3D Displays

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Overview

1 Introduction

2 Volumetric Displays

3 Auto-stereoscopic Displays

4 Stereoscopic Displays

5 NTE & HMD

6 Summary

Background data beside SID and SPIE conferences:
3rdDimension, www.veritasetvisus.com
Sources: Surman, Lee, De Montfort University;
P. Green, PLANAR; R. Salmon, BBC

- Not in short version
3D - an Old Story: Brewster Stereoscope

- Introduced in 19th century
- Stereo pair observed through 2 convex lenses
3D Display Market

Key driver: 3D movies like AVATAR
- Will this enable home cinema?
- Industrial & professional use?

Source: DISPLAYBANK
Why (not) use 3D Displays?

- It’s the natural progression for display evolution:
  
  Monochrome \(\Rightarrow\) Color \(\Rightarrow\) 3D

- 3D viewing potentially provides a way to extract information from complex data faster and more accurately
  
  \(\Rightarrow\) Potentially save time and improve efficiency

- Current 2D image processing and enhancement is good enough

- The real ROI for 3D is unproven for most applications

- 3D displays can create headache and eye strain

- Instead of 3D, consumer chooses better sound, color, screen, resolution, …
Professional Applications for 3D

- Molecular Modelling
- Geospatial
- Microscopy
- Engineering
- Data Visualization
- Oil & Gas Exploration
- Medical
Applications for 3D: Movies

- Main driver for 3D
- Introduced in the 1950’s
- Mainly animation
- AVATAR is all-time #1 blockbuster

From anaglyph

to polarization
4 requirements for 3D perception

- **Stereopsis**
  - Left and right eye see slightly different image

- **Accomodation**
  - Eye focusing on an object which is:
    - infinite: relaxed pupil
    - close: strong curvature of pupil

- **Realistic 3D Impression**

- **Vergence**
  - Eye position when looking at:
    - object in infinite: parallel
    - close objects: converging

- **Motion Parallax**
Fundamentals of 3D perception: Stereopsis

Each eye sees an object as a 2D image but from different perspective

⇒ Brain creates 3D impression
Stereoscopic Vision

• Human eye & brain in combination integrates multiple cues (‘Hilfestellungen zu Tiefenwahrnehmung’) to perceive depth

• **Primary Cues**
  are provided by slightly different views of each eye. The eye must be therefore of highest resolution (fovea). Practically, these differences are effective up to 30 m. Only these cues need a 3D display.

• **Secondary Cues**
  Many cues are seen by a person with one eye and can be therefore displayed on a 2D (standard) screen.
Primary Cues (Stereopsis)

Depth perception by stereopsis: with two slightly different images of our eyes (parallax): Disparity.

... difference is relative small:

→ large eye resolution necessary!
Secondary Cues (Monoscopic Cues)

3D is perceived by the human visual system in various ways. There are monoscopic cues (secondary cues) that do not exploit the fact we have two eyes ⇒ 2D screen could be OK!

Some of these cues are:

• Occlusion (Verdeckung)
• Linear perspective
• Size (constancy)
• Motion parallax (s.a.)
• Shadows & shading
Stereoscopic 3D Displays Overview

3D (non volumetric)

- Stereoscopic
- Auto-stereoscopic

Multi-view displays

- Limits:
  - Resolution
  - Size of viewing zone

- Systems:
  - Fixed position
  - Head-tracking displays
  - Multi-view displays

Near-The-Eye Helmet Mounted Displays

Individual displays dedicated to each eye

- often regarded as separate approach because stereoscopic (2 views)
- & auto-stereoscopic (no glasses)

Present two views, one for each eye

Glasses technologies:
- Polarisation
- Time-sequential
- Spectral

Displays:
- Direct View & projection

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- often regarded as separate approach because stereoscopic (2 views)
- & auto-stereoscopic
- (no glasses)
Fundamental Issues of 3D Displays: Accommodation

- Physiological issue: Accommodation (Fokus) vs. vergence (Augenstellung)

Accommodation - vergence conflicts in 3D displays cause fatigue & discomfort
Fundamental Issues of 3D Displays: Depth Perception

- Due to limited resolution of 3D displays, the display can show infinite depth content on 3D displays “looks compressed” in depth.
Fundamental Issues of 3D Displays: Cross Talk

- 3D Cross talk - if eye specific information is not well separated
- Information for left eye is visible with right eye and vice versa

3D cross talk creates a ghost image which may cause discomfort

This image is for one eye only, but contains a ghost image overlapping with the original content
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Autostereoscopic 3D

**Definition:** No glasses etc. are needed for 3D but limited ‘sweet spot’

- Autostereoscopic displays became feasible with FPDs
- Various autostereoscopic technologies exist
- They differ in advantages & disadvantages

**Autostereoscopic displays**

- Uses AMLCDs with an added optical element to create a dual view (left eye/right eye) presentation of the image on the screen (PDP: too large pixel size)
- A optimum viewing space is created (sweet spot)
Autostereoscopic Mask Principles

Parallax Barrier

Lenticular Lens

Source: WIKIPEDIA
Autostereoscopic Displays

Essential for mobile devices

TV sets and monitors (issue: 2+ viewers)
Autostereoscopic AMLCDs

• **Merits**
  - No eyewear required
  - Good chromaticity
  - Some designs allow easy conversion between 2D and 3D
  - Based on mainstream technology (AMLCDs)

• **Issues**
  - Horizontal display resolution is reduced by the number of domains
  - Very narrow viewing angle in two domain design, there are transition zones with higher domain count
  - Some designs are 3D only
Head Tracked: Principle of Operation

Liquid Crystal Display (LCD)

Moving mask controlled by head tracking
Head Tracking Single User

SeeReal Head Tracked Display

Head Tracker

This is a version of the fixed viewing zone display. The prism mask is moved laterally in accordance with the tracker output.
Multi-View: Philips Lenticular

PHILIPS 42” WOW DISPLAY (9-VIEW)
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Present two views, one for each eye

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Displays:
- Direct View
- Projection
Anaglyph

- Uses familiar red and green/cyan glasses for image separation
- Generally monoscopic but good color can be obtained
Polarisation Separation

• Left and right image is displayed at the same time

• Only half of resolution of display for 3D image

• Either diagonally or circularly polarised for each view, with appropriate polarisation in the glasses (cheap)

• Usually based on LCD technology.
Polarisation Separation
Polarisation Separation

TV set

Imaging

LCD pixel

Polarisation separation by patterned retarder

Passive Glasses

Decoding

Separation/Encoding by polarization
Polarisation Separation

• Polarised light separates left and right views from LCD

• Example below uses micropolariser screen

• Can also use 2 separate projectors with polarisers and polarisation retaining screen
Time - Sequential

- **Left** and **right** image is **displayed sequentially**

- Uses synchronized (usually IR) shutter glasses (expensive)

- Left and right image with full display resolution

- Requires fast display as minimum for $\geq 200$ Hz frame rate

- **Direct view** & **projection**
  - Direct view: LCD, PDP, CRT (gone)
  - Projection: mostly DLP
Time - Sequential Visualisation
**Time - Sequential:** AMLCD needs quad frame frequency

- New content is written to display from top to bottom
- Hold type display causes “double images” (old and new frame)
- Therefore 1 full 3D frame consists of four subframes (R, L, 2 for updating)
- Response time of LCD shall be below 2ms for cross-talk free 3D
Time – Sequential Direct View

Samsung 55-inch 240Hz 3D LCD Display
Time - Sequential

• Direct view-based solutions using frame sequential stereo (2x the typical refresh rate)
• LC Shutter Glasses with synchronization to the display
Time - Sequential Summary

• Merits
  - The established approach
  - Good chromaticity
  - Wide viewing angle, multiple viewers possible

• Issues
  - Quality glasses are expensive
  - Limited brightness (for the shutter approach)
  - Flicker can be an issue
  - Response time limitations of AMLCD monitors
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Head / Helmet Mounted Displays (HMD)

1990: 3D HMD for stereo-endoscope (BMBF: AESCULAP, SEL, AEG)

- 2 monochrome white CRTs
- 3 images (11 x 8 mm²) on each CRT
- Superposition with RGB filters

Research project: Commercial price would have been too high
Near To Eye Displays (NTE)

BRILLIAN: SVGA LCOS

VIKING

Cable !!!

KOPIN
Head / Helmet Mounted Displays (HMD)

Merits
- Good 3D effect possible
- Full resolution to each eye
- High contrast
- Immersive experience

Issues
- Potential discomfort: Some devices are bulky and have high weight
- User blocked from environment
- HMD isolates user
- Cost
- Resolution often too poor for superb 3D

Would you accept that? Even for video on the go?
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## Summary for 3D Displays

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<td>• Multi viewer</td>
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<td>• Standard panel upgraded by foil</td>
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