Head-Worn Projective Displays

- Announced product
  - castar.com

See also D. Krum, E. Suma, & M. Bolas, Augmented reality using personal projection and retroreflection, Personal and Ubiquitous Computing, Jan 2012, 16(1)
What Needs to Improve?

- Besides aesthetics and comfort,…

Wide Field of View for AR
K. Kiyokawa (Osaka U.), ISMAR 2007

- Head-worn projective display uses hyperbolic beam splitter
- 146° (in theory) horizontal FOV
Wide Field of View for VR

- Predistort image to counteract nonlinear lens distortion
  - Done in GPU
  - Typically not done in 20th C. systems because of computational overhead

See also [http://doc-ok.org/?p=1414](http://doc-ok.org/?p=1414)

Controllable Focus

H. Hua (U Arizona), ISMAR 2008

- Computer-controlled liquid lens
  - Can continuously vary focus or switch between discrete focal planes
- Example: Two discrete focal planes
  - Period limited by speed of lens
**Interaction of Real and Virtual**

K. Kiyokawa (Osaka U.)

- CRL (Communications Research Lab) per-pixel occlusive optical see-through display
  - K. Kiyokawa et al., *ISMAR 2003*

A depth camera is used to determine z values for the user's hand.

**Simplified optical path**

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**Interaction of Real and Virtual**

*Trivisio*

- AlphaBino per-pixel occlusive optical see-through display
Platform-Mounted Displays

- Fakespace Boom
  - High-resolution (opaque) stereo display
  - Mounted on a counterbalanced arm
    - Serves as a mechanical tracker
    - Makes it easy to manipulate massive display
- Virtual “telescopes”
  - Typically 1DOF (azimuth) or 2DOF (+ elevation) mechanically tracked video-see-through

Spatial Augmented Reality (SAR)

- Projectors in the environment project onto real world objects whose shape and texture we want to see
  - Augment the real world directly
  - Can avoid encumbering the user
SAR Models
R. Raskar, G. Welch, K. Low, D. Bandyopadhyay (UNC Chapel Hill), 2001

- Projecting on models dynamically adds detail, lighting

Steerable Projected Displays

- “Everywhere Displays”
  - Steerable projector/camera assembly
  - Monoscopic images coplanar with room surfaces

Volumetric Displays
Survey: G. Favalora, IEEE Computer, August 2005

- Rotating 2D array of LEDs

- RGB lasers perform a 2D scan of a rotating double helix surface
  - Surface
    - double helix
    - 36\" diameter x 18\" height
    - coated with white paint
    - rotates @ 600rpm (10 rps)
  - 20Hz update rate = 10 rps x 2 helices
  - Only half of helix is used (to increase resolution)
Volumetric Displays
Survey: G. Favalora, IEEE Computer, August 2005

- Actuality Perspecta Display 1.9
- Semitransparent screen is swept around vertical axis along with projection optics
  - 198 768×768 pixel slices × 24Hz, 10" diameter

See also N. Holliman et al., IEEE Trans. on Broadcasting, June 2011

https://www.youtube.com/watch?v=7Gim5OeKxwU

Volumetric Displays
Survey: G. Favalora, IEEE Computer, August 2005

- Depthcube: projector and multiplanar optical element of LC sequentially alternating scattering shutters
  - 1024×748×20
  - 25.6"×11.8"×4.1" volume

See also N. Holliman et al., IEEE Trans. on Broadcasting, June 2011

Volumetric Displays
Survey: G. Favalora, IEEE Computer, August 2005

- Solid-state 3D display
- Two-step two-frequency up conversion
  - Active ion that has been doped in small quantities into bulk transparent host material, is optically excited to higher energy levels by absorbing energy from two different-wavelength, near IR laser beams

http://www.sciencemag.org/content/273/5279/1185.full.pdf

- Prototype with 3 layers, with one dopant each (full color display @ 1/3 resolution could be made with interleaved layers)

Volumetric Displays

- USC Light field Display
- Projects onto anisotropic mirror spinning @ 1200Hz
  - 288 images per revolution, one for each 1.25° horizontal “slice”
    - Each pixel can be seen from a wide range of vertical angles
    - Each image contains rays for multiple viewpoints
    - Images should be rendered with multiple centers of projection

For correct perspective:
- Track each viewer’s position and render view for all across multiple images
- Only one viewer can occupy the slices for an L-R stereo pair
- R-L stereo pair for cross-eyed viewing

http://gl.ict.usc.edu/Research/3DDisplay/

Volumetric Displays

- Horizontal projection screen translates vertically, projected from below
- http://www.voxon.co
- 30 volumes/sec
- 18cm×18cm×8cm

The Ultimate Display

“The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming, such a display could literally be the Wonderland into which Alice walked.”

A side note regarding visual perception,…

http://web.mit.edu/persci/people/adelson/checkershadow_illusion.html

The squares marked A and B are the same shade of gray
Audio Perception

- Mapping of sound wave characteristics (acoustics) to perception (psychoacoustics) depends on physiology, genetics, history of sound exposure, age
  - Amplitude $\rightarrow$ Loudness
    - $\sim 10^{13}:1$ amplitude range $\rightarrow 10^6:1$ loudness range (barely audible $\rightarrow$ painful)
    - Depends on frequency
  - Frequency $\rightarrow$ Pitch
    - $\sim 20$Hz–20KHz
  - Waveshape $\rightarrow$ Timbre

Audio Perception

- Spatial cues
  - Monaural
  - Binaural
Monaural, Static Cues

- Volume
  - Intensity (≈ loudness) → distance/occlusion
- Spectrum
  - High frequency falloff → distance/occlusion
- Reverberation
  - Reflection from environment surfaces → environment geometry/materials