International Journal of Modern Science and Research Technology
ISSN NO-2584-2706

Next-Generation Web Accessibility: Leveraging AR/VR Technologies to Improve Web Experienc for Disabled users

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Abstract :
Digital encounters for impaired people are limited by the absence of immersive participation in traditional web accessibility technologies. Through gesture-based navigation, spatial audio guidance, and haptic feedback, this article investigates how AR/VR technologies can help users with visual, auditory, and motor impairments close this gap. Our framework is inclusive and improves web accessibility by utilizing WebXR, AI-powered assistive features, and multimodal inputs. The efficacy of these methods is demonstrated by a prototype-based evaluation that tackles important issues including standardization, hardware constraints, and ethical considerations. Our research paves the way for a more inclusive online experience by enabling next-generation accessibility in the Metaverse and Brain-Computer Interfaces (BCIs).Our work opens the door to next-generation accessibility in Brain-Computer Interfaces (BCIs) and the Metaverse, paving the path for a more inclusive online experience.

Keywords: Web Accessibility, AR, VR, Assistive Technology, WebXR, Inclusive Design

1. Introduction:

Although millions of impaired users still find the internet to be a barrier rather than a bridge, it is frequently praised as a portal to an infinite amount of information. Keyboard navigation, voice commands, and screen readers are examples of accessibility solutions that already exist [1]. While they offer some basic functionality, they fall short of providing the dynamic, immersive, and intuitive experience that contemporary users crave. It is becoming more difficult for traditional assistive devices to keep up with the visual and spatial nature of digital interactions [3].

The advent of virtual reality (VR) and augmented reality (AR) provides a radical change in web accessibility. Users with visual, auditory, and motor impairments can surf the web with gesture-based controls, real-time spatial audio, haptic feedback and AI-driven adaptive interfaces thanks to AR/VR's spatial, multimodal, and interactive environment, which sets it apart from static web pages [3]. Imagine a person with movement limitations using eye-tracking and neural inputs to browse the internet, or a visually challenged person "feeling" the structure of a webpage through haptic impulses. These are real possibilities, not sci-fi fantasies[8].

DOI: https://doi.org/10.5281/zenodo.15610126

integrating AR/VR into mainstream web accessibility comes with its own set of challenges—hardware limitations, standardization gaps, ethical dilemmas, and the need for a universally adaptive framework. Current guidelines such as WCAG 2.2 were designed for 2D interfaces, leaving a major gap in spatial web accessibility standards. To address this, our research presents:

1.A framework for integrating AR/VR-based assistive technologies with WebXR, AI-driven accessibility, and multimodal input methods.

2.A prototype-based evaluation, validating how immersive technologies can enhance digital accessibility.

3.A discussion on the challenges, limitations, and future research needed to drive AR/VR accessibility forward.

2. Related Work

Several studies have explored the role of AR and VR in assistive technology. For instance, AR-based object recognition systems have been developed to help visually impaired individuals identify objects in their surroundings using computer vision and real-time audio descriptions. Similarly, haptic feedback-enabled AR interfaces have been introduced to improve sensory perception for users with visual impairments.

On the VR side, VR-based web browsing systems have been designed to offer hands-free interactions, leveraging technologies like eye-tracking, voice commands, and gesture recognition to assist users with motor disabilities. Research has shown that VR enhances engagement by providing a spatial web experience where users can interact with content in a three-dimensional space rather than a traditional two-dimensional interface.

While these advancements show promise, a significant gap exists in integrating AR/VR with existing web standards to create an accessible digital ecosystem. Current solutions often focus on isolated features rather than a holistic approach to web accessibility. This paper aims to bridge this gap by proposing a unified framework that leverages AR and VR in combination with web accessibility guidelines.

3. Previous Background

Virtual reality and augmented reality are two revolutionary technologies that offer engaging and interactive experiences. AR improves real-time interaction for persons with visual impairments by superimposing digital content over the real world. Conversely, virtual reality (VR) generates a completely simulated environment that enables users to travel and engage through different input techniques including gesture recognition and voice commands.

Several studies have explored the potential of AR/VR in assistive technology. AR-based object recognition systems have been developed to help visually impaired individuals identify objects in their surroundings using computer vision and real-time audio descriptions. Similarly, haptic feedback-enabled AR interfaces have been introduced to improve sensory perception for users with visual impairment

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While these advancements show promise, a significant gap exists in integrating AR/VR with existing web standards to create an accessible digital ecosystem. Current solutions often focus on isolated features rather than a holistic approach to web accessibility. This paper aims to bridge this gap by proposing a unified framework that leverages AR and VR in combination with web accessibility guidelines.

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4. Methedology

To explore the feasibility of AR/VR-based web accessibility, we developed a prototype system utilizing WebXR, Three.js, and voice recognition APIs. The methodology follows a three-phase approach:

4.1. System Architecture

The proposed system consists of four core modules:

1. The AR Overlay Module recognizes items in the actual environment and provides vocal input that is descriptive by using AI-powered computer vision. By superimposing digital markers on real-world objects and reading out pertinent information, this module improves navigation for people with visual impairments.

2. By constructing a 3D environment in which users may interact with web items through gaze-based controls, hand-tracking, and spatial audio, the VR Navigation Module offers an immersive web browsing experience.

3. WebXR-based interactions are implemented by the Multimodal Interaction Module to offer accessible online features like gesture-based page scrolling, voice-activated menus, and adaptive font size for improved reading.

4. AI-Based Personalization: Enhances accessibility according to user preferences by analyzing user activity and dynamically modifying web elements using machine learning techniques.

4.2. Implementation Approach

The system follows a structured development process:

1. DataCollection&Preprocessing: Useraccessibility requirements were analyzed through surveys and case studies to determine the necessary features.

2. Prototype Development: Using Three.js, a VR-compatible browser interface was created, incorporating gesture-based controls, spatial audio, AI-powered object recognition, and voice command interactions.

3. Testing & Evaluation: The system was tested with users having varying degrees of disabilities to measure usability improvements over traditional assistive technologies.

4. Optimization & Feedback Loop: User feedback was integrated into iterative development cycles, improving interaction mechanisms and refining accessibility features based on real-world usability data.

5. User-Centric Interaction Models: Developed behavior prediction algorithms to dynamically adjust the user interface based on real-time user input.

6. Cloud-Integrated Personalization: Implemented a cloud-based system that stores accessibility preferences and adapts interfaces accordingly for returning users.

7. Cross-PlatformCompatibility Testing: Ensured seamless integration with different devices and web browsers supporting WebXR to maximize accessibility.

5. Analysis and Discussion

1. A number of crucial criteria were used to assess the prototype system:

2. User Engagement: With AR/VR-assisted navigation, users reported more ease of access and a notable rise in engagement.

3. In comparison to conventional accessibility tools, the voice-activated and gesture-based navigation system greatly decreased interaction time.

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4. **Enhancements in Accessibility:** Users with severe impairments had a better experience thanks to AR overlays and AI-driven customisation methods.

5. Web accessibility can be significantly improved by using AR/VR technologies, according to the findings, giving people with impairments a more engaging and inclusive online experience.

6. Conclusion

By integrating AR and VR with online accessibility, a groundbreaking approach to digital inclusivity is demonstrated. Immersion technology makes the web more participatory and accessible for people with disabilities. The potential of AR and VR to get over traditional accessibility barriers is demonstrated in this study, which also sets the foundation for future developments in accessible web design. Future research ought to focus on boosting user experience, ensuring the widespread adoption of AR/VR-based web accessibility solutions, and improving device compatibility.

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