The Impact of Eye Tracking on Head Mounted / Near Eye Display Development

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Outline

1. Summary
2. Discussion of fundamental head-mounted/near-eye display concepts
3. Historical development sampling
4. Persisting issues and challenges
5. Key eye tracking terminology
6. Discussion of selected papers
7. Conclusion

1. Summary

- Challenges
  - Size constraints
  - Cost constraints
  - Computational cost
  - Display technology not yet well adapted
- Goals
  - Improvement of image quality
    Rendering optimization
  - Additional, more natural depth cues
  - Enhanced interaction

2. Discussion of fundamental HM/NE display concepts

- Augmented Reality
  - Virtual environments enhance real environments
  - „See-through“ display
- Virtual Reality
  - Virtual environments replace real environments
- Mixed Reality
  - „anywhere between the extrema of the virtuality continuum”

2. Discussion of fundamental HM/NE display concepts

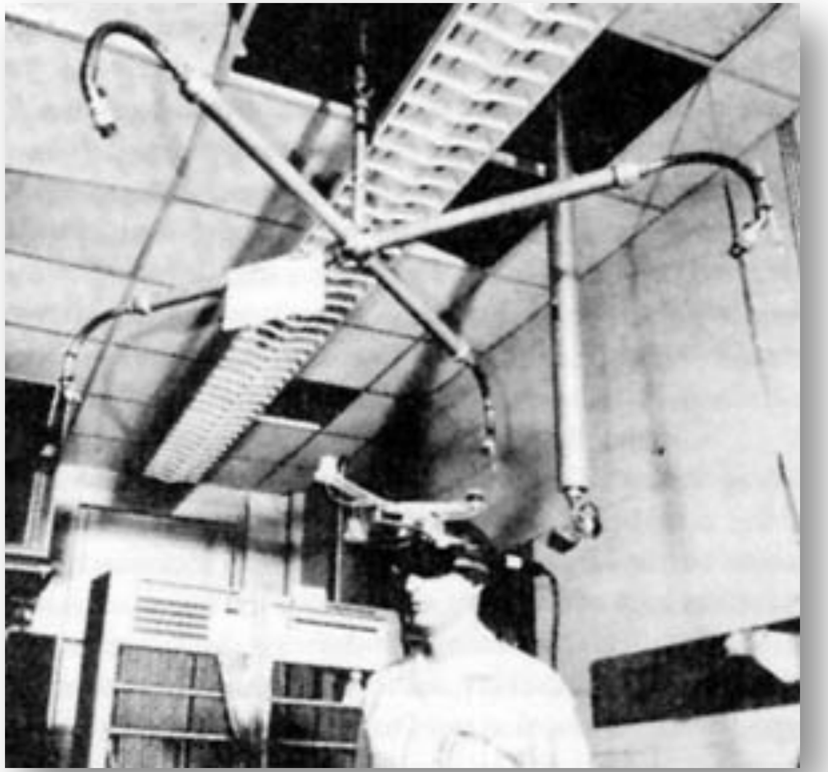
- Optical solutions
  - Semi-transparent mirrors
  - See-through by default
- Display-only solutions
  - Completely blocking the users view
  - See-through possible with cameras

2. Discussion of fundamental HM/NE display concepts

- Display technology
  - State-of-the art displays
  - Evolution of different technologies
    - CRT -> LCD -> OLED
    - Layered panels
    - Microlens arrays
- Rendering
  - Optimization

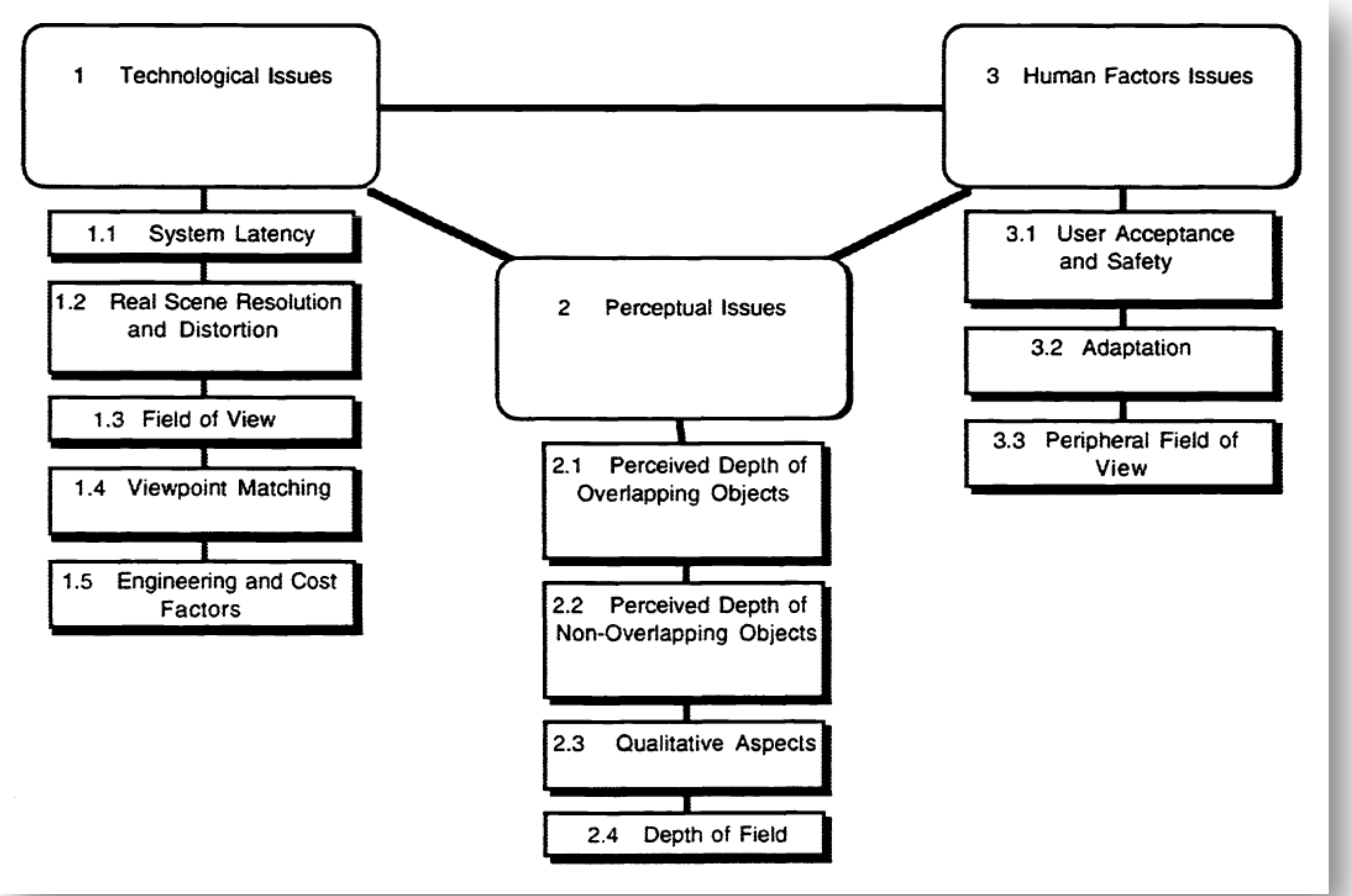
3. Short historical development sampling

- Early Example 1: [Sutherland 1968]
  - AR project via tracked HMD
  - Mirror/prism setup with miniature CRTs
  - HiRes ultrasonic head position sensor
  - Clipping divider for dynamic perspective display



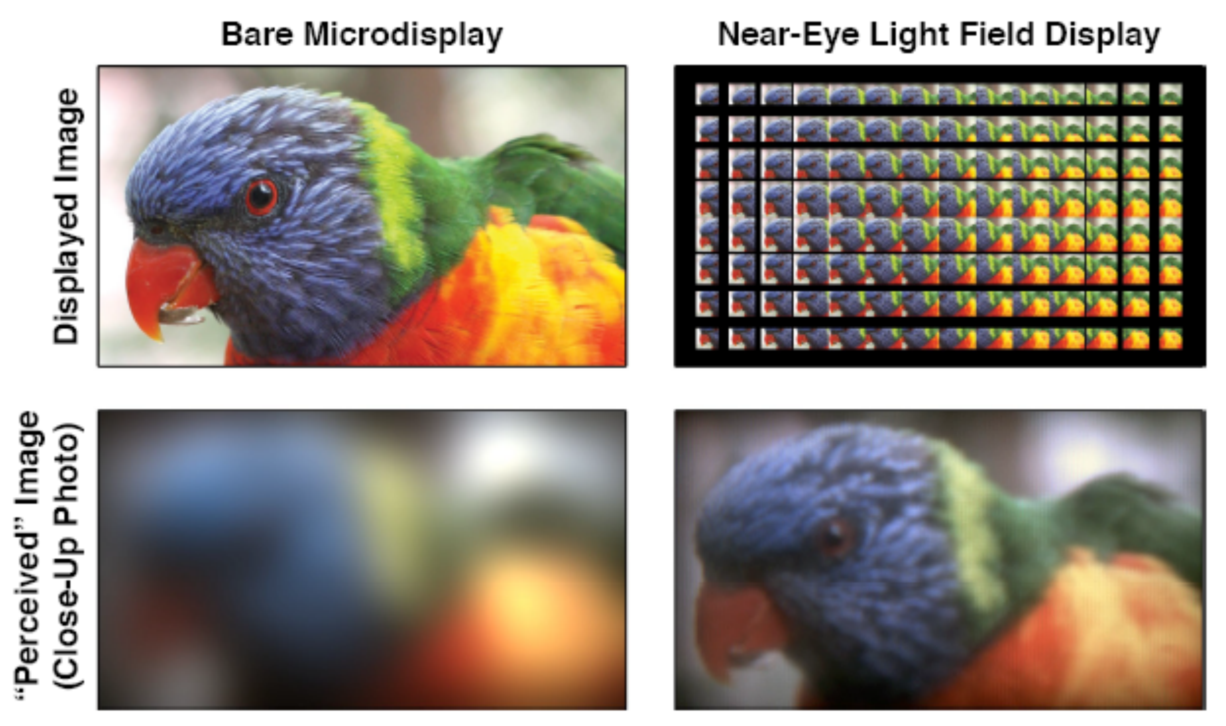
3. Short historical development sampling

- Early Example 2: [Rolland 1994]
  - Comparison of see-through HMDs
  - Excellent baseline of key issues



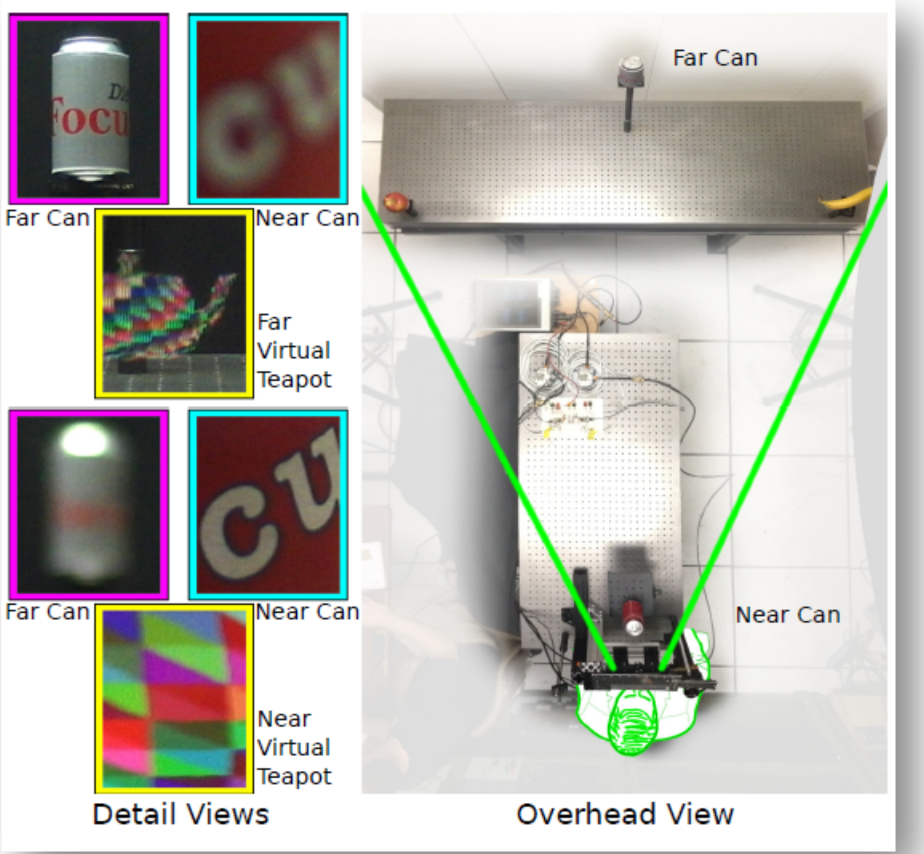
3. Short historical development sampling

- Current Example 1: [Lanman 2013]
  - NE light field display
  - Accurate accommodation, convergence, and binocular disparity depth cues
  - binocular prototype + a GPU-accelerated stereoscopic light field renderer.



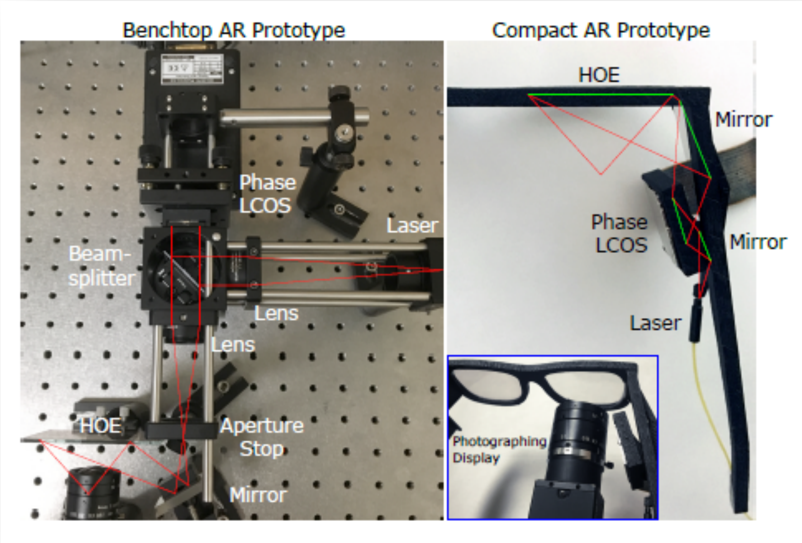
3. Short historical development sampling

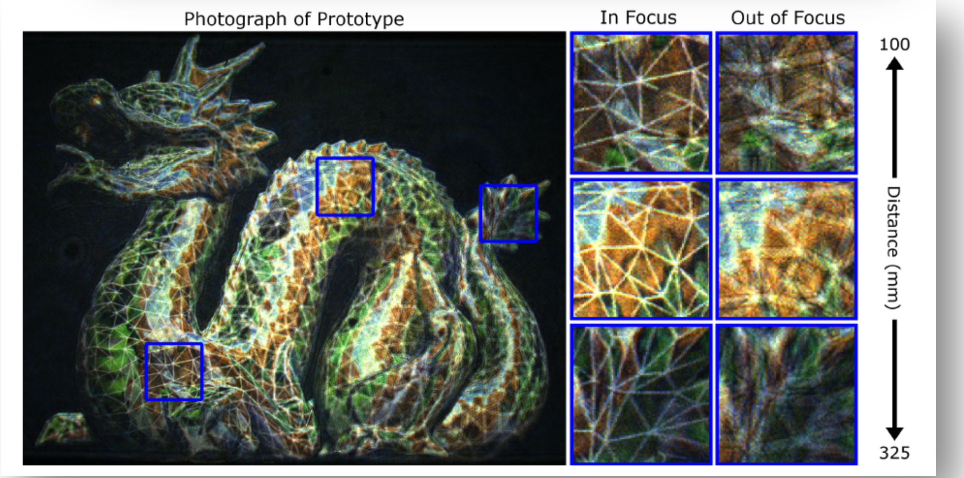
- Current Example 2: [Dunn 2017]
  - Augmented reality use case
  - Single see-through, varifocal deformable membrane mirror for each eye
  - Wide field of view (100° diagonal)
  - Fast depth switching (from 20cm to infinity within 300 ms)



3. Short historical development sampling

- Current Example 3: Maimone 2017
  - AR/VR use case
  - Fresnel holography
  - Double phase amplitude encoding
  - Full color, high contrast and low noise holograms
  - High resolution, true per-pixel focal control
  - Relatively wide field of view (80°)





3. Short historical development sampling

- Current Example 4: Consumer grade hardware
  - E.g. HTC Vive, Oculus Rift, PSVR, Windows MR, etc.
  - Adoption rate driving force for development
  - Affordable / enthusiast cost
  - High hardware demand
  - Resolution (screen door effect)

4. Persisting Challenges in NE/HM Display Development

Challenges	Goals
Missing natural vision features	Accommodative depth cues
Limited periphery	Wide field of view
Screen door effect	High resolution
High computational demand	Optimization
High hardware cost	Commodity solutions

- Problem: Usually a trade-off between different goals

5. Key eye tracking terminology

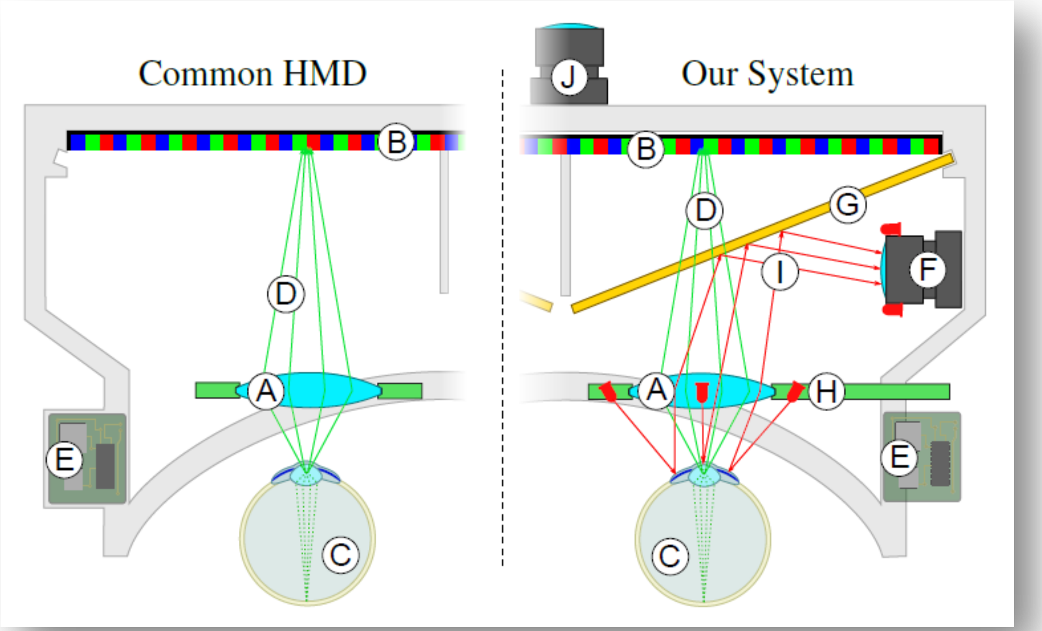
- Technical
  - Eye Tracking Techniques
  - Eye movement / gaze analysis
- Anatomical
  - Visual attention
  - Visual psychophysics
  - Taxonomy of eye movements

5. Key eye tracking terminology

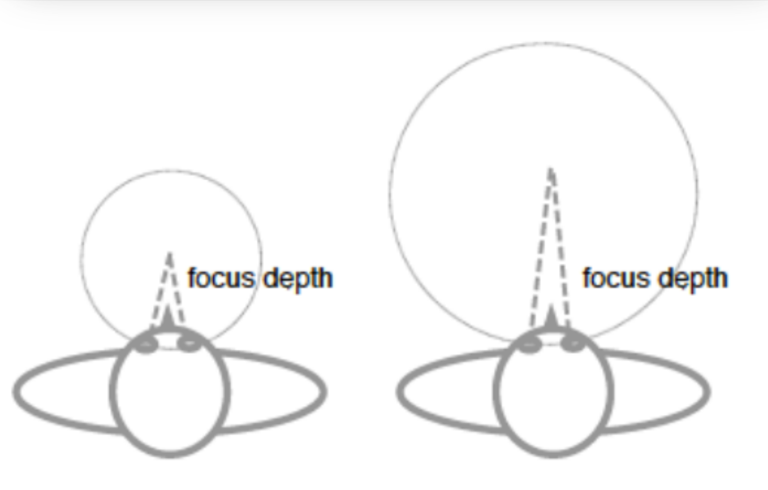
- For NE / HM display applications
  - Eye-gaze vs. eye-pose
  - Detection rate
  - Optical axis vs. visual axis
  - Eye-box / exit pupil
  - Pupil detection methods

6. Discussion of selected papers

- Example 1: [Stengel 2015]
- Contribution
  - Low cost (commodity cameras with dichroic mirrors)
  - Feature tracking approach
- Limitations
  - Interference with eyeglasses
  - Small scale user study and application tests

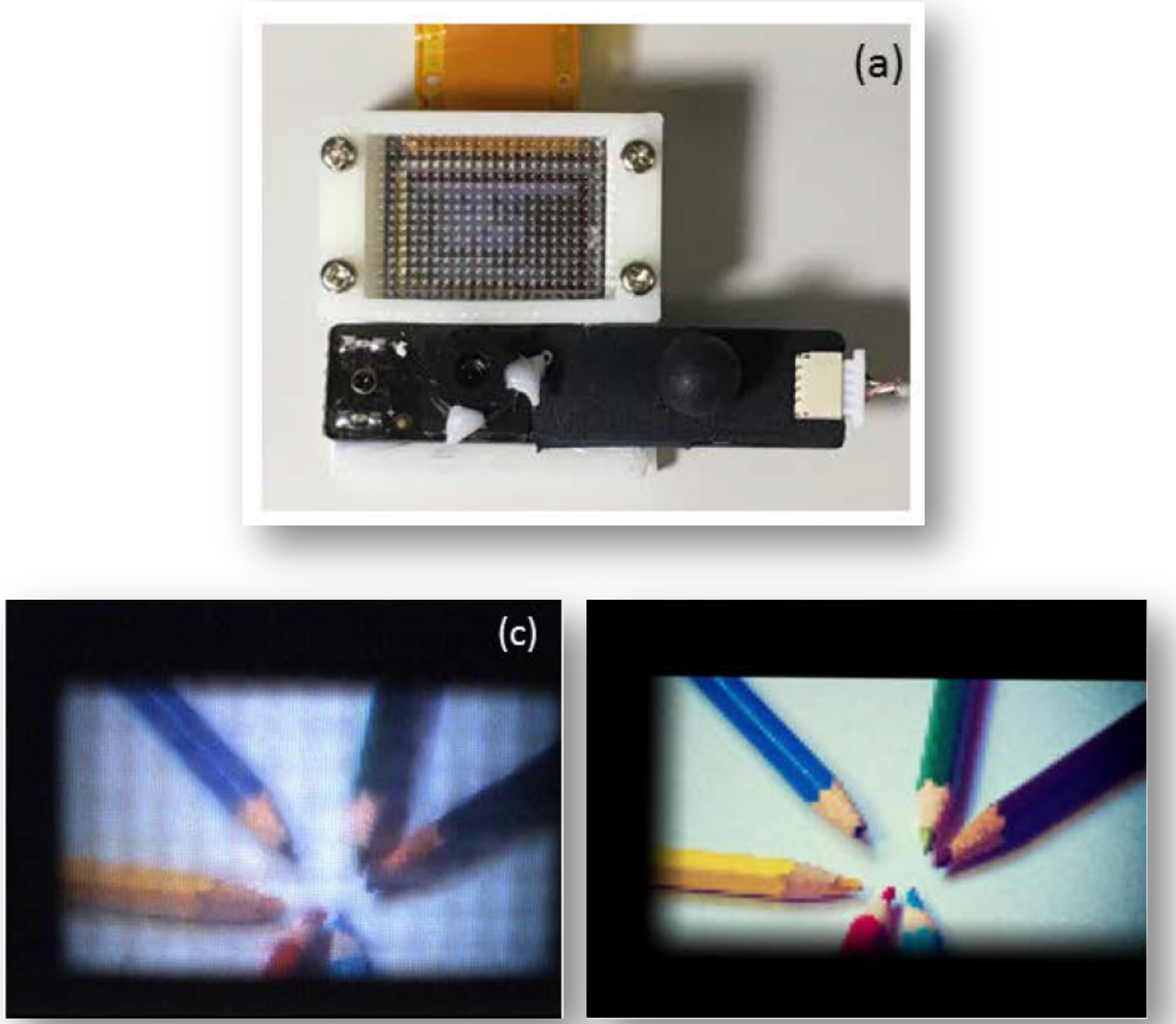


- Example 2: [Pai 2016]
- Contribution
  - Custom hardware
  - Gaze focus depth estimation
- Limitations
  - Limited focus depth accuracy
  - Reduced image quality through cut lenses
  - Limited application tests



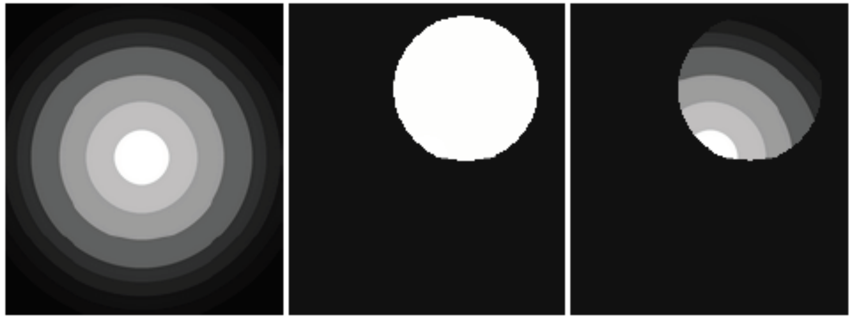
6. Discussion of selected papers

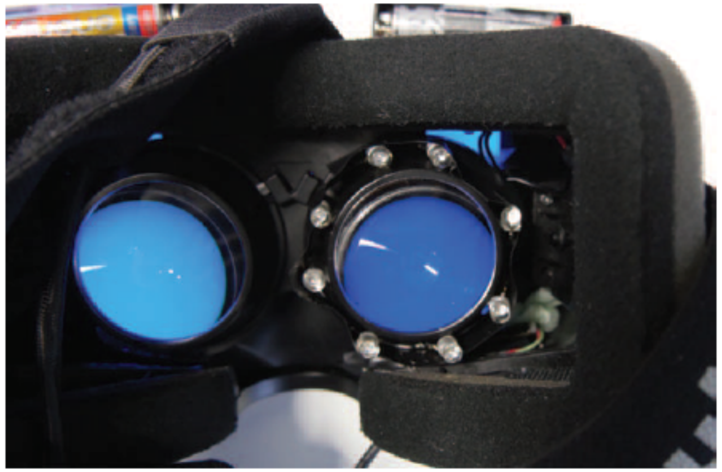
- Example 3: [Plopsky 2016]
- Contribution
  - Microlens display
  - Gaze tracking through eye-pose estimation
  - Accounts for pixels seen though multiple lenses
- Limitations
  - Calibration quick but inaccurate
  - Limited user study



6. Discussion of selected papers

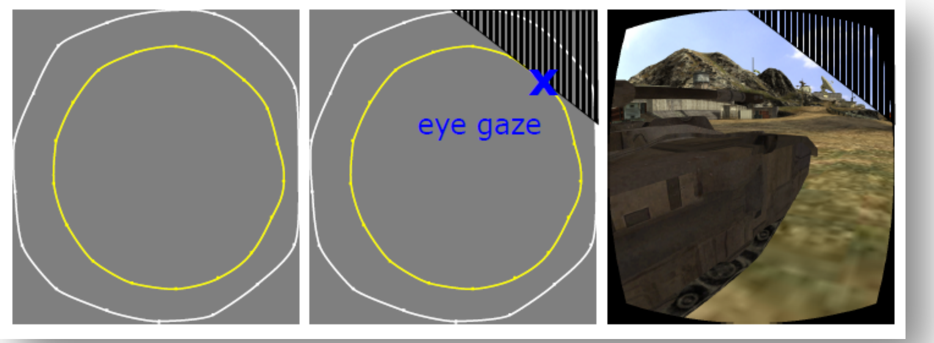
- Example 4: [Pohl 2016a]
- Contribution
  - Off-the-shelf hardware (Oculus DK2 + Pupil Pro)
  - Dynamic sampling map, combined from gaze and lens astigmatism data
- Limitations
  - Custom rendering architecture needed with per pixel supersampling capabilities (does not integrate in OpenGL45 or DX12)

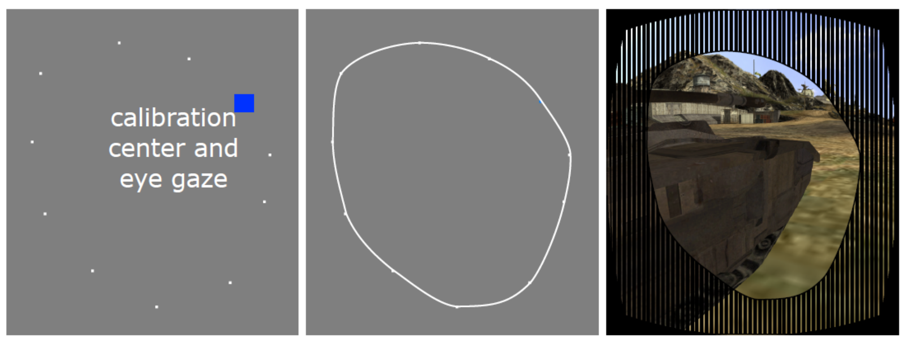




6. Discussion of selected papers

- Example 5: [Pohl 2016b]
- Contribution
  - Same hardware
  - Visual field mapping though extensive calibration
  - No rendering in invisible areas
- Limitations
  - Calibration tedious (lacks generic model)



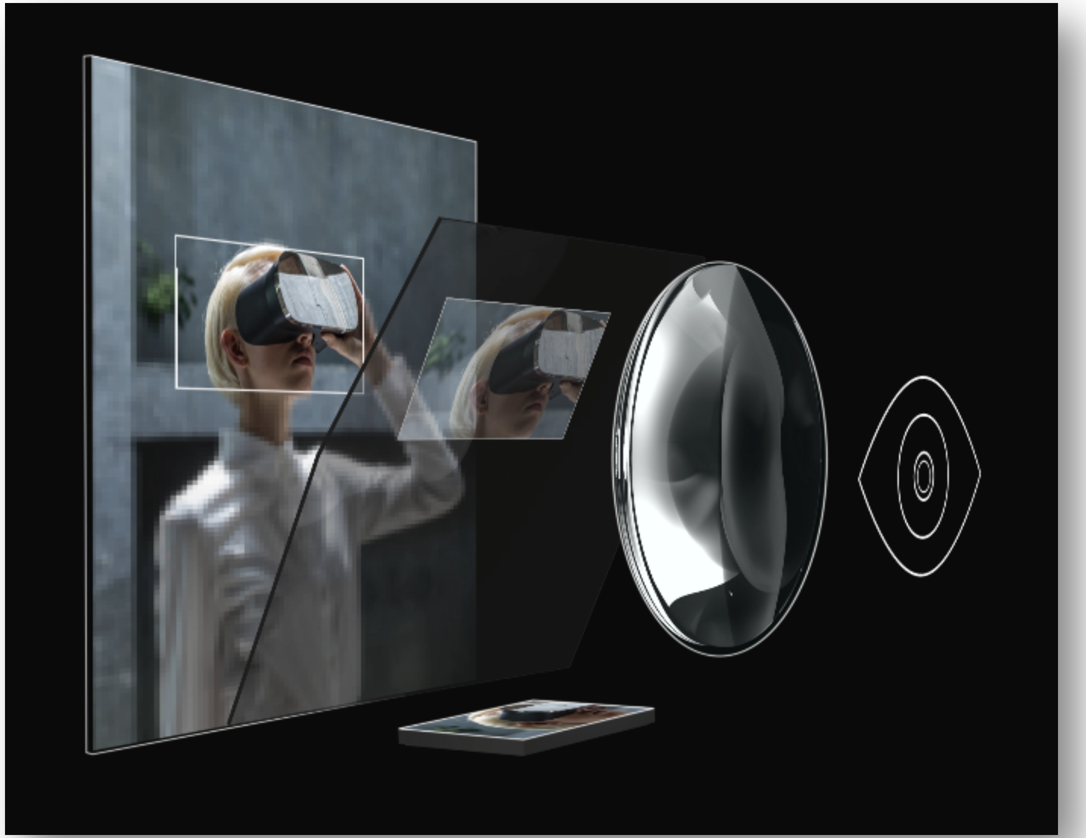


6. Discussion of selected papers

- Example 6: [Patney 2016] (and FOVE)
  - Focus on foveated rendering
  - Rapid, well funded development (NVIDIA/SMI)

6. Discussion of selected papers

- Example 7: Varjo Bionic Display
  - Foveated projection
  - Combining two displays
  - Eye tracking for gaze detections



6. Comparison of Discussed Devices

	Hardware	Cost	From factor	Contribution	Limitations
Lanman 2013	proprietary	high	wearable	accurate depth cues	(limited information)
Maimone 2017	proprietary	high	benchtop/ wearable	HiRes, true per pixel focal control	small eye-box
Dunn 2017	proprietary	high	benchtop	deformable membrane mirror tech.	bulky form factor
Stengel 2015	proprietary	very low	wearable	low cost tracking solution	interference with eyeglasses
Pai 2016	off-the-shelf	low	wearable	gaze focus depth est.	image quality, usability
Plopsky 2016	proprietary	high	wearable	Microlens display with eye-pose estimation	Inaccurate calibration
Pohl 2016a	off-the-shelf	low	wearable	rendering optimization	custom rendering architecture
Pohl 2016b	off-the-shelf	low	wearable	rendering optimization	calibration
Patney 2016/Fove	preproduction/ dev-kit	low	wearable	industry-standard rendering optimization	perceptual vs. optimized approach
Varjo	preproduction/ dev-kit	mid	wearable	foveated projections	(limited information)

7. Conclusion

Persisting challenges in HM/NE display development

- Display resolution needs to increase to retina resolution level
- More natural depth cues needed for higher fidelity
- Increased computational cost
- Eye tracking data highly valuable

Issues

- Tracking hardware and software need integration
- Detection reliability
- Calibration, generic model

Thank You for your Attention!

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