Enhancing Web Accessibility: Innovative Design Approaches and Evaluation Methods for Visually Impaired Users

[1]Christiana U. Ezeanya, [2] Adam T. Adam, [3]Abdullateef E. Salihu, [4]Farida S. Garki, and [5]Jane A. Ukaigwe
[1,3,4]Department of Information Systems and Technology, National Open University of Nigeria
[2,5]Department of Computer Science, National Open University of Nigeria
cezeanya@noun.edu.ng|adamtahiradam@gmail.com|asalihu@noun.edu.ng|fgarki@noun.edu.ng|jukaigwe@noun.edu.ng

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ORIGINAL RESEARCH

Abstract— Individuals with visual impairments often encounter significant accessibility and usability challenges when navigating websites, despite advances in web technologies and assistive tools. These challenges can restrict access to online information and digital services, highlighting the need for more user-centred browsing solutions. This research introduces an assistive web browser application designed to enhance the browsing experience for individuals with visual impairments. The application integrates a simplified web interface, text-to-speech capabilities, shortcut keys, and a magnification tool into a unified platform, enabling users to access and interact with web content more efficiently by entering any website's URL. The research methodology includes individual surveys and interviews, system design, and implementation using ReactJS and NodeJs. The software was evaluated through structured interviews and questionnaire-based surveys conducted with visually impaired users to assess usability, accessibility, and overall satisfaction. The evaluation results indicated that the application significantly improved users' browsing experience by enhancing ease of navigation, content accessibility, and overall satisfaction. The findings demonstrate that integrating multiple accessibility features within a single web browser application can promote more inclusive access to online information and contribute to improving digital accessibility for individuals with visual impairments.

Keywords—Assistive Technology, Human-Centred Design, Magnification Tool, Text-to-Speech (TTS), Visually Impaired Users.

1 INTRODUCTION

As digital platforms continue to expand and serve an increasing number of users, web accessibility has become vital for delivering equitable access and addressing the diverse needs of all individuals. Its growing importance is driven by advancements in assistive technologies, the adoption of inclusive design principles, and changes in the ways people access information online (Manoj & Shankar. 2024). Assistive technology (AT), refers to the hardware and software that enable people with disabilities to utilize technology in a way that improves their quality of life. It encompasses a wide range of devices, systems, services, and applications (Muhsin, et al. 2024). Despite these technological advancements, web accessibility remains a significant challenge in the digital era, as millions of people with disabilities continue to encounter barriers when accessing online content and services (Dhanasekaran, 2024). According to the World Wide Web Consortium (W3C) and the Web Accessibility Initiative (WAI) report, accessibility is a broad and evolving concept that extends beyond permanent disabilities to include users with limited skills and those experiencing situational impairments (Ara, et al. 2024). Although internationally recognized standards, such as the *Web Content Accessibility Guidelines (WCAG) 2.2*, provide comprehensive recommendations for accessible web design, many websites still fail to meet accessibility requirements, limiting access for users with visual impairments and other disabilities. From an accessibility perspective, these users often face numerous obstacles that hinder their ability to access and interact with web content effectively. In many cases, the lack of proper accessibility features can make certain platforms completely unusable for individuals with specific needs, so they are excluded from the benefits and opportunities offered by the digital world (Bercaru & Nirvana, 2024). Furthermore, while numerous assistive technologies such as screen readers, browser extensions, and magnification software are available, most of them typically operate independently and require users to switch between multiple tools. To address this limitation, this research addresses the gap by designing and implementing an assistive web browser application that integrates real-time text-to-speech, keyboard shortcut navigation, screen magnification, and simplified web interaction within a unified platform developed using ReactJS and Node.js. Unlike conventional browsers that depend primarily on external assistive technologies, the proposed application consolidates essential accessibility functions within the browser environment, thereby reducing interaction complexity while improving usability for visually impaired users and promoting compliance with WCAG 2.2. It is predicted that the results will help in the creation of inclusive web apps and offer useful advice for software engineers that prioritise accessibility.

Corresponding Author: asalihu@noun.edu.ng
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2 RELATED WORKS

2.1 INTRODUCTION

Droutsas et al. (2025) analysed web accessibility barriers across multiple disability groups. Their work reveals that many solutions remain siloed, addressing only one type of impairment. In comparison, the proposed system,

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while primarily targeting visual impairments, incorporates interaction techniques (keyboard shortcuts and speech) that can be extended to users with motor impairments. In order to assess the design and efficacy of assistive technologies intended to enhance internet navigation for visually impaired screen reader users, Juan et al. (2024) conducted a narrative evaluation of the body of literature.

However, the research focuses on screen reader technologies and extensions but does not evaluate complete assistive browser systems that integrate simplified interfaces, TTS, navigation keys and magnification. Numerous studies have explored the intersection of web accessibility, assistive technology, and inclusive design. This section presents an in-depth review of significant related works from 2024 onward.

Droutsas et al. (2025) analysed web accessibility barriers across multiple disability groups. Their work reveals that many solutions remain siloed, addressing only one type of impairment. In comparison, the proposed system, while primarily targeting visual impairments, incorporates interaction techniques (keyboard shortcuts and speech) that can be extended to users with motor impairments.

Juan et al. (2024) undertook a narrative review of the existing literature to evaluate the design and effectiveness of Assistive Technologies aimed at improving internet navigation for visually impaired screen reader users. However, the research focuses on screen reader technologies and extensions but does not evaluate complete assistive browser systems that integrate simplified interfaces, TTS, navigation keys and magnification.

Dhanasekaran (2024) introduces Inclusive Web, a new accessibility-focused web browser designed to increase digital inclusion for people with diverse disabilities. The browser addresses the persistent challenge of widespread non-compliance with web accessibility standards by implementing real-time content adaptation mechanisms, disability- specific tools, and a highly customizable user interface. However, these solutions do not provide text-to-speech functionality.

Kerdar et al. (2024) aimed to improve the understanding of the accessibility of digital technologies for people with visual impairment and blindness, identifying items facilitating their use based on first-hand experiences of the target group and the existing accessibility guidelines. The research is broad in scope, with general digital accessibility challenges, but it lacks a detailed focus on interactive web navigation tools or custom browser development.

The review of Bercaru & Nirvana (2024) explored and analysed the current state of the art in developing accessible online interfaces that incorporated ML algorithms, and it is focused on key tools such as sign language recognition, speech-to-text, text-to-speech and voice recognition. However, the review is not on web browser app development that integrates these interactively.

Souza et al., 2024; Vera-Amaro & Rojano-Cáceres (2025) present a literature survey focused on the accessibility of web systems, targeting users with visual impairments, emphasising the importance of including accessibility from the initial phases to the completion of system development.

Pavel (2025) explores existing adaptive approaches to making web applications accessible to users with disabilities. The experiment involved pilot-testing the developed adaptive web interface on a limited sample of users with various disabilities, representing different age and educational groups to ensure demographic diversity. However, it focuses on web application interfaces, not a browser that can accept websites.

- **Voice-Based and Intelligent Web Navigation Systems**

Several studies explore voice-enabled and AI-driven approaches to improve web navigation for users with disabilities.

Mehendale and Walishetti (2024) proposed DexAssist, a dual-LLM framework enabling voice-based interaction for users with motor impairments. While the system improves navigation efficiency through conversational control, it does not function as a standalone browser and lacks integrated features such as content magnification and keyboard shortcuts. Moreover, its evaluation was limited to a restricted set of web tasks, reducing generalizability.

- **Text-to-Speech and Speech-Centred Accessibility Solutions**

Speech synthesis remains a cornerstone of web accessibility for visually impaired users. Dhaliwal and Sharma (2024) examined the role of text-to-speech (TTS) in enhancing independence for blind and visually impaired individuals. Their work validates the importance of high-quality speech output but does not integrate TTS into a browser-based framework capable of dynamically loading arbitrary websites.

Pucci et al. (2024) explored the integration of conversational AI with web augmentation through a co-design approach. Their findings demonstrate how voice-based interfaces can compensate for inaccessible web structures. However, the solution emphasises conversational augmentation rather than direct browser interaction and omits features such as magnification and shortcut-key accessibility, which are central to the proposed system.

- **Web Accessibility Evaluation Frameworks and Reviews**

Evaluation methodologies are critical for validating accessibility tools. Souza (2024) proposed a structured framework for evaluating web systems for users with visual impairments, emphasising WCAG compliance, task performance, and user satisfaction. While this work does not introduce a new assistive tool, it provides a

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strong methodological foundation that can be adopted to evaluate the proposed browser application.

Similarly, Srinivasan and Patapati (2025) introduced WebNav, an intelligent agent that dynamically labels web elements to support voice-controlled navigation. Although effective for interaction flow, WebNav does not directly address content accessibility through text-to-speech conversion or visual enhancement mechanisms. In contrast, the proposed system integrates both navigation and content transformation, enabling users to access any website via URL input and receive auditory and visual support simultaneously.

In order to improve the experience of visually impaired students, Srinivas et al. (2024) created an Android application called Enhance Voice Based Learning to Visually Challenged People. The software provides information and notes, including voice-activated navigation. However, the lack of magnification and web browsing capability in their approach restricts its wider use.

3 METHODOLOGY

This study adopted a mixed-methods research design, combining quantitative and qualitative approaches with a user-centred system development methodology to design, develop, and evaluate an assistive web browser for visually impaired users (Tuah & Kwateng, 2026). The quantitative component used a structured questionnaire administered through Google Forms, while the qualitative component collected semi-structured interviews to gather in-depth information on users' browsing experiences, accessibility challenges, and preferred assistive features.

The study targeted visually impaired individuals aged 18 years and above, primarily tertiary institution students and employed adults who regularly used the internet. Participants were recruited using purposive sampling because they possessed the characteristics required to provide relevant information for the study. The questionnaire collected demographic information, including gender (male and female), age, and confirmation of visual impairment, in addition to information on internet usage, accessibility challenges, and preferred browser features. A total of 40 questionnaires were distributed, of which 27 were completed and returned, while five participants were selected for semi-structured interviews to obtain more detailed insights into their web browsing experiences.

Quantitative data were analysed using descriptive statistics, specifically frequencies and percentages, to summarise participants' responses and identify the most significant accessibility challenges and user requirements. Qualitative analysis was done on the interview responses were analysed through thematic review to identify recurring themes that informed the functional requirements and design of the proposed browser.

The browser was developed using Agile Software Development and User-Centred Design (UCD) principles, enabling iterative development and continuous incorporation of user feedback throughout the design process. Low-fidelity wireframes were initially created to validate the interface before implementation. The system was designed in accordance with the Web Content Accessibility Guidelines (WCAG) 2.1/2.2 to promote accessibility and compatibility with assistive technologies.

The application was implemented using ReactJS for the front-end interface and Node.js for the back-end application logic. Integrated accessibility features included a real-time text-to-speech module implemented using Google Text-to-Speech and the Web Speech API, together with a dynamic magnification tool developed using CSS scaling and JavaScript to improve webpage readability while maintaining layout consistency. System functionality and interaction were modelled using use case, class, and activity diagrams to define the system architecture and guide implementation. The completed prototype underwent iterative usability evaluation with visually impaired users throughout the development process. Participants tested the browser and provided feedback on navigation, speech clarity, magnification effectiveness, interface usability, and overall user experience. Their feedback was incorporated into successive development iterations to improve the application's accessibility and usability before final implementation. Ethical considerations were observed throughout the study.

System Key Features

The proposed assistive web browser for visually impaired users offers an intuitive and accessible interface that simplifies web navigation. It integrates built-in real-time text-to-speech (TTS) functionality, allowing users to listen to web content with convenient controls for playback management. A dynamic magnification tool enables adjustable zooming of webpage elements to improve readability without disrupting page layout.

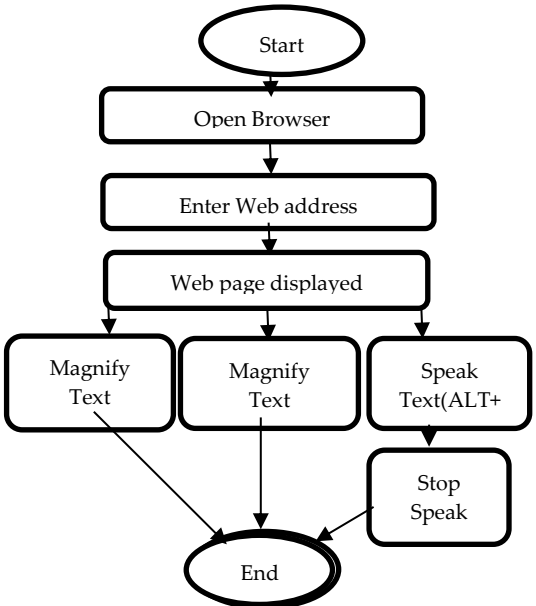

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Fig. 1. Activity diagram of the key features of the system

4 RESULTS AND DISCUSSION

1. Assistive Web Browser Screenshots

Figures 2–3 present the Assistive Web Browser interfaces developed for efficient use by visually impaired users. The screenshots illustrate key functions such as inserting the URL and Text to Speech feature, and shortcut keys, it demonstrates the system's functionality and usability these describe and give the pictorial representation of the assistive web browser; it shows and gives clear understanding of the design, and displays all the interfaces.

Fig. 2. Landing Page Interface

This is the initial interface of the assistive browser, allowing users to enter and navigate to any desired web address. It serves as the entry point for accessing web content with assistive features like text-to-speech and magnification.

Fig. 3. Speaking Webpage Text Content Interface

This screen shows the assistive browser reading a webpage's text content aloud. The text-to-speech feature helps users, especially those with visual impairments, listen to webpage information instead of reading it, making web browsing more accessible and convenient.

Figures 4–6 present the responses from surveyed web users, covering demographic characteristics, accessibility needs, and the adoption of assistive web technologies. These results highlight the respondents' profile, the significant challenges they face in web navigation due to visual impairments, and the extent to which they use accessibility features of the proposed Assistive Web Browser—such as text-to-speech, screen magnification, and keyboard navigation—in everyday browsing.

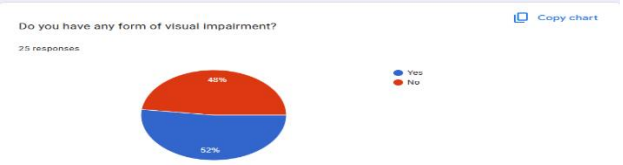

Fig. 4. Pie chart showing the distribution of visually impaired users, out of the respondents, (52%) were visually impaired while (48 %) were very ok with the contents of websites.

2. Evaluation Metrics

Task Completion Rate: 94% of the web users who responded to the questionnaire were able to operate the assistive web browser without any complaints. Only about 6%, who suggested that the Application should be updated regularly.

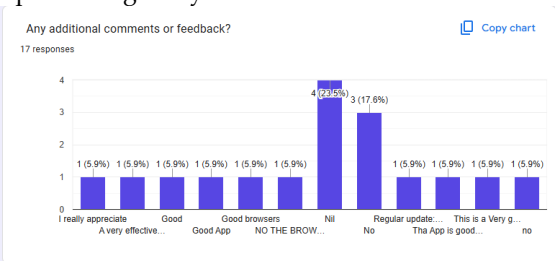

Fig. 5. Trend showing the assistive web browsers used by web users. Among 17 individuals responded, only 1 person suggested regular update.

Average Task Completion Time: The majority of users completed the task of launching the assistive web browser and navigating its content within an average time of 2 minutes.

User Satisfaction: Scored an average of **4.6 out of 5**, based on clarity of audio, ease of navigation, and visual comfort.

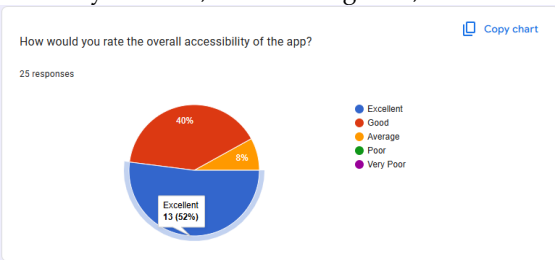

Fig. 6. Pie chart showing how 92% of the responded are satisfied with overall accessibility of the Assistive Web browser Application giving the rate of 52% for Excellent and 40 % for Good.

5 CONCLUSION AND FUTURE WORKS

This study presented the design and development of a prototype assistive web browser aimed at improving web accessibility for visually impaired users. By integrating essential accessibility features such as real-time text-to-speech, keyboard shortcut keys, screen magnification, and simplified navigation, the browser addresses key challenges faced by visually impaired individuals when accessing web content. The use of modern web technologies, specifically ReactJS and Node.js, enabled the development of a responsive, scalable, and user-friendly application. The evaluation of the system through system testing and user feedback confirmed the effectiveness and ease of use of the proposed browser. The findings indicate that the assistive features improved user interaction and overall browsing experience, thereby supporting greater independence and inclusivity for

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visually impaired users. Specifically, 94% of the web users who responded to the questionnaire were able to operate the assistive web browser without any complaints. Only about 6%, who suggested that the Application should be updated regularly. In terms of efficiency, the **average task completion time for launching and navigating the browser was approximately 2 minutes**, indicating relatively quick adaptation to the system's interface. Furthermore, user satisfaction results showed a **mean rating of 4.7 out of 5**, based on criteria such as clarity of audio output, ease of navigation, and visual comfort. Overall satisfaction analysis further revealed that **92% of participants rated the system positively**, with **52% indicating "excellent" usability and 40% rating it as "good."** Despite these positive outcomes, there remain opportunities for further enhancement. Future enhancements may include the addition of voice command functionality for hands-free operation, as well as multi-language and dialect support to increase accessibility for users with a range of linguistic and cultural backgrounds. Overall, this work advances accessible web technology and lays a solid platform for the future building inclusive digital solutions.

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