25/May/2023

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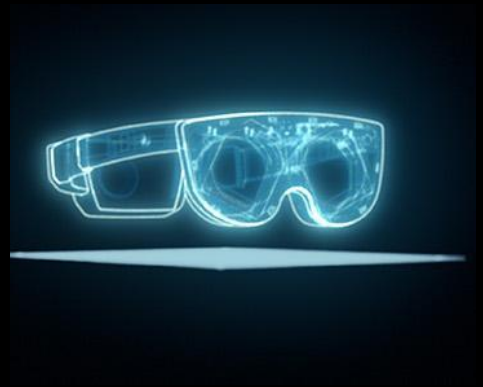
Achieving the Visual Turing Test: Integrated Display and Eye Tracking Technologies



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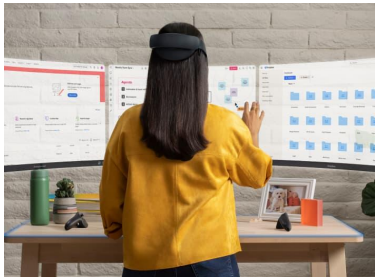
Introduction

With AR and VR displays, we aim to deliver visual experiences that are indistinguishable from reality - a bar we call the Visual Turing Test. This sets a high bar for the technology that is being used to deliver the photons to the user's eyes.



To meet this bar, we will have to ensure the efficient use of generated display photons and image rendering compute. This means that the eye tracking and light delivery will have to converge into a seamless single system.

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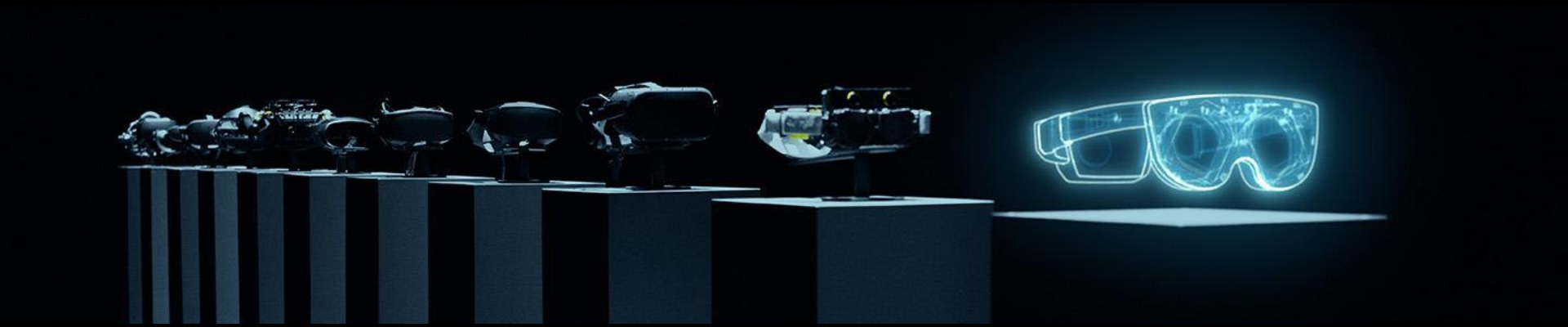


Visual Turing test and AR/VR

Visual Turing Test:

The Holy Grail of Display Research

1

Resolution: The device must have a display that not appear to have lower resolution than human eye can perceive, ensuring sharp and detailed visuals.

2

Eye State Accommodation: The device should account for a standard range of eye adjustments and movements, providing a comfortable and natural viewing experience.

3

Prescription Correction : The interface optics must either correct for or be compatible with prescription corrections, allowing users with different visual acuities to experience the virtual environment accurately.

4

Dynamic Range: The device must have a high dynamic range, enabling it to display a wide range of colors, tones, and contrasts to mimic real-life environments accurately.

5

Peak Brightness: The system should meet the levels of peak brightness experienced in real life, both indoors and outdoors, ensuring realistic lighting conditions and visual experiences.

6

Field of view: A wide field of view is essential for creating immersive virtual experiences that closely resemble reality. The device must provide a broad field of view, covering the user's natural range of vision, to enable a truly realistic and engaging experience.

Unlocking AR/VR Potential: High-Performance Displays and Eye Tracking

Achieving high-performance displays and eye tracking systems in AR/VR wearable devices is important to revolutionizing various aspects of our lives, such as entertainment, education, training, and communication. These advances enable realistic, life-like virtual environments, and accommodate users with different vision needs, paving the way for future innovations.

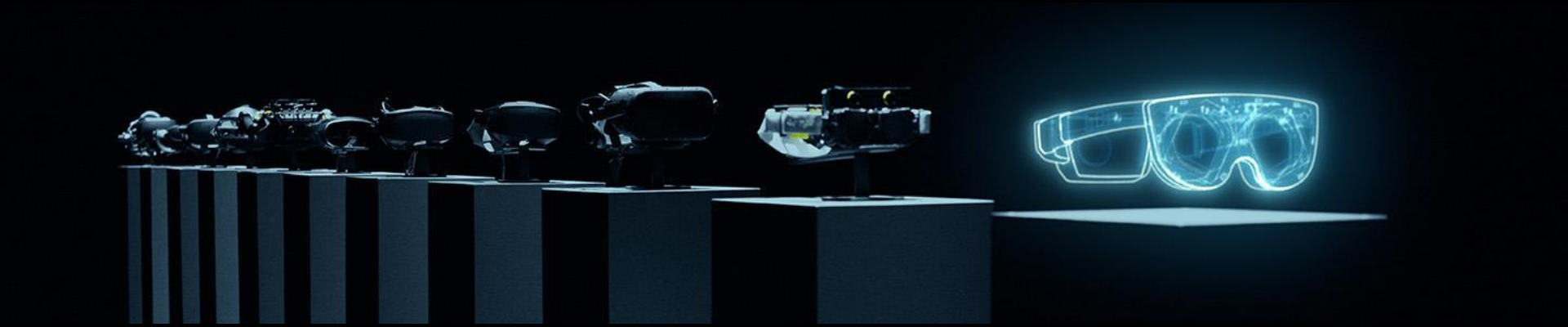
- Revolutionizing entertainment, education, training, and communication
- Creating realistic and life-like virtual environments
- Accommodating users with different vision needs
- Enhancing interactivity with accurate eye tracking
- Supporting future innovations in AR/VR technology

Seamless Integration: Display and Eye Tracking in AR/VR

Integrating display and eye tracking technologies as two dependant architectural elements in AR/VR devices is important for achieving the Visual Turing Test and unlocking the full potential of immersive experiences, enabling efficient use of resources, better trade-offs, and enhanced interactivity.

- Helps achieving the Visual Turing Test
- Efficient use of display photons and image rendering compute
- Better trade-offs between performance and system complexity
- Enhanced interactivity through accurate eye-based interactions
- Important for unlocking the full potential of AR/VR experiences

02 AR/VR displays

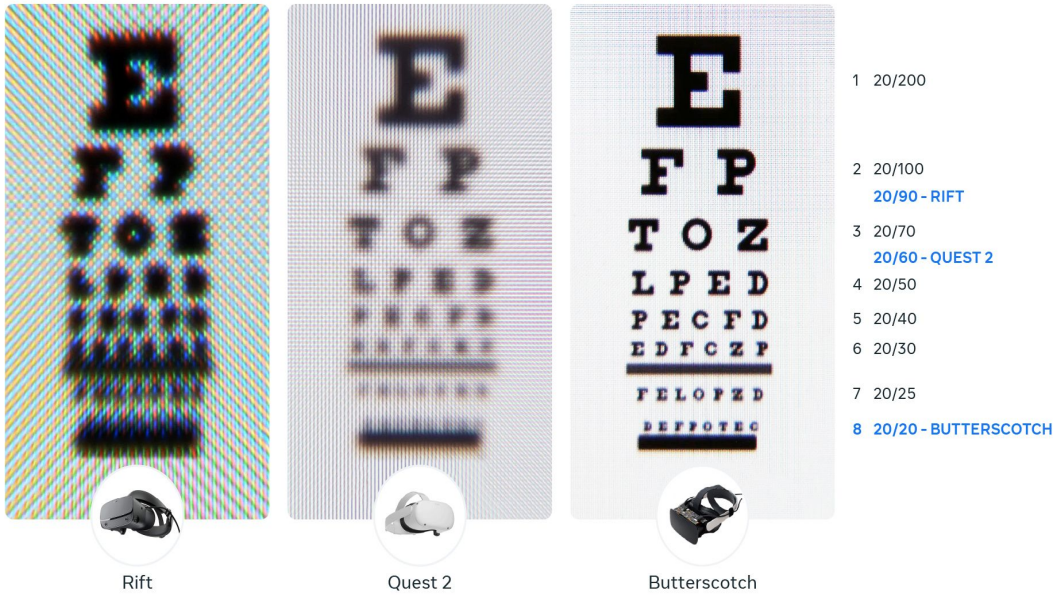


Key performance characteristics

Resolution

High-resolution displays helps to achieve realistic visuals in AR/VR devices, closely resembling reality, and maintaining user immersion.

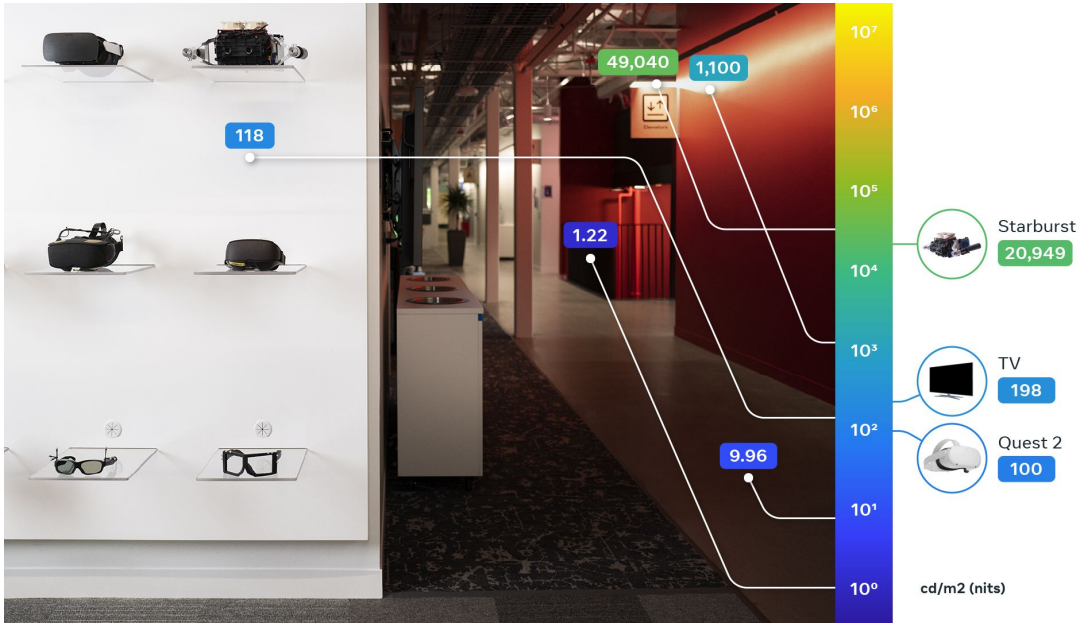
- Essential for realistic visuals
- Match human eye resolution
- Challenges: pixel density, display technologies, and power consumption



Peak brightness and dynamic range

High-resolution displays are important for achieving realistic visuals in AR/VR devices, closely resembling reality, and maintaining user immersion.

- Essential for realistic visuals
- Match human eye resolution
- Challenges: pixel density, MTF, inherent contrast limit, and power consumption



Eye accommodation and prescription correction

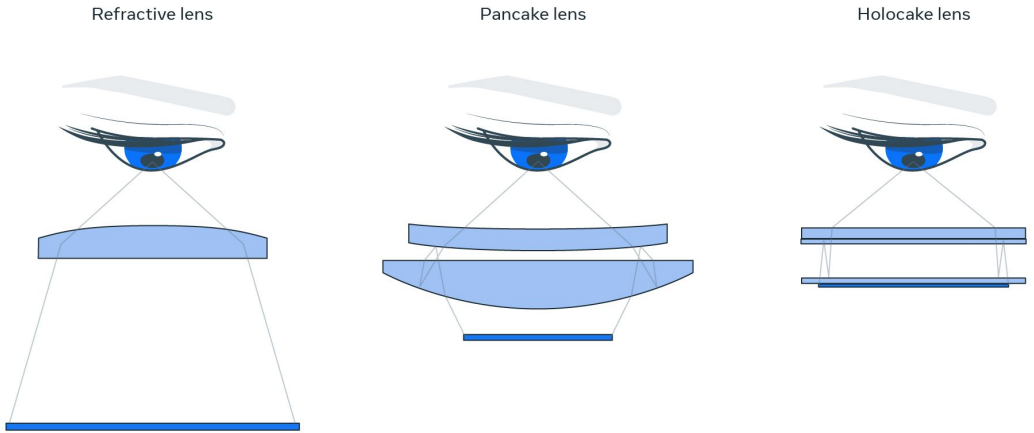
Eye accommodation and prescription correction compatibility in AR/VR displays ensure a comfortable and natural viewing experience while accommodating users with varying visual acuities.

- Comfortable and natural viewing experience
- Accommodating different viewing distances and eye movements
- Adaptive optics, light field displays or holographic displays for eye accommodation
- Adjustable optics, modular lens attachments, and solutions for prescription correction
- Enhancing accessibility and enjoyment for all users

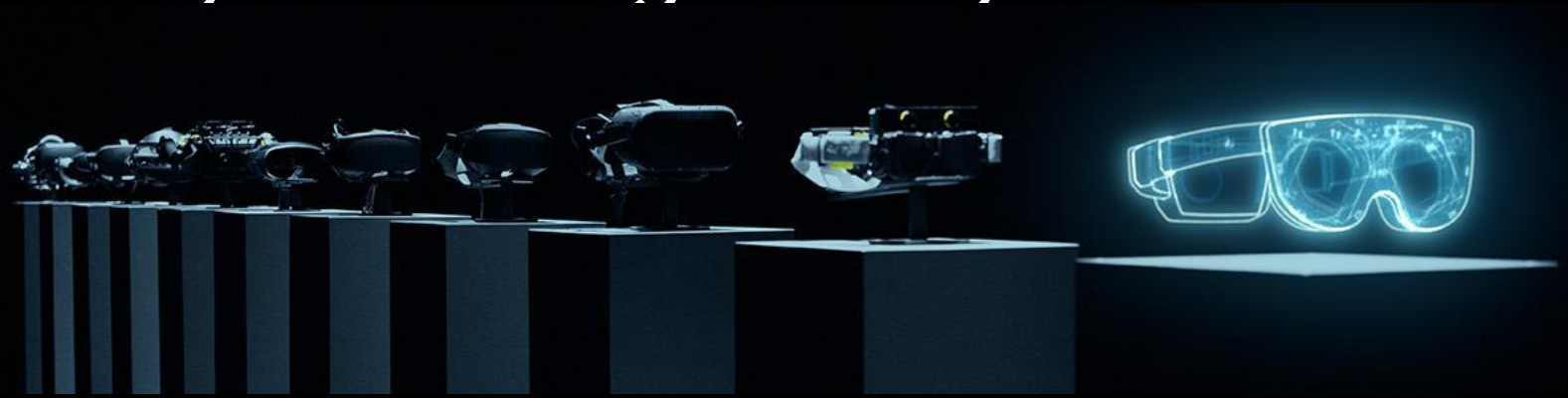
Eyebox and complexity of interface optics

An optimal eyebox in AR/VR displays ensures a comfortable and natural viewing experience, but it also increases system complexity and display technology requirements.

- Comfortable viewing experience with a wide range of eye positions
- Advanced optical design and calibration for larger eyeboxes
- Increased system complexity with larger eyeboxes (size, weight, power consumption)
- Product complexity. Per-user fit by optometrist vs. small number of versions.
- Sophisticated eye tracking for real-time adaptation
- Advanced display technologies (microLED, OLED) for higher resolution and brightness
- Balancing performance and system constraints through ongoing research and development



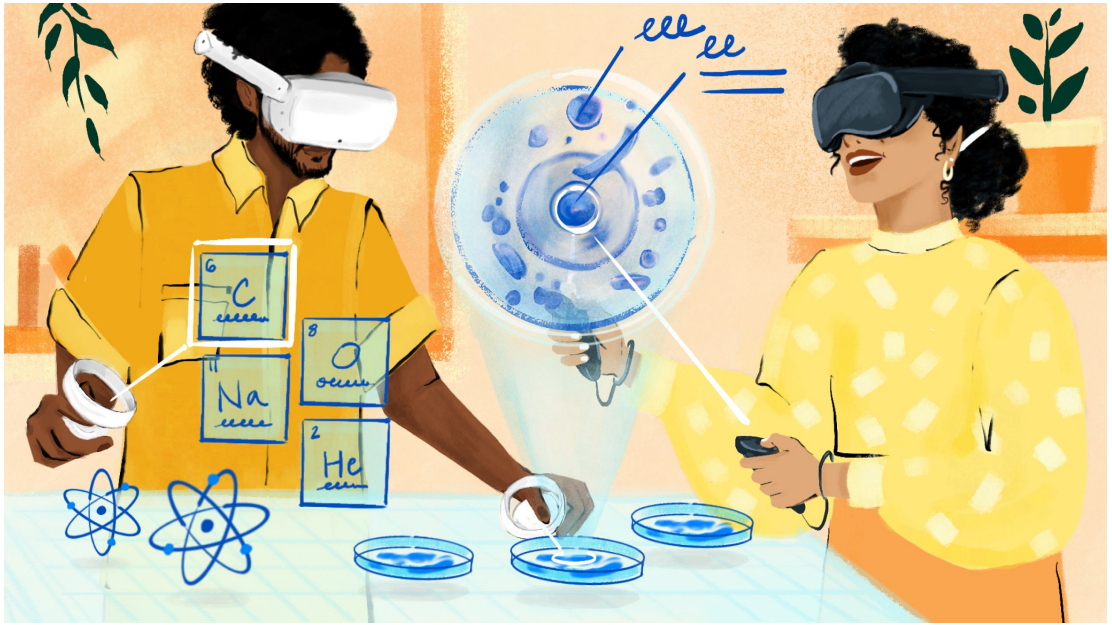
03 Challenges of integrating display and eye tracking sub-systems



Global vs. local solutions

Global vs. local solutions in integrating display and eye tracking sub-systems, with local solutions providing a more efficient and practical approach for wearable AR/VR devices.

- Global solutions: computationally expensive, impractical for wearable devices
- Local solutions: focus on user's current eye state, reduced complexity and resource demands
- More efficient use of computational resources, display photons, and image rendering compute
- Advanced algorithms, real-time eye tracking, and adaptive optics
- Challenges in hardware design and software optimization for seamless integration
- Improved performance, reduced power consumption, and comfortable user experiences with local solutions



Necessity for continuous knowledge of eye conditions

Continuous knowledge of eye conditions is useful for integrating display and eye tracking sub-systems for maintaining realistic visuals and a comfortable viewing experience in AR/VR devices.

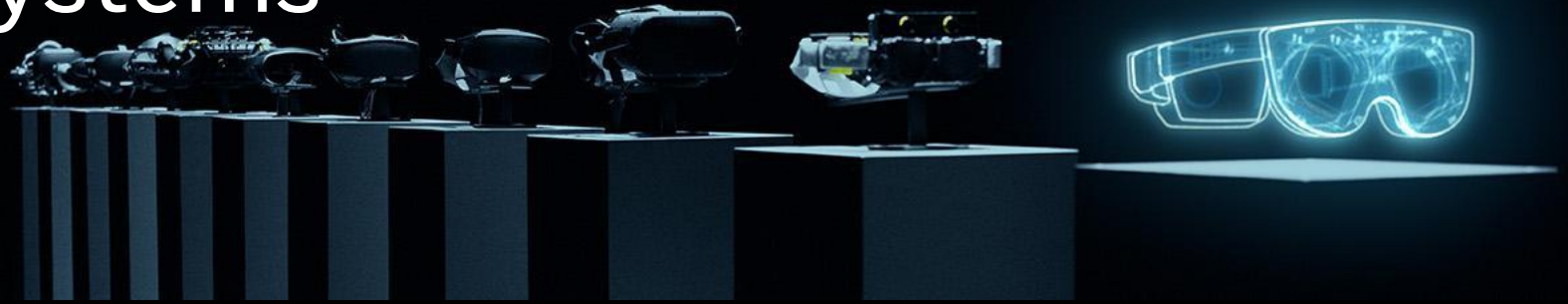
- Eye states change constantly during interactions
- Advanced eye tracking technologies required
- Real-time monitoring of gaze direction, pupil size.
- Overcoming technical hurdles and seamless integration

The need for anticipating optical performance under varying conditions

Anticipating optical performance under varying conditions is important for maintaining a consistent and comfortable visual experience in AR/VR devices with integrated display and eye tracking sub-systems.

- Consistent visual experience under varying conditions
- Adaptive algorithms and systems for prediction and adjustment
- Continuous monitoring of eye conditions and environmental factors
- Real-time adjustments to display parameters
- Sophisticated integration and ongoing research in adaptive optics and algorithms

04 Benefits of early integration and co-design of display and eye tracking systems



Trade-offs between performance and system complexity

Early integration and co-design of display and eye tracking systems enable informed trade-offs between performance and system complexity, leading to more efficient and user-centric AR/VR devices.

- Identify areas of overlap and synergy
- Minimize redundancies and optimize resource allocation
- Reduce system complexity for more comfortable wearable devices
- Innovative solutions addressing challenges of both subsystems
- Example: High-resolution visuals focused on user's gaze, lower-resolution visuals for peripheral areas
- Example: Eye tracking for dynamic accommodation and prescription correction
- Streamlined design process and user-centric devices

Power management and system efficiency

Improved power management and system efficiency are achieved through early integration and co-design of display and eye tracking systems in AR/VR devices.

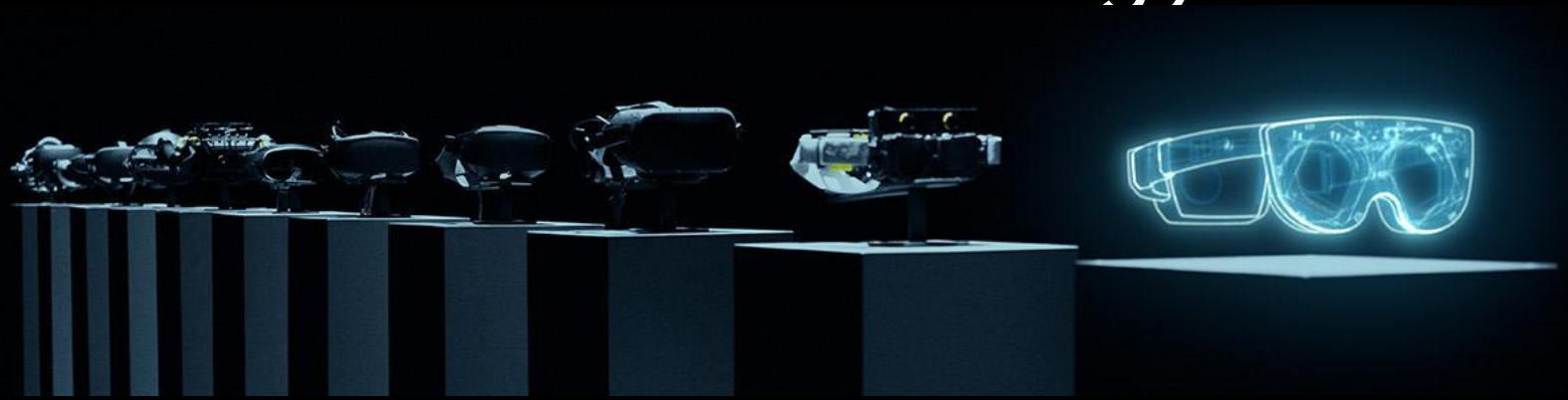
- Optimize power usage and battery life
- Efficient use of resources and reduced power consumption
- Render and process relevant visual information based on user's gaze
- Smart power management strategies
- Dynamically adjust system settings based on user behavior and environment

Improved user experience and immersion

Improved user experience and immersion are achieved through early integration and co-design of display and eye tracking systems in AR/VR devices.

- Accurate response to user's eye movements, gaze direction, and focus
- Natural and realistic visual experience
- Enhanced depth perception, image clarity, and realism
- Increased sense of presence and overall immersion
- Address user-specific needs for a comfortable and accessible experience

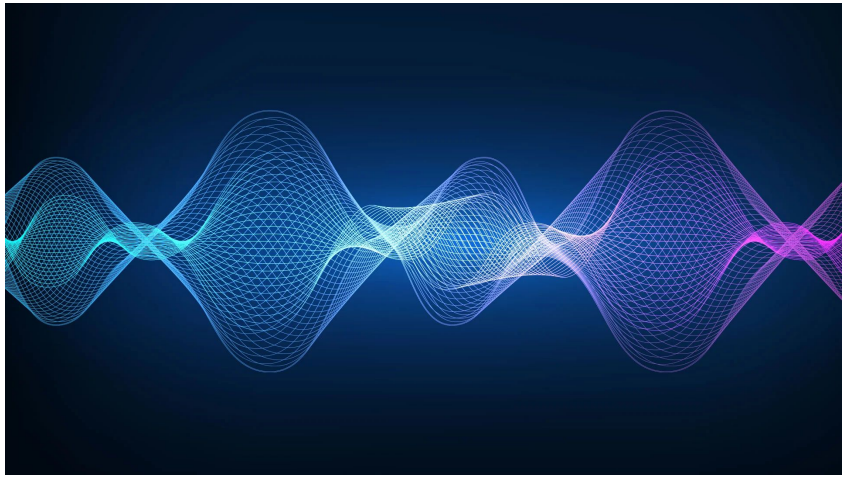
05 Optimizations and state-of-the-art technology



Overview of the Optimization Space

Overview of the optimization space for integrating display and eye tracking systems in AR/VR devices, focusing on factors such as resolution, dynamic range, eye accommodation, and eye tracking accuracy.

- Display resolution, dynamic range, eye accommodation, prescription correction
- Eye tracking accuracy
- Power management and system efficiency
- Overall device complexity
- Balancing performance and system complexity
- Interdependencies and potential areas of improvement



Current state-of-the-art and emerging display technologies

Current state-of-the-art display technologies, including MicroLED displays, foveated rendering, and light field displays, have the potential to significantly enhance the performance and user experience of AR/VR devices.

- MicroLED displays: high resolution, color accuracy, fast refresh rates, energy efficiency, HDR capability
- Foveated rendering: reduced computational resources and power consumption
- Light field displays: realistic depth cues, natural and comfortable viewing experience
- Integration with eye tracking systems

Advances in Eye Tracking Technology

Advancements in eye tracking technology, including pupil detection algorithms, machine learning, and miniaturized hardware components, contribute to the optimization and improvement of AR/VR devices.

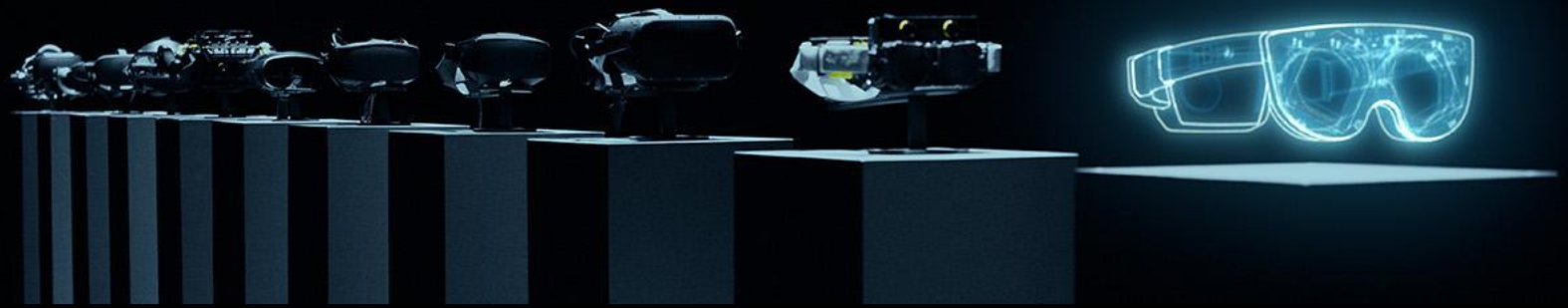
- Pupil detection algorithms: accurate and fast gaze direction determination
- Machine learning: adaptive and improving eye tracking performance
- Eye tracking hardware: miniaturized, low-power components
- Integration with state-of-the-art display technologies

Example of Successful Integration in AR/VR

The Meta Quest Pro exemplifies the successful integration of state-of-the-art display and eye tracking technologies in an AR/VR device, demonstrating improved performance, user experience, and immersion.

- High-resolution, fast-switching display for immersive visuals
- Advanced eye tracking for gaze-based interaction, dynamic image rendering, and guided IPD adjustment
- Face tracking for expressive and lifelike avatars in social VR experiences
- Foveated rendering for optimized graphics rendering and reduced power consumption
- Improved performance, user experience, and immersion in AR/VR devices

06 Future directions and convergence of display and eye tracking systems



The need for seamless single system integration

The importance of integrating display and eye tracking systems into a seamless single system for better form-factor, improved efficiency, performance, and user experience.

- Streamlined hardware and software components
- Improved trade-offs between performance, power consumption, and system complexity
- Enhanced optimization for various use cases and applications

Potential impact on display photon efficiency and image rendering compute

The impact of seamless integration on display photon efficiency and image rendering compute, leading to more efficient energy consumption and improved image quality.

- Foveated rendering: reduced computational power and improved energy efficiency
- Precise and efficient use of generated display photons
- Higher image quality and more accurate representation of real-world environments

Emerging Technologies and Research Areas

Emerging technologies and research areas that can advance the convergence of display and eye tracking systems, leading to improved performance and user experience.

- Machine learning and AI for improved eye tracking accuracy and adaptiveness
- Advanced display technologies: MicroLED, OLED, etc.
- Novel light delivery methods: light field displays, holography
- Potential for a single, efficient, and high-performing system

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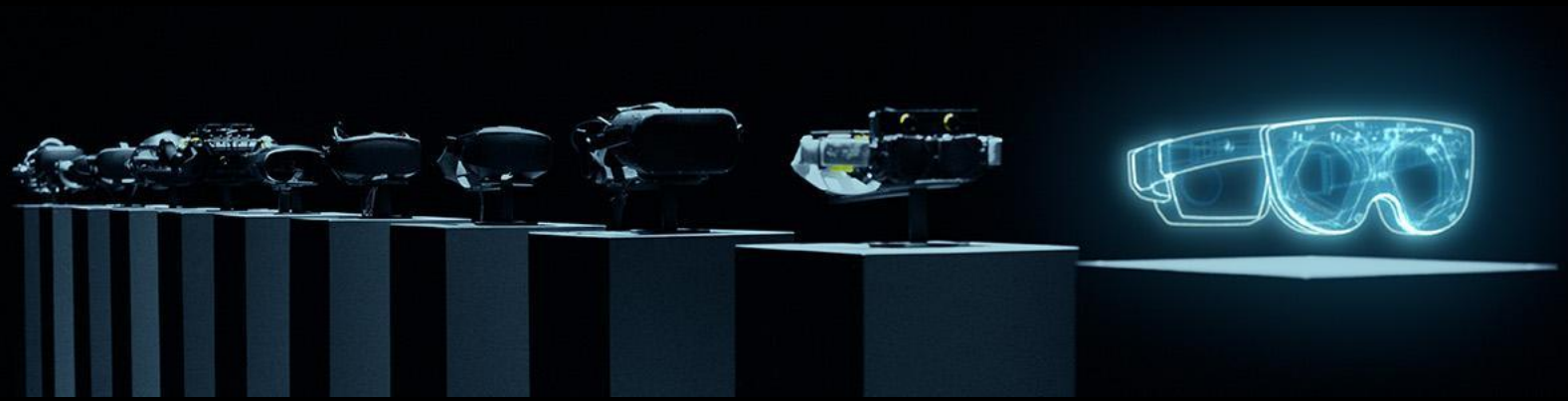
06 Conclusion



Conclusion

The seamless convergence of display and eye tracking systems holds immense potential for improved performance, user experience, and broader applications in various industries. As we continue to explore emerging technologies and research areas, we can advance the development of AR/VR devices that are more efficient, immersive, and versatile.

- Importance of co-designing display and eye tracking systems
- Balancing performance, complexity, and power management
- Unlocking potential for enhanced performance and user experience
- Exploring emerging technologies and research areas
- Revolutionizing interaction with the digital world

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Thank you.