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Smart Glasses for Safety and Hazard Awareness: A Review of Context-Aware Assistive Systems in Safety-Critical Environments

Pratishtha Srivastava

World University of Design

Abstract - Global estimates indicate that approximately 285 million individuals live with visual impairments, confronting severe barriers to independent mobility in complex urban environments [1]. This navigation gap is most pronounced in high-traffic transit hubs; the Indian Railway system, for instance, manages over 23 million daily passengers [12] and an annual volume exceeding 8.6 billion [12], yet its navigational infrastructure remains largely inaccessible to the visually impaired. This paper provides a systematic review of the field, employing the PRISMA methodology to synthesize findings from 60 relevant articles published between 2015 and 2025 [2]. Our primary objective is to define the technical and design requirements necessary to bridge the "Information-Safety Gap" in safety-critical hubs. By shifting from basic "Assisted Seeing" to a paradigm of "Managed Reaction," we evaluate how Augmented Reality (AR) smart glasses—integrated with context-aware sensors and conversational User Experience (UX)—can transform hazardous environments into navigable spaces.

Keywords: Smart glasses, Visually impaired, Wayfinding, PRISMA, Augmented Reality, UX Design Standards, Indian Railways.

Introduction

Existing assistive infrastructure in high-traffic environments often falls victim to the "Information-Safety Gap," where the tools intended to aid navigation instead contribute to cognitive overload. At the Delhi Metro Rail Corporation (DMRC), for example, the convergence of multiple color-coded footprint stickers intended for wayfinding often creates a state of visual clutter that hinders orientation for sighted and visually impaired users alike [12, 17].

Addressing this requires a theoretical shift from "Assisted Seeing"—the passive identification of obstacles—to "Managed Reaction." In this framework, the system does not merely report data; it uses AI to decipher environmental clutter and present a filtered "Safety Overlay." This transition is best understood through the "Reality-Virtuality Continuum" [2], which positions AR as a critical tool for maintaining the user's proximity to the physical world while providing digital safety triggers in real time. Unlike Virtual Reality, which isolates the user, AR preserves situational awareness while managing the user's reaction to potential hazards through prioritized feedback.

Methods

This review utilized a systematic search strategy to identify the engineering constraints and UX benchmarks of AR-based assistive systems.

- Search Strategy: We conducted comprehensive searches across IEEE Xplore, ScienceDirect, and Google Scholar for studies published between 2015 and 2025 [2].
- Inclusion Criteria: The selection focused on AR applications within safety-critical contexts, open-access studies, and papers providing rigorous technical performance evaluations [2].
- PICOS Approach: To ensure scientific rigor, we constructed research questions using the PICOS (People, Intervention, Comparison, Outcome, and Study Design) framework [2], comparing AR-enhanced navigation against traditional mobility aids.

Technical Analysis: Performance Metrics and Navigation Efficacy

The efficacy of assistive smart glasses is governed by the intersection of sensor throughput and computational latency.

Latency and Performance

HCI benchmarks reveal that complex AR serious games often experience a 32% drop in Frames Per Second (FPS) [2]. Research indicates this performance degradation is frequently linked to the high computational overhead of peripheral feedback systems, such as the 14-actuator vibrotactile jackets used for immersive haptic warnings [66]. In safety-critical environments, such latency can delay collision alerts beyond the user's reaction threshold.

Proximity Safety and Scanning

Hardware prototypes leverage ultrasonic sensors capable of scanning a 10-meter radius to provide early hazard detection [1]. However, safety-critical performance is defined by the "critical zone"—a 1-meter radius around the user where immediate intervention is required [1]. Furthermore, safety-critical systems must integrate GSM and GPS modules to provide a fail-safe; in the event of a fall or disorientation, the system can automatically transmit exact coordinates to caregivers via emergency SMS [1].

Navigation Efficacy

Meta-analyses demonstrate that AR technology provides a significantly higher effectiveness for navigation compared to traditional tools. The wayfinding Standardized Mean Difference (SMD) for AR is 0.992, vastly outperforming driving navigation (0.246) and the development of general spatial knowledge (0.274) [11].

Table 1*. Hardware Comparison: Navatia Shipyard Benchmarks*

Hardware Type	Obstacle Detection Accuracy	Latency Impact	Ergonomic Suitability	Lighting Sensitivity
Smartphones	High	Moderate	Low(hand-held)	Moderate
Tablets	High	Moderate	Very low	Moderate
Smart Glasses	Moderate-high	High	High(Hands free)	High(Marker Failure

Note: Marker-based tracking systems (e.g., those using ARToolKit) in smart glasses often fail under the fluctuating lighting conditions typical of industrial or transit environments [32].

The SCDF Framework: Three Rules for Safety-Critical Design

To govern the behavior of assistive systems, we propose the Safety-Critical Design Framework (SCDF), codified into three primary technical rules:

- Rule 1: 1-Meter Lockdown: When integrated sensors (Ultrasonic or LiDAR) detect an object within the 1-meter "critical zone," the system must enter a "Lockdown" state. This suppresses non-essential navigation data to deliver an exclusive, high-priority collision alert and, if programmed, triggers the GSM emergency SMS protocol [1].
- Rule 2: Environmental Decibel Triggering: Assistive systems must be environment-adaptive. In high-noise environments, auditory buzzers become ineffective; the system must automatically shift its feedback modality to haptic vibrations to ensure the user perceives hazard warnings [1, 2].
- Rule 3: Latency Buffer: To mitigate the 32% rendering delay observed in complex environments, systems should utilize frameworks such as Vuforia or ARToolKit in conjunction with cloudlets or fog computing [2, 33]. Localizing processing power reduces the delay in projecting digital safety overlays onto the user’s real-world foveal view.

Recommendations

Strategic development must move beyond standalone prototypes toward integrated ecosystem solutions.

- IoT and Contextual Extraction: Future systems should utilize Bluetooth to pair smart glasses with station-wide IoT sensors. This facilitates the "Adi" voice bot concept, where the system extracts ticket data (platform number, coach location) automatically, allowing for "zero-input" navigation [12].
- Overcoming Training Barriers: Current research highlights that the complexity of AR systems remains a significant barrier to adoption in educational and professional contexts [2]. Practitioners must prioritize intuitive, conversational interfaces to reduce the training burden for the 285 million potential visually impaired users.

Conclusion

While Augmented Reality is currently in an "immature stage" regarding hardware ergonomics and lighting sensitivity [2], the synthesis of SCDF rules and conversational UX offers a viable path forward. By leveraging a high wayfinding efficacy (SMD 0.992) and filtering the visual clutter found in hubs like the Indian Railways, AR smart glasses can transform safety-critical environments into navigable, inclusive spaces for the visually impaired.

Tips for Usability Practitioners

- Environment-Adaptive Modality: Always implement haptic/vibration motors as a fail-safe. In high-decibel environments, auditory alerts are insufficient for hazard awareness [1, 2].
- Foveal Transparency and the "Phantom Edge": Digital overlays must not occlude the "phantom edge"—the critical boundaries, such as platform edges or stair risers, that the user must perceive to avoid falls [2, 51].

Hands-Free Prioritization: In high-traffic railway hubs, users must often carry luggage or utilize mobility aids. System interaction must rely on voice commands and gesture recognition to ensure hands-free stability [12].

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References

[1] Dr. Suvarna Nandyal. "Smart Glasses for Visually Impaired Person." Zenodo (CERN), 2023.

[2] "Applications Analyses, Challenges and Development of Augmented Reality in Education, Industry, Marketing, Medicine, and Entertainment." Applied Sciences, MDPI, 2023.

[3] Siu Shing Man, et al. "Effectiveness of augmented reality technology in improving navigation performance: a systematic review and meta-analysis." Ergonomics, 2025.

[4] Shweta Srivastava, et al. "Application of Conversational UX for Navigation at Indian Railway Stations." HCII, 2024.

[6] Blanco-Novoa, Ó., et al. "A Practical Evaluation of Commercial Industrial Augmented Reality Systems in an Industry 4.0 Shipyard." IEEE Access, 2018.

[7] Fraga-Lamas, P., et al. "A Review on Industrial Augmented Reality Systems for the Industry 4.0 Shipyard." IEEE Access, 2018.

[8] Gierwiało, R., et al. "Medical Augmented-Reality Visualizer for Surgical Training." Applied Sciences, 2019.

[9] Zhu, L., et al. "Development of Augmented Reality Serious Games with a Vibrotactile Feedback Jacket." Virtual Reality & Intelligent Hardware, 2020