depth running on an off-the-shelf PC for applications beginning in entertainment and signage, and then complementing desktop 2-D. By 2009, they will be viable substitutes for desktop displays.

Biographic Sketch: Gregg Favalora

I'm Gregg Favalora; I have been developing 3-D displays since 1988. My research includes multiplanar 3-D displays (such as those using parallel raster scanning and 3-DMD bitmap projection), and a variety of holographic and quasi-holographic displays, such as those my firm is developing under a $1.7 million government contract.

I founded Actuality Systems, Inc. in 1997 to commercialize Perspecta, an interactive volumetric 3-D display platform. It is being used worldwide in the fields of medicine, military visualization, and molecular modeling. Our 20 employees have been focused on the development of the mathematics, electronics, software, and optical systems which make possible some of the world's most advanced 3-D displays.

I hold approx. 5 patents and many pending in the fields of 3-D display, am on the committee of "the" 3-D display conference (SPIE Stereoscopic Displays and Applications), and really get a kick out of being a part of panel discussions.

Position Statement: David Luebke

THE FUTURE IS NOT FRAMED

The ultimate display will not show images. To drive the display of the future, we must abandon our traditional concepts of pixels, and of images as grids of coherent pixels, and of imagery as a sequence of images.

So what is this ultimate display? One thing is obvious: the display of the future will have incredibly high resolution. A typical monitor today has 100 dpi — far below a satisfactory printer. Several technologies offer the prospect of much higher resolutions; even today you can buy a 300 dpi e-book. Accounting for hyperacuity, one can make the argument that a "perfect" desktop-sized monitor would require about 6000 dpi — call it 11 gigapixels. Even if we don't seek a perfect monitor, we do want large displays. The very walls of our offices should be active display surfaces, addressable to a resolution comparable to or better than current monitors.

It's not just spatial resolution, either. We need higher temporal resolution: hardcore gamers already use single buffering to reduce delays. The human factors literature justifies this: even 15 ms of delay can harm task performance. Exotic technologies (holographic, autostereoscopic...) just increase the spatial, temporal, and directional resolution required.

Suppose we settle for 1 gigapixel displays that can refresh at 240 Hz — roughly 4000x typical display bandwidths today. Recomputing and refreshing every pixel every time is a Bad Idea, for power and thermal reasons if nothing else.

We present an alternative: discard the frame. Send the display streams of samples (location+color) instead of sequences of images. Build hardware into the display to buffer and reconstruct images from these samples. Exploit temporal coherence: send samples less often where imagery is changing slowly. Exploit spatial coherence: send fewer samples where imagery is low-frequency. We argue that this will reduce bandwidth requirements by 1-2 orders of magnitude.

Biographic Sketch: David Luebke

David Luebke is a professor at the University of Virginia. He holds a Ph.D. from the University of North Carolina.

Position Statement: Ramesh Raskar

A portable pocket projector with embedded sensing will support everywhere display, augmented-reality and new interaction paradigms.

Our ever shrinking portable devices carry more and more data but are running out of room to display the data in a visually satisfying way. A pocket projector built into such devices can turn virtually any surface into a display.

Projectors have three distinct advantages over other display devices. First, the size of the image is decoupled from the size of the device enabling large image from a small device. Second, the projected image can be overlaid on real objects making the composition ideal for visual augmentation of real world surfaces even if surfaces are colored and non-planar. Third, images from two or more projectors can be superimposed and physically blended together, allowing configurations than improve resolution, aspect ratio or brightness.

These advantages could turn a pocket projector into an effective personal display. Battery powered pocket projectors are available since January 2005. But there are hardware challenges in improving the image quality. Embedding active sensors (imaging and accelerometers) can allow the projector to adapt to its surrounding and user motion. And modes for effective user interaction need to be developed. Our group's work on these issues appeared in SIGGRAPH 2004 Papers and EmergingTechnologies program.

Success of portable projector is driven by: modulated long life instant on LEDs, reflective and high speed DLP and LCOS image modulators, MEMS mirrors for steering Lasers and controlled diffraction-optics.

Projectors, however, are affected by ambient illumination and need a suitable display surface. Some of these limitations can be overcome with a pop-out umbrella-like screen for opportunistic rear-projection. Beyond creating larger size images, projector will be used for augmented-reality, single handed user interaction (a glorified laser-pointer), communication with photosensing devices (glorified IR-remote-control) and for collaborative efforts (by optical superimposition).

Biographic Sketch: Ramesh Raskar

Ramesh Raskar is a Senior Research Scientist at MERL-Cambridge Research. His research interests include projector-based graphics, projective geometry and non-photorealistic rendering. During his doctoral research at U. of North Carolina at Chapel Hill, he developed a framework for projector based 3D graphics, which can simplify the constraints on conventional immersive displays, and enable new projector-assisted applications. He has published several articles on immersive projector-based displays, spatially augmented reality and has introduced Shader Lamps, a new approach for projector-based augmentation. His technical papers have appeared in SIGGRAPH, EuroGraphics, IEEE VR, IEEE Visualization, CVPR and many other graphics and vision conferences. He was a course organizer and speaker for Siggraph 2002, 2003 and 2004. He is a co-organizer of the Projector-Camera (PROCAMS) workshop at CVPR'05 and co-author of an upcoming book on augmented reality. He is a member of the ACM and IEEE.

Position Statement: Chris Slinger

If there is such a thing as an "ultimate display technology" computer generated holography (CGH) is the leading contender. CGHs use sophisticated algorithms and compute engines to calculate synthetic holographic fringe patterns. These are then fed to specialised, very high pixel count (~10 billion pixel) display hardware. The two dimensional CGH patterns are then typically replayed with lasers, diffracting their light, to produce floating 3D images. The technology is available today to allow fully interactive, reconfigurable, full colour 3D images to be produced using CGHs. Some salient facts differentiating CGH from other display technologies:

1) CGH is the ONLY 3D display technology capable of providing ALL the depth cues that the eyes and brain use. It does this without the need for special glasses or trackers. Other display technologies are deficient in some of the depth cues, or, worse still, give conflicting depth cues, resulting in viewer discomfort and/or poorer viewer performance.

2) if required, CGHs can provide images having detail beyond that resolvable by the eye.

3) CGHs can produce geometrically correct and stable images floating in space, fully accessible to users.

4) not only can CGH provide holographic 3D, but they can be reconfigured to generate imagery of the type produced by all other classes of display, including high resolution 2D, volumetric and multiview autostereo. They can do this at higher optical efficiency than other display technologies.

However, whilst CGHs may be the ultimate, they are not a panacea. The high pixel counts needed to produce large images and viewing angles mean that they are expensive systems - pixels cost money, and CGH have an appetite for pixels which far exceed other display types: 2D/stereo/multiview autostereo/CGH pixel count requirements go as ~ N/2N/50N/1000N.

Finally, CGHs can't break the laws of physics - so no Princess Leias please!

Biographic Sketch: Chris Slinger

Dr Chris Slinger is a QinetiQ Fellow and former Chief Scientific Officer for Holographic Imaging LLC, the US based QinetiQ/Ford Motor Company joint venture that was set up in 2000 to develop and exploit advanced visualisation technology. He is QinetiQ technical leader for holography, and Technical Director of the Optronics Department at QinetiQ Malvern.

He has served as conference program chair, session chair, committee member and panelist on numerous occasions and can always be relied on to promote and participate in a lively debate !

After completing his undergraduate and postgraduate degrees at Oxford University, he joined QinetiQ Malvern in 1985. Author or co-author of over 75 conference, open-literature publications and patents, his current research interests include computer generated holography and high performance 2D and 3D displays. He was made a QinetiQ Fellow in 1998 and awarded an inaugural QinetiQ Prize for Exceptional Innovation by Prince Michael of Kent in 1999 for his work on Advanced Liquid Crystal and Holographic Displays. In 2002 he was co-recipient of Institute of Physics Paterson Medal and Prize, for contributions to the utilization and application of physics and its commercial exploitation. He was elected as an Institute of Physics Fellow in 2003.