Advanced Display Technology-
Technologie d’Affichaghe Avancée

Winter 2013/14

Ivo Ihrke
Introduction to 3D Technologies
Taxonomy of Direct 3D Displays: 
Glasses-bound vs. Unencumbered Designs

Glasses-bound

Stereoscopic

- Head-mounted (eyepiece-objective and microdisplay)
- Multiplexed (stereo pair with same display surface)

Unencumbered

Automultiscopic

- Parallax-based (2D display with light-directing elements)
- Volumetric (directly illuminate points within a volume)
- Holographic (reconstructs wavefront using 2D element)

Immersive (blocks direct-viewing of real world)
See-through (superimposes synthetic images onto real world)
Spatially-multiplexed (field-concurrent) (color filters, polarizers, autostereograms, etc.)
Temporally-multiplexed (field-sequential) (LCD shutter glasses)
Parallax Barriers (uniform array of 1D slits or 2D pinhole arrays)
Integral Imaging (lenticular sheets or fly’s eye lenslet arrays)
Multi-planar (time-sequential projection onto swept surfaces)
Transparent Substrates (intersecting laser beams, fog layers, etc.)
Static (holographic films)
Dynamic (holovideo)

Taxonomy adapted from Hong Hua
Taxonomy of 3D Displays:

**Immersive Head-mounted Displays (HMDs)**

- **Head-mounted**
  (eyepiece-objective and microdisplay)

- **Glasses-bound**
  Stereoscopic

- **Multiplexed**
  (stereo pair with same display surface)

**Immersive**
(blocks direct-viewing of real world)
Taxonomy of 3D Displays:

See-through Head-mounted Displays (HMDs)

Glasses-bound
Stereoscopic

Head-mounted
(eyepiece-objective and microdisplay)

Multiplexed
(stereo pair with same display surface)

Immersive
(blocks direct-viewing of real world)

See-through
(superimposes synthetic images onto real world)
Taxonomy of 3D Displays:

Spatial Multiplexing (e.g., Anaglyphs)

- **Glasses-bound**
  - **Stereoscopic**
  - **Multiplexed**
    - (stereo pair with same display surface)

- **Head-mounted**
  - (eyepiece-objective and microdisplay)

- **Immersive**
  - (blocks direct-viewing of real world)

- **See-through**
  - (superimposes synthetic images onto real world)

- **Spatially-multiplexed**
  - (field-concurrent)
    - (color filters, polarizers, etc.)

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Taxonomy of 3D Displays:
Temporal Multiplexing (e.g., Shutter Glasses)

- Head-mounted (eyepiece-objective and microdisplay)
- Spatially-multiplexed (field-concurrent) (color filters, polarizers, autostereograms, etc.)
- Temporally-multiplexed (field-sequential) (LCD shutter glasses)
- See-through (superimposes synthetic images onto real world)

Glasses-bound Stereoscopic

Immersive (blocks direct-viewing of real world)

- Overlapping Images displayed on the screen. The images switch so fast that without glasses the images seem to be blended.
- Projector 1: displays image for left eye alternating with a black image
- Projector 2: displays image for right eye alternating with a black image
- Glasses: are opaque for one eye at a time, controlled by an infrared shutter signal that is synchronized with the projectors
Is “glasses-free 3D” ready?

- Nintendo 3DS
  E3 2010

- MasterImage 3D
  Computex 2011

- Asus Eee Pad MeMO 3D
  Computex 2011

- LG Optimus 3D
  Mobile World Congress 2011

- Toshiba 3DTV Prototype
  CES 2011

- Sony 3DTV Prototype
  CES 2011

- LG 3DTV Prototype
  CES 2011
Taxonomy of Direct 3D Displays:

Parallax Barriers

Unencumbered Automultiscopic

Parallax-based
(2D display with light-directing elements)

Volumetric
(directly illuminate points within a volume)

Holographic
(reconstructs wavefront using 2D element)

NewSight MV-42AD3 42"
(1920x1080, 1x8 views)

Parallax Barriers
(uniform array of 1D slits or 2D pinhole arrays)
Taxonomy of Direct 3D Displays:

Integral Imaging

Parallax-based
(2D display with light-directing elements)

Unencumbered Automultiscopic

Volumetric
(directly illuminate points within a volume)

Holographic
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Parallax Barriers
(uniform array of 1D slits or 2D pinhole arrays)

Integral Imaging
(lenticular sheets or fly’s eye lenslet arrays)

Alioscopy 3DHD 42''
(1920x1200, 1x8 views)
Display Technologies – 3D Displays

- integral photography, e.g. [Okano98]
- micro lens-array in front of screen
- screen at focal distance of micro lenses
  - parallel rays for each pixel
  - every eye sees a different pixel
Display Technologies – 3D Displays

- need high resolution images
- micro lens array
- arrays of graded index (GRIN) lenses
- screen is auto-stereoscopic
  → no glasses, multiple users
Display Technologies – 3D Displays

- 3D-TV system [Matusik04]
- uses lenticular lenses in a multi-projector system
- same principle as in integral photography, but only in one dimension (cylindrical lenses)
Display Technologies – 3D Displays

- for 3D video, need a high resolution screen
- multiple projectors increase resolution
- two possibilities
  - rear-projection system
  - front-projection system
Rear Projection Design

Lens = Pixel

Semi-transparent Material

Lens
Rear Projection Design

Lens = Pixel

Semi-transparent Material

Lens

Focal length

Focal length

Dist. >> f
Rear Projection Design

Emitted Light

Lens = Pixel

Semi-transparent Material

Lens

Focal length

Focal length

Dist. >> f
Rear Projection Design

Requirements on diffuser material:
- Scattering lobe must be broad enough to cover projected cone of rays!
Realized Rear Projection Display

- Viewer-Side Lenticular Sheet
- Semi-transparent material
- Projection-Side Lenticular Sheet
- Projectors

[Diagram of the rear projection display with labels for each component]
Front Projection Design

Lens

Reflective Material
Front Projection Design

Dist. >> f

Focal length

Lens

Reflective Material
Front Projection Design

Reflective Material

Lens

Reflected Light

Dist. >> f

Focal length

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Front Projection Design

Requirements on reflective material:
• BRDF lobe must be broad enough to cover projected cone of rays
• Reflective case less requiring then transmissive
Realized Front Projection Display

- Projectors
- Lenticular Sheet
- Reflective Material
- Viewer
Directional Backlighting

- Currently promoted by 3M
- Requires a high-speed (120 Hz) LCD panel, an additional double-sided prism film, and a pair of LEDs
- Allows multi-view display, but requires higher-speed LCD and additional light source for each view

Nelson and Brott, 2010
US Patent 7,847,869
## Design Trade-offs

<table>
<thead>
<tr>
<th></th>
<th>Integral Imaging</th>
<th>Parallax Barriers</th>
<th>Directional Backlighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial Resolution</td>
<td>low</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Brightness</td>
<td>high</td>
<td>low</td>
<td>moderate</td>
</tr>
<tr>
<td>Cost</td>
<td>low</td>
<td>low – moderate</td>
<td>moderate – high</td>
</tr>
<tr>
<td>Full-resolution 2D</td>
<td>no</td>
<td>yes (dual-layer LCD)</td>
<td>yes</td>
</tr>
<tr>
<td>Motion Parallax</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>
Taxonomy of Direct 3D Displays:

Multi-planar Volumetric Displays

- **Parallax-based**
  (2D display with light-directing elements)

- **Unencumbered Automultiscopic**

- **Volumetric**
  (directly illuminate points within a volume)

- **Holographic**
  (reconstructs wavefront using 2D element)

- **Parallax Barriers**
  (uniform array of 1D slits or 2D pinhole arrays)

- **Integral Imaging**
  (lenticular sheets or fly’s eye lenslet arrays)

- **Multi-planar**
  (time-sequential projection onto swept surfaces)
Display Technologies – 3D Displays

- rotating diffusers [Ketchpel64]
- cathode ray illuminates quickly rotating phosphor screen
- voxels can be addressed individually
- volumetric display is transparent (no opaque surfaces)
image & prototype by Barry Blundell
Display Technologies – 3D Displays

- modern version –
  
  Autostereoscopic Light Field Display [Jones07]

- enables
  - opaque surfaces
  - horizontal parallax built-in
  - vertical parallax with head-tracking
  - multiple users possible
  - auto-stereoscopic
  - display of dynamic light fields in 3D
Display Technologies – 3D Displays

- principle of operation
- rotating front surface mirror with anisotropic diffusion filter on top
- diffuses light in vertical direction perfectly
- in horizontal direction only in a very limited angle
Display Technologies – 3D Displays

- can be regarded as a rotating projector
- ~17 3D frames per second
- 288 angular bins
- need ~5000 frames per second rendering for the projector
Display Technologies – 3D Displays

- render only binary images (dithered)
- specially encoded DVI signal (every bit is a pixel instead of RGB value → 24 pixels per normal color pixel)
- 200 Hz refresh rate (GeForce 8800) = 4800 fps
- special decoder chip necessary
Varifocal Mirror Screens

[Fuchs’86]
Varifocal Mirror Screen - Implementation

In early systems (fig. 1) users viewed sequentially-presented 2D image slices on a high speed CRT display via reflection in an opaque flexing mirror. The mirror was comprised of a reflective Mylar membrane stretched over the mouth of a loudspeaker. The effect was optical sweep of the 2D display’s reflection through a virtual (behind the mirror) volume.

A fixed concave mirror corrects the depth inversion inherent in the vibrating mirror system, and makes the images real so that they float out in front of the system where they are accessible to the user.

[Disney2012]
Varifocal Mirror Screen - Implementation

[Disney2012]
Taxonomy of Direct 3D Displays:

**Transparent-substrate Volumetric Displays**

- **Unencumbered Automultiscopic**
- **Parallax-based** (2D display with light-directing elements)
- **Volumetric** (directly illuminate points within a volume)
- **Holographic** (reconstructs wavefront using 2D element)

**Parallax Barriers** (uniform array of 1D slits or 2D pinhole arrays)

**Integral Imaging** (lenticular sheets or fly’s eye lenslet arrays)

**Multi-planar** (time-sequential projection onto swept surfaces)

**Transparent Substrates** (intersecting laser beams, fog layers, etc.)
Taxonomy of Direct 3D Displays:

Static Holograms

- **Parallax-based** (2D display with light-directing elements)
- **Volumetric** (directly illuminate points within a volume)
- **Holographic** (reconstructs wavefront using 2D element)

**Unencumbered Automultiscopic**

- **Parallax Barriers** (uniform array of 1D slits or 2D pinhole arrays)
- **Integral Imaging** (lenticular sheets or fly’s eye lenslet arrays)
- **Multi-planar** (time-sequential projection onto swept surfaces)
- **Transparent Substrates** (intersecting laser beams, fog layers, etc.)
- **Static** (holographic films)
Display Technologies – 3D Displays

- Rendering for holographic displays [Ahrenberg06]
- GPU-based superposition of spherical waves in the virtual film plane
- object consists of points
- no occlusion
- monochromatic
- <movies>
Display Technologies – 3D Displays

- combined holograms and auto-stereoscopic displays

**Figure 1. Optical functioning.** The explosion model of the optical layers’ stacked structure shows, from left to right: glass protection, holographic emulsion, mirror beam splitter for transmission holograms only, lenticular-lens sheet, and LCD array. Reflected light rays (red arrows) reconstruct the object wave on their return through the emulsion. Stereoscopic images (green arrows) pass through all layers until they merge with the hologram.

Selective Illumination leaves part of hologram dark!

[Bimber’04]
Display Technologies – 3D Displays

[Bimber’04]
Taxonomy of Direct 3D Displays:

Dynamic Holograms (Holovideo)

- **Parallax-based**
  (2D display with light-directing elements)

- **Volumetric**
  (directly illuminate points within a volume)

- **Holographic**
  (reconstructs wavefront using 2D element)

- **Unencumbered Automultiscopic**

- **Parallax Barriers**
  (uniform array of 1D slits or 2D pinhole arrays)

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  (lenticular sheets or fly’s eye lenslet arrays)

- **Multi-planar**
  (time-sequential projection onto swept surfaces)

- **Transparent Substrates**
  (intersecting laser beams, fog layers, etc.)

- **Static**
  (holographic films)

- **Dynamic**
  (holovideo)

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Tay et al. [Nature, 2008]

MIT Media Lab Spatial Imaging Group
[Holovideo, 1989 – present]
What is meant by “glasses-free 3D”?

- Binocular disparity
- Convergence
- Motion parallax
- Accommodation/blur

- Current glasses-based (stereoscopic) displays
- Near-term glasses-free (automultiscopic) displays
- Longer-term volumetric and holographic displays
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THE END
References


