“But People Move Things Around”: Augmented Reality for Wayfinding in Dynamic and Social Environments

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Abstract

The emergence of mobile Augmented Reality (AR) frameworks such as ARKit and ARCore has transformed AR into an accessible platform for assistive technologies. For individuals with visual impairments (VI), AR offers new possibilities for navigation by augmenting spatial understanding through multimodal feedback. However, existing systems often prioritize technical performance while overlooking social and contextual factors, limiting real-world adoption. This paper presents a collaborative mobile AR system designed to support indoor navigation for blind users. Sighted users can author navigable paths using spatial anchors, which are later conveyed through spatialized audio cues. The system also integrates LiDAR-based obstacle detection to enhance safety and situational awareness. I further address challenges posed by dynamic environments and propose a community-driven approach in which spatial information is continuously updated, enabling more adaptive and socially grounded navigation experiences.

Keywords

Augmented Reality, Visual Impairment, Accessibility, Inclusive Design, Collaborative Work

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1 Introduction

The landscape of Augmented Reality (AR) underwent a significant shift in 2017 and 2018 with the release of ARKit and ARCore [10]. These frameworks transitioned AR from a niche technology requiring specialized, high-cost Head-Mounted Displays (HMDs) to a ubiquitous tool available on standard consumer hardware. This proliferation of AR via mobile platforms has broadened its application across numerous sectors, including education, retail, and, most crucially, assistive technology. Mobile AR is particularly compelling for inclusive design because it leverages the smartphone, a device already deeply integrated into the daily lives of global users [2]. For individuals with disabilities, the familiarity of the smartphone interface reduces the social friction and stigma often associated with specialized assistive hardware [12, 13].

For the community of people with Visual Impairment (VI), AR has evolved into a versatile tool for enhancing environmental accessibility. Research has demonstrated its potential in translating purely visual experiences into multimodal ones, ranging from making vision-based fine art accessible through audio [1] to different applications for accessible navigation [15, 16]. However, despite these technical advancements, the adoption of such assistive technologies remains low. This gap highlights a significant lack of social consideration in the design process. Many systems focus solely on the technical challenge of navigation while ignoring the social friction they create [4].

Beyond individual assistance, AR serves as a powerful mediator for collaborative work, establishing a shared spatial understanding between VI users and sighted peers [6, 11]. By utilizing shared spatial anchors—digital markers that persist at specific physical coordinates, a sighted colleague can tag the environment with virtual notes, instructions, or directional cues. This AR-mediated collaboration facilitates a more seamless, cooperative experience in professional environments or complex transit hubs, as it allows both parties to reference the same physical space through a unified digital layer [3]. While standard assistive tools often provide fragmented snapshots of information, AR allows for the continuous integration of these details into a cohesive spatial narrative. By leveraging the high-precision 3D tracking inherent in modern frameworks, we can transform static information into an interactive, navigable environment that fosters the collaborative spatial awareness necessary for VI users to navigate the world with greater autonomy.

2 Related Work

The intersection of AR and accessibility for visually impaired users has been explored across several domains, including navigation, content accessibility, and collaborative interaction. Early work in AR accessibility focused on translating visual information into alternative modalities. For instance, systems have been developed to make visual art accessible through auditory descriptions, demonstrating the potential of AR to reinterpret traditionally visual experiences into multimodal forms [1]. Furthermore, prior research has investigated AR-based guidance systems that provide directional cues, object recognition, and environmental awareness through audio and haptic feedback [15, 16]. Spatialized audio, in particular, has emerged as an effective modality for conveying directional information, allowing users to orient themselves and perform fine-grained navigation tasks [7, 9]. However, many of these systems focus primarily on technical performance and often overlook the social and contextual aspects that influence real-world adoption.

Recent studies have explored AR as a medium for collaboration between users, enabling shared spatial understanding through techniques such as spatial anchoring [6, 11]. This collaborative perspective opens up possibilities beyond traditional single-user assistive systems and highlights the potential of AR to support cooperative practices in accessibility design. Rather than replacing human interaction through automation, such approaches align with broader Human–Computer Interaction (HCI) principles that emphasize augmenting and sustaining collaboration between individuals [3, 12, 13]. In this sense, AR can help bridge the gap between technological innovation and socially grounded design practices.

Despite these advances, a recurring limitation in existing work is the limited consideration of dynamic environments. Many AR navigation systems assume relatively stable surroundings, which can lead to inaccuracies as physical spaces evolve over time. Building on these insights, this work positions itself at the intersection of collaborative AR and assistive navigation by proposing a system that supports wayfinding for individuals with VI while preserving the inherently social nature of navigation practices.

3 Designed and Developed system

Unlike many other AR applications designed primarily for entertainment or immersive experiences, the purpose of this application is functional: to assist blind individuals in navigating complex indoor environments. In this context, immersion is not a design goal as discussed by Grimshaw [8] and it may even be counterproductive. Blind users must remain fully attuned to their surroundings, relying on all available sensory input to detect spatial and environmental cues. Therefore, the AR experience should enhance, rather than distract from, their situational awareness.

To guide the development of the application, existing AR design frameworks were reviewed. Billinghurst et al. [5] offer a general set of guidelines for building handheld AR prototypes. These include recommendations such as ensuring a clear AR view, using simple input mechanisms, providing feedback on sensor performance, and minimizing system latency. While these principles provide a useful foundation, they are primarily intended for sighted users and do not address the specific needs of users with visual impairments.

To bridge this gap, additional considerations were drawn from the XR Accessibility User Requirements (XAUR) [14]. XAUR emphasizes the importance of inclusive design practices, with a particular focus on multimodal interaction to accommodate diverse user preferences and abilities. One of its core recommendations is the support of multiple modalities, allowing users to interact with the system in the way that best suits their needs.

In alignment with this principle, the application incorporates spatialized audio as a key output modality alongside traditional visual feedback. Spatial audio has been shown to be highly effective for navigation tasks in prior research [7], particularly in supporting fine adjustments in orientation and direction [9]. By leveraging auditory spatial cues, the system enables blind users to build a mental map of their surroundings and make real-time decisions during navigation, thereby enhancing both independence and safety.

3.1 Application Interfaces and Core Functionality

The application consists of two primary goal: *way-finding* and *obstacle detection*. To this end we designed two interfaces: *path editing* and *navigation*. The core concept is to mediate a collaboration among people in societies to make the vision-dominant world more accessible to everyone. The two interfaces allow a sighted user to record a navigable path that a blind user can later follow independently.

3.1.1 Path Editing Interface. In this interface, a sighted user scans the environment and places virtual arrow-shaped markers that are scalable, rotatable, and movable along the desired route. These markers act as waypoints and serve as directional indicators in the real world. Each waypoint is associated with a spatial audio cue, which is later used to guide blind users accurately along the intended path.

3.1.2 Navigation Interface. In navigation mode, a previously recorded path is reloaded with all associated waypoints rendered in the scene. Blind users are guided along this path using 3D spatial audio cues. Upon reaching the destination, an audio notification is played to indicate arrival.

3.1.3 Obstacle Detection. The application also includes real-time obstacle detection using LiDAR technology. This feature identifies nearby objects and provides immediate audio alerts to help blind users avoid collisions. Virtual prefabs are excluded from this feature to reduce potential confusion and maintain focus on real-world obstacles.

4 Challenges and Opportunities

One of the primary hurdles for AR on-the-move is that physical spaces are rarely static, this is something mentioned by blind users during the user study. Most current AR frameworks operate on the assumption of environmental consistency; however, in reality, people are constantly "replacing things." Furniture is moved, temporary signage is erected, and architectural layouts may be modified for events. For a visually impaired user relying on persistent spatial anchors, can become misleading if the physical landmarks have been relocated or obscured.

Despite these challenges, the "on-the-move" nature of AR presents a massive opportunity to create socially-aware assistive technologies, such as navigation systems. If the environment is changing, AR can act as a real-time bridge for collaborative updates. For example, a sighted user could update a shared spatial anchor to reflect a new obstacle, essentially "warning" the VI user of a change in the environment before they reach it. This transforms the challenge of a non-static world into an opportunity for community-driven accessibility.

This turns the "problem" of a changing world into a way for people to work together. Instead of just having a map that stays the same, we can have a "living" map that people update as they move. By focusing on these real-world issues, we can build AR that doesn't just give directions, but actually understands the messy, moving world we live in.

5 Conclusion

This work presents a collaborative mobile AR system designed to support indoor wayfinding for individuals with visual impairments. By combining spatial anchors authored by sighted users with spatialized audio cues and real-time obstacle detection, the system demonstrates how AR can extend beyond individual assistance to enable socially grounded navigation. Rather than prioritizing immersion, the design emphasizes situational awareness and multimodal interaction, aligning with the practical needs of blind users in real-world environments. The paper also highlights the limitations of current AR systems in dynamic settings, where environmental changes can undermine the reliability of static spatial information. In response, we propose a shift toward community-driven, continuously updated spatial mappings that reflect the evolving nature of physical spaces. Future work will involve user evaluations with visually impaired participants and further exploration of scalable mechanisms for maintaining shared spatial data. Ultimately, this research contributes to a broader vision of AR as a socially embedded assistive technology that supports both interdependence and collaboration.

6 Acknowledgment

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