XRAI Care: A Systems Perspective on Remote Assistance for Older Adults with XR and AI

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Abstract

Many prior approaches believe that smart home/AI-enabled devices are the answer to the aging-in-place problem. Unfortunately, it misses an "elephant in the room" problem – understanding, configuring and using these systems is itself a high cognitive burden task. In some sense, the systems several of us believe are the solution may in fact be an impediment, and adding to the problem and frustration! As computer systems researchers, we want to bring a different perspective to this problem. In this position paper, we outline key challenges and opportunities in tackling the root issue of making these smart homes usable in the first place. We introduce XRAI Care, a system that combines XR and AI-driven contextual guidance to provide hands-free, real-time remote assistance to older adults. We discuss various systems-level challenges and opportunities of leveraging XR and AI, and layout initial ideas to fully realize XRAI Care.

1 Introduction

The rapid adoption of smart home technologies and AI-enabled devices has often been framed as the key to enhancing independence and quality of life for older adults [3, 4, 11, 15]. However, this perspective overlooks a critical issue: understanding, configuring, and using these systems is a cognitively demanding task, often introducing new frustrations rather than alleviating them. The very technologies intended to support aging in place may, paradoxically, contribute to the problem by imposing high cognitive and technical burdens on users with limited digital literacy or cognitive impairments [4].

Today, smartphones are the primary tools for remote assistance, with applications like FaceTime and WhatsApp enabling real-time video calls and screen sharing to provide a point-of-view (PoV) perspective for those in need [5, 12]. While these methods have proven useful, they come with limitations, such as the need for active device handling, poor camera angles, and difficulty maintaining continuous engagement, particularly for older adults with cognitive challenges.

More recently, AI-driven solutions, including large language models (LLMs) integrated with avatars, have gained attention for their ability to provide conversational support and guidance [1, 8, 9]. However, these solutions come with several limitations. First, these AI systems are primarily based on text- or voice-based interactions, which may not always be intuitive or sufficient for complex troubleshooting tasks that require visual or spatial understanding. Second, AI assistants often struggle with contextual awareness, making it difficult to accurately interpret real-world environments, particularly for users who may have difficulty articulating their issues clearly. Third, these solutions depend on users actively engaging with a device—whether through typing, speaking, or navigating an app—which can be cumbersome for older adults with cognitive impairments. Additionally, privacy, trust, and security concerns further complicate widespread adoption, as users may be hesitant to share sensitive personal or home-related information with AI systems.

To address these limitations, we envision XRAI Care, a new remote assist design integrating extended reality (XR) with AI advancements to create a more immersive, context-aware remote assistance experience. Instead of treating smart home technologies as a given, we focus on making them truly usable by integrating intuitive, hands-free, and context-aware assistance. XR enables real-time visual overlays with object detection and spatial awareness, eliminating the need for users to physically handle a device while receiving guidance. Existing AR glasses, such as XReal, Meta Ray-Ban, and Frame, already support key functionalities like streaming point-of-view (PoV) video and overlaying virtual elements in physical space. Integrating AI-driven conversational agents and incorporating remote manual assistance when available or as needed, can further enhance the quality of experience (QoE) and improve efficiency in task completion without imposing additional cognitive burdens.

However, several challenges—both fundamental and practical—must be addressed before XRAI Care can become a viable and widely adopted solution. Managing smart home infrastructure remains a major hurdle, with a diverse range of devices that often lack standardization, making integration complex and frustrating. Many homes still rely on legacy or lower-powered devices, which may not support advanced AI or XR-driven assistance. Privacy is another critical concern—any system operating within a personal home environment must ensure secure data handling and transparent user control. Finally, trust is essential; users need to feel confident that the system is reliable and genuinely helpful.

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Existing Work	Key Features	Limitations
FaceTime / WhatsApp Calls [5, 12]	Real-time voice/video communication, point-of-view (PoV) sharing	Requires active handling of smartphone, limited contextual awareness
Screen Sharing (Zoom, TeamViewer) [7, 14]	Remote desktop/mobile control, screen annotation	Limited real-world interaction, requires manual navigation
AI Chatbots (LLMs, Avatars) [1, 8, 9]	Conversational AI assistance, task guidance	Lacks real-world visual context, depends on user articulation
AR Smart Glasses (XReal, Meta Ray-Ban) [2, 6, 10]	Live PoV streaming, virtual overlays, head tracking	Limited AI integration, lacks interactive AI-based assistance
`XRAI Care` (Proposed)	AI-integrated XR, object detection, spatial awareness, real-time PoV streaming, hybrid AI-human remote assistance	Challenges in usability, security/privacy, low-latency streaming, and precise object recognition

Table 1: Comparison of Existing Work and `XRAI Care`.

2 Motivation and Vision

In this section, we briefly discuss the challenges that older adults can face in managing their cyber- smart home infrastructure. Motivated by these limitations, we sketch our vision for `XRAI Care` that envisions a novel XR-AI assisted framework for helping older adults navigate the complex digital and cyberphysical systems (CPS) infrastructure inside their homes.

2.1 Status Quo and Limitations

One of the biggest challenges for older adults is the sheer range of smart home devices they may encounter, from cutting-edge AI-driven assistants to older, legacy systems that lack modern connectivity. Many appliances, such as thermostats, lighting systems, or even security cameras, operate on proprietary protocols, making interoperability difficult. Smart home devices vary widely in design, control mechanisms, and setup complexity. For older adults, navigating this fragmented landscape can be overwhelming. A simple task—such as adjusting a smart thermostat or resetting a WiFi router—may require understanding inconsistent interfaces, app-based controls (e.g., Xifinity [13]), and device-specific troubleshooting steps. Worse, some devices rely entirely on touchscreens, voice commands, or mobile apps, which may not be intuitive for individuals who are less comfortable with technology.

Even when smart home devices work as intended, managing them over time is a significant challenge. Unlike standalone appliances, smart home ecosystems require ongoing configuration, software updates, connectivity maintenance, and security monitoring. Devices may unexpectedly disconnect from the network, require firmware updates, or need re-authentication with cloud services, leading to frustration and technical dependency. For older adults, troubleshooting these problems is often difficult without external help. Even if remote assistance is available through family members or technical support teams, the process can be cumbersome and inefficient.

The current landscape of remote assistance technologies offers a range of solutions to address the above issues (see Table 1), but each comes with inherent limitations. Video calls (FaceTime, WhatsApp) allow real-time PoV sharing [5, 12] but require active smartphone handling and lack contextual awareness, making them impractical for hands-free troubleshooting. Screen-sharing tools (Zoom, TeamViewer) enable remote control of digital devices [7, 14] but do not extend to physical device interactions, limiting their usefulness for smart home assistance.

Conversational AI chatbots powered by LLMs have introduced a new paradigm for digital assistance, offering task-specific guidance and interactive responses [1, 8, 9]. However, these systems lack real-world visual context, relying entirely on user articulation to describe their issues accurately which makes them inadequate for tasks requiring precise spatial understanding or object recognition. AR-based solutions, attempt to bridge this gap by offering live PoV streaming and hands-free operation with an immersive experience [2, 6, 10]. However, they still fall short in AI-driven interactive assistance, as they primarily serve as display devices without deep integration of intelligent guidance or real-time problem-solving capabilities.

2.2 `XRAI Care`: Vision

To address the above limitations, we introduce `XRAI Care`, a context-aware, AI-driven extended reality (XR) system designed to provide hands-free, intuitive troubleshooting for older adults and individuals with limited technical expertise. Unlike traditional solutions that rely on manual smartphone

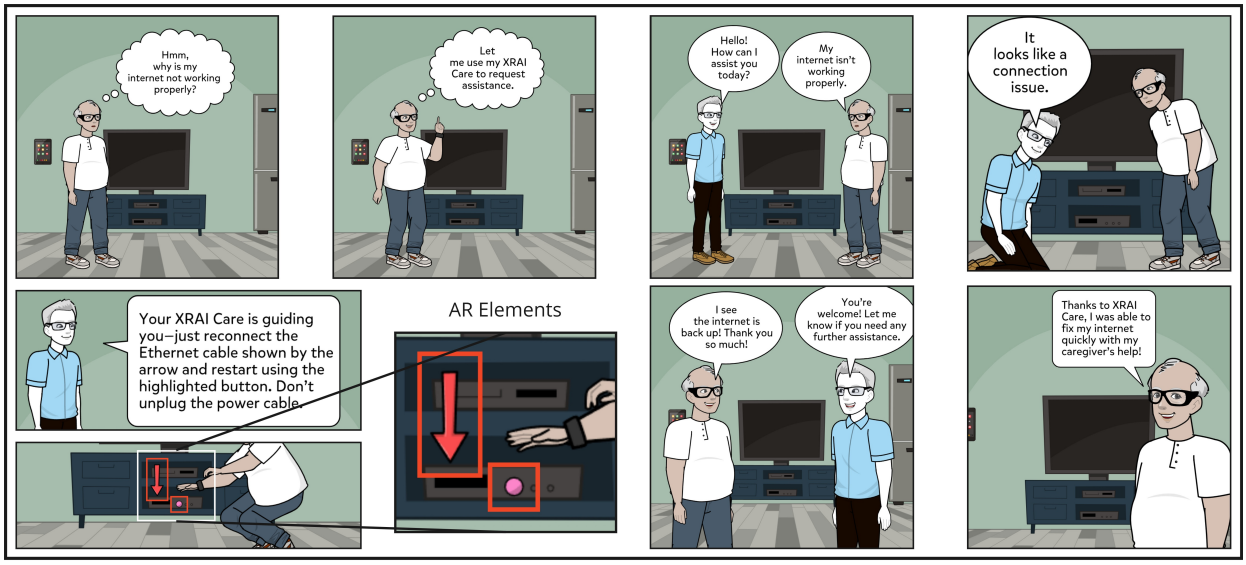

Figure 1: A scenario where an elderly individual is being assisted remotely with `XRAI Care` to diagnose and fix a WiFi connection issue at home. Using AR guidance, the system provides step-by-step instructions to reconnect the Ethernet cable and restart the device. The caregiver, appearing as an AI virtual assistant, helps troubleshoot the problem, enabling the elderly user to restore internet connectivity independently with minimal external help.

handling, verbal instructions, or screen sharing, `XRAI Care` integrates real-time AI guidance with augmented reality (AR) overlays to offer step-by-step, visual, and interactive support for resolving smart home issues.

Figure 1 illustrates a real-world scenario where an older adult encounters an internet connectivity issue. Instead of struggling with a video call or navigating complex app interfaces, the user activates `XRAI Care`, which analyzes their environment, detects the relevant components (e.g., Ethernet cable, power button), and overlays clear visual instructions using AR elements. The user can efficiently troubleshoot the issue without external assistance by following AI-guided highlights and directional cues.

`XRAI Care`'s key advantage is its ability to provide hands-free, real-time, and context-aware support. It eliminates the need for device handling, ensures accurate object recognition, and provides AI-driven spatial overlays for interactive troubleshooting. Additionally, its hybrid AI-human assistance model allows users to escalate issues to a remote caregiver or technician when necessary, ensuring seamless support without the frustration of traditional methods.

3 Challenges and Initial Ideas

While the vision of `XRAI Care` is a promising alternative to the status quo, there are key technical systems, usability, and security and privacy challenges to be addressed to make this a reality. In this section, we discuss these challenges and outline initial ideas to tackle these.

3.1 Device Diversity and Legacy Systems

Smart home ecosystems are not uniform—they consist of a mix of devices from different manufacturers, each with its own interface, control mechanisms, and communication protocols. `XRAI Care` must be able to recognize and interact with a wide range of devices, many of which lack standardized integration points. This diversity creates several challenges:

- Inconsistent Control Methods: Some devices use physical buttons, others rely on touchscreens, smartphone apps, or voice commands. `XRAI Care` must be able to detect and assist with multiple types of interactions without requiring users to manually specify their device type.
- Proprietary Ecosystems: Many smart home brands (e.g., Google Nest, Amazon Alexa, Apple HomeKit) use closed ecosystems that do not easily interoperate. This makes it difficult for an `XRAI Care` system to access or control certain devices unless explicitly supported.
- Unstructured UIs: For digital applications (e.g., smart home apps on smartphones), UI elements are not always fixed or easily detectable. Identifying menu options, settings, or troubleshooting steps requires adaptive computer vision models that can work across multiple apps and device firmware versions.

`XRAI Care` leverages object recognition, adaptive UI parsing, and multi-modal interaction capabilities. Instead of relying on predefined integration points, object detection models enable the system to visually detect and interpret device

interfaces in real-time, allowing it to recognize physical buttons, touchscreens, and voice-controlled devices without requiring manual configuration. To overcome proprietary ecosystem restrictions, XRAI Care prioritizes universal interaction methods, such as overlaying step-by-step AR guidance on detected device components rather than relying on direct API access. For unstructured UIs in smartphone-based smart home apps, adaptive ML models trained on diverse UI layouts allow dynamic element detection, enabling users to navigate and interact with digital interfaces more intuitively.

3.2 Quality of Experience of Spatial Overlays

A significant challenge in conventional remote assistance is the lack of contextual awareness and precise object tracking. For example, screen-sharing applications or video calls, rely on users manually adjusting their camera to align with the relevant object or interface, often leading to inefficiencies and frustration. Similarly, navigating digital applications on smartphones or interacting with smart home devices can be cumbersome, especially when users must interpret complex interfaces with limited technical knowledge.

Instead, XRAI Care leverages region of interest (RoI) detection and spatial overlays to provide intuitive and interactive guidance. RoI detection enables the system to analyze the user's environment in real-time, automatically identifying key components of devices (e.g., power buttons or reset buttons on WiFi routers) and digital interfaces on smartphones (e.g., finding a screen share option during a video call).

Once the RoI is identified, we render spatial overlays dynamically to guide users through specific tasks. The key functionality of these overlays includes: 1) clear, visual markers that highlight important controls or buttons, 2) step-by-step augmented guidance, ensuring that users follow the correct sequence of actions, 3) context-sensitive adjustments, adapting overlays based on user movement and interaction, 4) in case of digital apps, UI navigation enhancements to highlight interactive elements such as input fields, confirmation buttons, or menu options.

A major challenge in overlay systems is preventing visual clutter while ensuring key interface elements remain highlighted. To address this, XRAI Care employs dynamic focus adjustment, which prioritizes critical UI elements based on task relevance and user engagement. The system continuously evaluates metrics related to object importance score based on task context, user gaze tracking to ensure overlays are positioned in line with the user's visual attention, and scene complexity metrics to prevent overcrowding the display with overlays. To minimize the visual clutter in the XR display, we formulate and optimize a quality of experience (QoE) function $p(e_i|I) + g(e_i) - c_\eta$, where $p(e_i|I)$ is the probability of detecting an element e_i in image I, $g(e_i)$ is the gaze likelihood of the element, and c_η is a penalty factor for visual complexity used to reduce the clutter.

User-specific adaptation: Given that different users have varying visual and cognitive requirements, XRAI Care incorporates adaptive UI settings to personalize the overlay experience based on 1) text size preferences, ensuring overlays are easily readable, 2) color contrast optimization, benefiting users with vision impairments, 3) interaction history, dynamically adjusting overlays based on past usage patterns. These personalizations can be implemented through the commonly available reinforcement learning models that learn user preferences over time, continuously improving the experience.

3.3 Usability of XRAI Care Design

Designing XRAI Care for older adults presents several usability challenges that must be addressed at the system level to ensure accessibility, efficiency, and intuitive interaction. Many older users experience cognitive overload, navigation difficulties, and sensory impairments, making it difficult to engage with complex smart home interfaces.

One of the primary challenges in XRAI Care is designing an interface that remains clear, readable, and easy to interact with across different display mediums. Many smart home applications suffer from small fonts, closely spaced buttons, and low contrast, making them difficult to use for individuals with declining vision or motor impairments. To address this, XRAI Care prioritizes high-contrast text, adjustable font sizes, and simplified interaction models that reduce the risk of errors. Additionally, gesture-based and voice-driven controls will replace fine motor inputs, ensuring that users can navigate the system without requiring precise touchscreen interactions.

Another key usability challenge is error handling and real-time guidance. Many older users struggle to recover from mistakes or interpret ambiguous feedback, making troubleshooting a frustrating experience. Instead of relying on static notifications, XRAI Care will integrate real-time step validation and corrective overlays, ensuring that users receive immediate, context-aware feedback when performing tasks. Additionally, adaptive error recovery mechanisms will provide alternative instructions when users deviate from recommended actions, reducing confusion and increasing system usability.

Lastly, XRAI Care must accommodate varying levels of user familiarity with technology. Some users may need detailed, step-by-step guidance, while others may prefer shorter, streamlined workflows after repeated interactions. To address this, XRAI Care will implement adaptive instructional overlays that dynamically adjust complexity based on user

behavior. The system will also support personalized interface settings, allowing users to customize text size, contrast, and interaction modes according to their comfort level.

3.4 Trust and Privacy Issues in XRAI Care

One of the key privacy concerns in XRAI Care is the continuous video capture required for real-time assistance. AR glasses must stream visual data for AI analysis or remote support, raising concerns about who has access to the footage, where it is stored, and how long it is retained. Older adults, in particular, may struggle with understanding these aspects, making transparency and controlled data access essential for trust and adoption. To address this, XRAI Care implements a tiered trust model that not only controls who can assist the user but also regulates how much video data is shared and under what conditions. This model ensures that more trusted individuals receive greater access privileges, while AI-based or external assistance remains limited in scope.

- Level 1: Fully Trusted Assistants – Close family members, caregivers, or designated guardians have the highest level of access to video streams and other environmental data. These individuals can assist with sensitive tasks like managing finances, adjusting home security settings, or troubleshooting medical devices.
- Level 2: Semi**-Trusted Professional Assistants** – Technicians from service providers, home maintenance personnel, or healthcare professionals may require temporary or task-specific access to a subset of the user's devices. Their access is time-bound and region-specific, meaning that they can only view the relevant workspace—for example, a network technician may see only the router area while the rest of the home remains blurred. Privacy-enhancing algorithms further redact personal objects and faces to minimize unnecessary exposure. Additionally, users must explicitly approve each session, ensuring that professional assistants do not retain long-term access to their home environment.
- Level 3: Semi-Trusted AI Assistance – At the most restricted level, AI-driven assistance operates with no external video streaming by leveraging on-device edge processing. Instead of transmitting raw video to the cloud, the AI analyzes frames locally, detecting key elements such as a disconnected Ethernet cable or a blinking error light. Only metadata and visual cues (rather than full video frames) are used to generate step-by-step troubleshooting instructions, preserving privacy while still enabling effective guidance.

4 Conclusions

Our goal in writing this paper is to bring a computer and cyberphysical systems management perspective to the problem of supporting older adults. Our primary motivation was the observation that we often forget the cognitive burden of using modern smart infrastructure, which can be daunting even for digitally savvy adults and can be extremely frustrating for older adults facing cognitive decline. We do believe that with a suitable combination of XR and AI, we can take a first but significant step toward improving remote assistance for older adults. Admittedly, we have more challenges and questions than answers, but we hope that this work serves as a starting point for a technical discussion on this possibly neglected topic.

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