Video See-Through Displays
Approaches to Combining Real & Virtual

- Full visible-surface determination
- Fill frame buffer $f$ with camera image
- Fill z-buffer $z$ with depth camera image
  - for each pixel $p$ in each graphics object {
    - $z(p) = z$ of object @ pixel coords $(x, y)$
    - if $z(p)$ not farther than $z[x, y]$ {
      - // update $z$ and draw object @ pixel $p$
      - $z[x, y] = z(p)$
      - $f[x, y] = color$ of object @ pixel coords $(x, y)$
    }
  }
- Or blend graphics and camera images in then clause
See-Through Head-Worn Displays

- Binocular (stereoscopic)
  - Different image to each eye

- Monocular (monoscopic)
  - One image to one eye
  - Biocular (same image to both eyes)

See-Through Head-Worn Displays

- Helmet-mount

- Clip-on

- Built-in
See-Through Head-Worn Displays

- Issues
  - Field of view
  - Transparency
  - Brightness
  - Contrast
  - Focus
  - Size
  - Weight
  - Appearance
  - ...

See-Through Head-Worn Displays++

- Integrate ≥ 1 of
  - Orientation tracker
  - Input device
  - RGB camera
  - Depth camera
  - Computer
  - Radio
Head-Worn Projective Displays


- Head-worn projector image
  - reflected from beam splitter…
  - on to retroreflective screen…
  - reflected back along angle of incidence to viewer

- Image is too dim to see well on non-retroreflective surface
- “X-ray vision”
- Camouflage

Head-Worn Projective Displays

M. Inami and N. Kawakami, X’tal Vision, 1998
M. Inami, D. Sekiguchi, S. Tachi, 2003

http://tachilab.org/modules/projects/transparentcockpit.html

Feiner, COMS W4172, Spring 2014
Head-Worn Projective Displays

- Announced product
  - technicalillusions.com

See also D. Krum, E. Suma, & M. Boles, 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

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) 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
Interaction of Real and Virtual

- AlphaBino 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)

- Projecting on models dynamically adds detail, lighting
**Steerable Projected Displays**

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

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**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,…

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

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

Edward H. Adelson
Audio Perception

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

Audio Perception

- **Spatial cues**
  - Monaural
  - Binaural
Monaural, Static Cues

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

Monaural, Dynamic Cues

- Changes in monaural cues perceived based on head movement
- Doppler effect
  - Frequency perceived by observer increases/decreases based on relative motion towards/away from source
Binaural Cues

- Difference in arrival time at ears
  - Interaural time difference (ITD) → azimuth
- Difference in intensity at ears
  - Interaural intensity difference (IID)
- Intersection of perceptually same ITD and IID volumes forms “torus of confusion”
- Note potential for midline ambiguities
  - How to account for ability to hear sources as being front, behind, above, below?

Head-Related Transfer Function (HRTF)

- Spatial filter characterizing interaction of sound waves with torso, shoulders, head, and pinnae (outer ears), based on source azimuth, elevation, and range
- Encode
  - volume/spectrum as absolute magnitude of wavelengths
  - ITD/IID as relative phase and magnitude of wavelengths
- Listener-specific
  - Based on anatomy

Binaural Cues

- Head-Related Transfer Function (HRTF)
- Computed from recordings of localized sources with in-ear probe mics

Audio Spatialization (aka Localization)

- Use HRTFs to process audio
  - Realism
  - Separation of sources can make them more understandable
  - But, doesn’t account for environment
Auralization  
*aka Sound Rendering*  
- Generate sound field by modeling interaction of sources with environment  
- Usually defined to include potential application of HRTFs  

Uses of Audio in 3D UIs  
- Location cue  
  - Accomplished through spatialization  
- *Sonification*  
  - *aka Auralization* [a different use of the term] or *Audification*  
  - “Sonic visualization” to map information to sound  
- Sound track  
- Realistic ambient sound  
- Sensory substitution  
  - For example, to indicate physical contact  
- Annotation  
  - For example, narration