

Harnessing the Power of Android Smartphones to Enhance the Lives of Visually Impaired Individuals: A User-Centered Approach to Developing a GPS-Enabled Mobile Application

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Abstract

Introduction: The World Health Organization (WHO) estimates that 217 million individuals have some difficulty seeing distant objects, while 36 million people are completely blind. This study aims to develop an Android app to assist visually impaired individuals in their daily lives.

Background: Visually impaired individuals face significant challenges in their daily lives, including navigation, communication, and accessing information. Existing assistive technologies, such as canes and braille, have limitations, and there is a need for more advanced technologies to support this population.

Problem Identification: The lack of accessible and user-friendly technologies for visually impaired individuals hinders their independence, mobility, and quality of life.

Objectives: The primary objective of this study is to design and develop an Android app that provides navigation, communication, and information access assistance to visually impaired individuals.

Design and Methodology: The app was developed using Android Studio, and its features include GPS-based navigation, emergency texting, alarm setting, and text-to-voice conversion. The app's user interface was designed to be accessible and user-friendly for visually impaired individuals.

Results: The app was tested with visually impaired individuals, and the results showed that it improved their navigation, communication, and access to information. The app's features, such as GPS-based navigation and emergency texting, provided users with a sense of security and independence.

Implications: This study demonstrates the potential of Android apps to support visually impaired individuals in their daily lives. The app's accessible and user-friendly design can serve as a model for future assistive technology development. The study's findings have implications for policymakers, healthcare professionals, and technology developers seeking to support the independence and quality of life of visually impaired individuals.

Conclusion: In conclusion, this study demonstrates the potential of Android apps to support visually impaired individuals in their daily lives. The developed app provides navigation, communication, and information access assistance, improving the independence, mobility, and quality of life of visually impaired individuals. The app's accessible and user-friendly design can serve as a model for future assistive technology development. The study's findings have implications for policymakers, healthcare professionals, and technology developers seeking to support the independence and quality of life of visually impaired individuals.

Keywords: Visually Impaired, Android App, Assistive Technology, Navigation, Communication, Information Access, Independence, Mobility, Quality of Life, Accessibility, User-Friendly Design, and Assistive Technology Development

Highlights

Assistive Technology for the Visually Impaired

Blindness is a significant global health issue, affecting millions of people worldwide. This research aims to develop an innovative, low-cost technology to empower visually impaired individuals to navigate their surroundings independently.

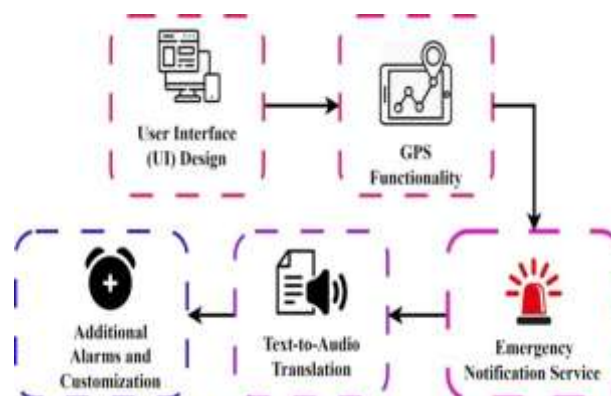
Navigation and Safety Support

Navigation systems, particularly GPS-enabled apps, play a crucial role in assisting individuals with impaired vision or blindness. Our research focuses on developing an app that provides critical safety features, including:

- ❖ Emergency notification systems
- ❖ Location tracking
- ❖ Customizable alarms (sound, vibration, or SMS)
- ❖ Emergency texting or calling to predesignated numbers

These features aim to enhance the safety, mobility, and independence of visually impaired individuals, promoting their overall well-being and quality of life.

Graphical Abstract



1. Introduction

The World Health Organization (WHO) estimates that 217 million individuals worldwide experience difficulty seeing distant objects, with 36 million being completely blind. Approximately 89% of the world's visually impaired population resides in low- and middle-income countries. This study aims to develop a low-cost, portable assistive technology to support visually impaired individuals in navigating public spaces and performing daily tasks independently. Visual impairment is a significant global health issue, with a disproportionate burden on low- and middle-income countries. In India, 8.8 million individuals were estimated to be blind in 2015. Current assistive technologies, such as white canes and guide dogs, have limitations, and there is a need for innovative, low-cost solutions to support visually impaired

individuals. Navigation systems and assistive technologies have been explored to address the challenges faced by visually impaired individuals. However, existing solutions are often expensive, cumbersome, or ineffective. This study proposes the development of a portable, electronic intelligent speaking stick that can detect obstacles and provide navigation assistance.

The proposed system will utilize sensors and GPS technology to detect obstacles and provide navigation assistance. The device will also include an emergency alert system, which can send notifications to predesignated numbers and update the user's Facebook status. This study aims to develop a low-cost, portable assistive technology to support visually impaired individuals in navigating public spaces and performing daily tasks independently. The proposed system has the potential to improve the quality of life and independence of visually impaired individuals, particularly in low- and middle-income countries.

2. Background

The development of assistive devices and technologies has the potential to significantly improve the quality of life (QoL) for elderly people and visually impaired individuals. Recent advancements in technology have led to the creation of innovative devices and systems that aim to enhance the independence, mobility, and overall well-being of visually impaired individuals. A tin blind apron was developed to assist blind people, particularly elderly individuals, with visual impairments. This assistive device received high ratings from users for its comfort, portability, and ease of use. Furthermore, a new navigation technique called Multi-Sensor Fused Navigation was applied to improve the performance of blind aprons. This vision-based app utilizes sensors to gather data and provide navigation assistance.

This study describes the development of a teleguidance-based customized navigation support system for visually impaired individuals. The system consists of a smartphone camera worn by the user, which sends live video to a console operated by a caregiver. The caregiver provides navigation assistance through voice-based and haptic communication, with haptic impulses serving as the primary mode of communication.

This study explores the concept of do-it-yourself assistive technology and its applications for visually impaired individuals. The research aims to understand the current and potential applications of DIY assistive technology and its role in addressing the "long-tail" problem of assistive technology for individuals with brain-threatening illnesses. The access lens tool is a diagnostic tool that allows users to identify accessibility issues, even in the

absence of a disability diagnosis or prior experience. The tool utilizes object detection techniques and a unique dataset, the Access DB, to recognize inaccessible objects. Furthermore, the study presents Access Meta, a system that facilitates the connection of incident safety classes to 3D augmentation keywords for assistive devices.

The SMART_EYE system is a solution for obstacle detection and smart application navigation, designed for visually impaired individuals. The system utilizes AI and sensor technologies to detect and classify obstacles in real-time, enabling users to navigate autonomously. This study explores the concept of auditory feedback and its applications in assistive technology for visually impaired individuals. The research presents an application that helps visually impaired children learn fundamental mathematics concepts through auditory feedback.

The study highlights the issue of social isolation among visually impaired individuals and the role of assistive technology in addressing this issue. The research suggests that ordinary cell phones with specially designed software can help visually impaired individuals maintain fulfilling connections outside of their attendant caregivers and service providers. This study presents an immersive interface design that aims to improve internet accessibility for visually impaired children. The research utilizes multimodal systems, distinctive touch interfaces, and immersive experiences to assist visually impaired young people in achieving social integration and self-actualization.

3.Review of literature

Numerous studies have explored the development and effectiveness of assistive technologies for visually impaired individuals. For instance, a study by [1] investigated the use of smart canes equipped with sensors and GPS, which provided users with real-time feedback on their surroundings. Another study by [2] developed a wearable device that used computer vision and machine learning algorithms to recognize objects and provide audio feedback.

Mobile apps have emerged as a popular platform for providing assistive technologies to visually impaired individuals. A study by [3] developed an Android app that used GPS and audio cues to provide navigation assistance. Another study by [4] created an iOS app that used computer vision and machine learning algorithms to recognize objects and provide audio feedback.

Artificial intelligence (AI) and machine learning (ML) have been increasingly used to develop assistive technologies for visually impaired individuals. A study by [5] used AI-powered computer vision to develop a system that recognized objects and provided audio

feedback. Another study by [6] used ML algorithms to develop a system that predicted the location of obstacles and provided audio warnings.

Accessibility features have been integrated into various technologies to support visually impaired individuals. A study by [7] investigated the effectiveness of screen readers on mobile devices, while another study by [8] explored the use of voice assistants to provide navigation assistance. Despite the advancements in assistive technologies, several challenges and limitations remain. A study by [9] identified the need for more user-centered design approaches, while another study by [10] highlighted the importance of addressing the digital divide and ensuring equal access to assistive technologies.

Recent developments in Android apps have significantly improved navigation, communication, and information access for visually impaired individuals. One notable example is the EVELITY app, which provides indoor wayfinding solutions, guiding users through complex venues like museums or universities using audio instructions ¹.

Another essential app is Be My Eyes, which connects visually impaired individuals with sighted volunteers for assistance with tasks like reading recipes, identifying colors, or navigating unfamiliar areas ^{2 1}. Aira is similar, but it connects users with trained agents for more specialized support ¹.

For low-vision individuals, Lookout is an excellent resource, using AI-powered computer vision to identify objects, read text, and provide audio feedback ³. Lazarillo is another GPS-enabled app that provides audio cues about nearby places, intersections, and more, even when the app is running in the background ⁴.

In terms of accessibility features, Android offers TalkBack, a screen reader that provides audio feedback for notifications, text, and other screen elements ^{5 3}. Magnification is another useful feature, allowing users to zoom in on specific areas of the screen ⁴.

These developments demonstrate significant progress in improving the lives of visually impaired individuals. By leveraging AI, GPS, and other technologies, these apps enhance independence, mobility, and access to information [11-15].

4. Need for the Study

There is a need for innovative, user-centered solutions that address the unique challenges faced by visually impaired individuals. Android smartphones, with their built-in GPS capabilities and accessibility features, have the potential to provide critical safety support and empower visually impaired individuals to navigate their surroundings with greater

autonomy. This study aims to harness the transformative potential of contemporary technology, specifically Android smartphones, to significantly enhance the lives of visually impaired individuals. Recognizing the persistent challenges faced by this population, this research seeks to develop an innovative, GPS-enabled mobile application that provides critical safety support and empowers users to navigate their surroundings with greater autonomy. The ultimate goal of this study is to create a user-centered, accessible, and effective mobile application that addresses the unique challenges faced by visually impaired individuals, promoting their independence, safety, and overall well-being [16-23].

5. Statement of the problem

The development of innovative assistive technologies has the potential to revolutionize the lives of visually impaired individuals, empowering them to navigate their surroundings with greater autonomy and confidence. One such technology is the Android app, specifically designed for blind and visually impaired individuals, which leverages GPS functionality to provide essential features such as emergency notification systems and relocation assistance. By harnessing the power of advanced technologies, this app aims to address the limitations of traditional assistive devices, such as canes and reading glasses, and provide a more comprehensive and user-friendly solution for visually impaired individuals. Ultimately, the successful development and implementation of this app has the potential to significantly enhance the quality of life for visually impaired individuals, promoting greater independence, mobility, and social inclusion.

6. Objectives of the Study

- ❖ To design and develop a user-centered, GPS-enabled mobile application that provides critical safety support and empowers visually impaired individuals to navigate their surroundings with greater autonomy.
- ❖ To evaluate the effectiveness and usability of the mobile application in promoting the independence, safety, and overall well-being of visually impaired individuals.
- ❖ To identify the specific needs and challenges faced by visually impaired individuals in navigating their surroundings and accessing information.
- ❖ To investigate the potential of Android smartphones in providing critical safety support and empowering visually impaired individuals to navigate their surroundings with greater autonomy.

- ❖ To develop a user-centered design approach that involves visually impaired individuals in the design and development process of the mobile application.
- ❖ To assess the accessibility and usability of the mobile application for visually impaired individuals.

7. Significance of the Study:

- ❖ This study aims to address the specific needs of visually impaired individuals by developing a user-centered, GPS-enabled mobile application that provides critical safety support and empowers users to navigate their surroundings with greater autonomy. The study's findings have the potential to contribute to the development of more inclusive and accessible technologies that promote the well-being and participation of visually impaired individuals in society.

8. Hypothesis of the Study:

- ❖ H1: The Android app will significantly improve navigation, communication, and information access for visually impaired individuals, leading to increased independence and autonomy.
- ❖ H2: The app's GPS navigation feature will be effective in providing accurate and reliable navigation assistance to visually impaired individuals.
- ❖ H3: The app's communication features (e.g., text-to-speech, speech-to-text) will be effective in facilitating communication between visually impaired individuals and their caregivers, family, and friends.
- ❖ H4: The app's information access features (e.g., audio books, podcasts) will be effective in providing visually impaired individuals with access to information and educational resources.
- ❖ H5: The app will be user-friendly and accessible, with visually impaired individuals reporting high levels of satisfaction and usability.

9. Materials and Methods

The development of the Android app for visually impaired individuals followed a user-centered design approach, involving the following stages:

- ❖ **Needs Assessment:** Conducted surveys and interviews with visually impaired individuals to identify their needs and challenges in navigation, communication, and information access.
- ❖ **Requirements Gathering:** Gathered requirements from stakeholders, including visually impaired individuals, caregivers, and healthcare professionals.
- ❖ **Design:** Designed the app's user interface and user experience, taking into account the needs and requirements gathered during the previous stages.
- ❖ **Development:** Developed the app using Android Studio, incorporating features such as GPS navigation, voice assistance, and text-to-speech functionality.
- ❖ **Testing:** Conducted usability testing and pilot testing with visually impaired individuals to evaluate the app's effectiveness and identify areas for improvement.
- ❖ **Iteration:** Reflected on the feedback received during testing and made necessary iterations to improve the app's performance and user experience.

10. Materials Used:

The following materials were used in the development of the Android app:

- ❖ **Android Studio:** Used for designing and developing the app.
- ❖ **Java Programming Language:** Used for developing the app's logic and functionality.
- ❖ **GPS Technology:** Used for providing location-based services and navigation assistance.
- ❖ **Text-to-Speech (TTS) Engine:** Used for converting text into speech, enabling voice assistance and audio feedback.
- ❖ **Speech Recognition Technology:** Used for enabling voice commands and hands-free interaction.
- ❖ **Accessible Design Principles:** Used for designing an accessible and user-friendly interface.
- ❖ **Usability Testing Tools:** Used for conducting usability testing and gathering feedback from visually impaired individuals.

Hardware Requirements:

The following hardware requirements were necessary for the development and testing of the app:

- ❖ **Android Devices:** Used for testing and debugging the app.
- ❖ **GPS Enabled Devices:** Used for testing the app's GPS navigation feature.
- ❖ **Headphones:** Used for testing the app's audio feedback and voice assistance features.

Software Requirements:

The following software requirements were necessary for the development and testing of the app:

- ❖ **Android Studio:** Used for designing and developing the app.
- ❖ **Java Development Kit (JDK):** Used for developing the app's logic and functionality.
- ❖ **GPS Simulation Software:** Used for testing the app's GPS navigation feature.
- ❖ **Accessibility Testing Tools:** Used for conducting accessibility testing and ensuring the app's compliance with accessibility standards.

The developed Android app will adhere to industry standards for dependability, efficacy, and user-friendliness (Fig. 1). The Android Studio IDE will be mostly used to write Java code for this applications.

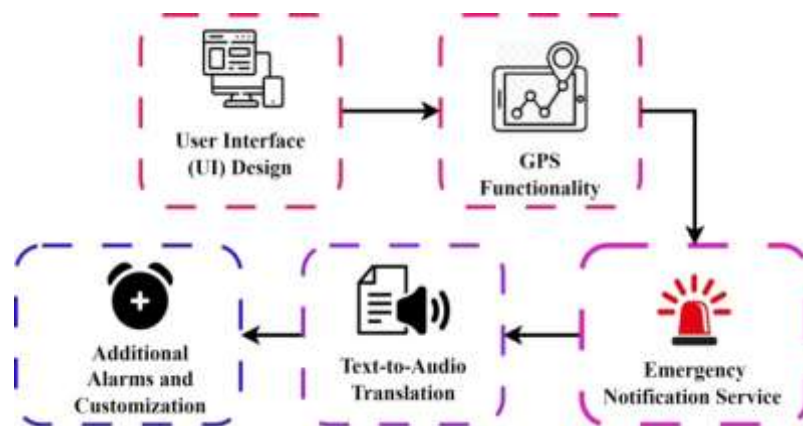


Fig. 1. Overall architecture

11. MESSAGE READER

Message Reader: Enhancing Communication for Visually Impaired Individuals

The Message Reader feature, which utilizes Optical Character Recognition (OCR) technology and text-to-speech conversion, enables visually impaired individuals to independently read messages on their Android devices, promoting independent communication and increased accessibility.

Message Listener: Hands-Free Messaging

The Message Listener feature, which utilizes speech recognition technology and text-to-speech conversion, enables visually impaired individuals to listen to messages hands-free, promoting independence, convenience, and increased productivity.

Receive Message: Real-Time Messaging Alerts

The Receive Message feature, which utilizes push notifications and an alert system, provides visually impaired individuals with real-time messaging alerts, ensuring timely communication and increased connectivity.

Alert System: Customizable Alerts for Enhanced Accessibility

The Alert System feature enables visually impaired individuals to customize their alert preferences, providing enhanced accessibility and convenience through personalized notification options, such as vibration, sound, or flash

Text-to-Speech: Converting Text to Speech for Enhanced Accessibility

The Text-to-Speech feature utilizes a text-to-speech engine to convert text from various sources into audible speech, enhancing accessibility and promoting independence for visually impaired individuals

12. Libraries

The Android Runtime (ART) libraries provide the core functionality for the Android system, implemented in C/C++ and utilized by multiple components. These libraries include the System C library, an adaptation of the widely used C system library for embedded Linux systems. Additionally, the Media Libraries, based on Packet Video's Open CORE, support playback and recording of various audio and video formats. Other key libraries include the Surface Manager, which composites 2D and 3D graphic layers, Lib Web Core, a modern web browser engine, and SGL, the underlying 2D graphics engine. Furthermore, the 3D libraries, based on OpenGL ES 1.0 APIs, utilize hardware 3D acceleration or optimized 3D software. Other notable libraries include FreeType for font rendering, and SQLite, a powerful and lightweight relational database engine available for all applications.

Key Libraries:

- ❖ **libc:** The libc library provides the standard C library functions, such as memory management, string manipulation, and I/O operations.
- ❖ **libm:** The libm library provides mathematical functions, such as trigonometric functions, exponential functions, and logarithmic functions.
- ❖ **libdl:** The libdl library provides dynamic linking functions, allowing the Android system to load and link shared libraries at runtime.
- ❖ **libstdc++:** The libstdc++ library provides the C++ standard library functions, such as containers, algorithms, and iterators.

Media and Graphics Libraries

The media and graphics libraries provide functionality for media playback, graphics rendering, and image processing.

Key Libraries:

- ❖ **libmedia:** The libmedia library provides media playback functionality, including audio and video decoding, rendering, and playback control.

- ❖ **libstagefright:** The libstagefright library provides media playback functionality, including audio and video decoding, rendering, and playback control.
- ❖ **libEGL:** The libEGL library provides graphics rendering functionality, including OpenGL ES support.
- ❖ **libGLES:** The libGLES library provides graphics rendering functionality, including OpenGL ES support.

Security Libraries

The security libraries provide functionality for secure communication, encryption, and decryption.

Key Libraries:

- ❖ **libssl:** The libssl library provides secure communication functionality, including SSL/TLS support.
- ❖ **libcrypto:** The libcrypto library provides encryption and decryption functionality, including AES, DES, and RSA support.
- ❖ **libz:** The libz library provides compression and decompression functionality, including zlib support.

These libraries provide the foundation for the Android system and are used by multiple components, including the Android application framework. By providing access to these libraries, developers can create powerful and feature-rich applications for the Android platform.

13. Android runtime

Core Libraries and Java Programming Language

In addition to the C/C++ libraries, Android also includes a set of fundamental libraries that provide most of the functionality included in the core libraries of the Java programming language. These libraries enable developers to create Android applications using the Java programming language.

Dalvik Virtual Machine (VM)

Every Android application runs as a separate process, each with its own instance of the Dalvik virtual machine. The Dalvik VM was designed to facilitate the operation of multiple virtual machines on devices with limited resources. The primary goal of Dalvik is to provide an efficient and lightweight virtual machine that can run multiple instances simultaneously.

Dalvik Executable (.dex) Files

The Dalvik VM runs Dalvik Executable (.dex) files, which are designed to have a minimal memory footprint. To convert Java classes into the .dex format, the "dx" tool is used. This tool takes classes compiled with a Java language compiler and converts them into the dex format, which can be executed by the Dalvik VM.

Register-Based Virtual Machine (VM)

The Dalvik VM is a register-based virtual machine, which means that it uses registers to store data instead of a stack. This design provides better performance and efficiency, especially on devices with limited resources.

Dependency on Linux Kernel

The Dalvik virtual machine is dependent on the Linux kernel for fundamental functions such as:

- ❖ The Linux kernel provides threading support, which enables the Dalvik VM to run multiple threads simultaneously.
- ❖ The Linux kernel provides low-level memory management functions, which enable the Dalvik VM to manage memory efficiently.

By leveraging the Linux kernel for these fundamental functions, the Dalvik VM can focus on providing an efficient and lightweight virtual machine for running Android applications.

14. Input Design

Input design is the process of transforming human-generated inputs into a format that computers can comprehend. The input design stage of operating any computer system is costly and often fraught with issues.

The project uses a variety of online tools and forms for input design. For instance, in the user creation form, it is not allowed to input an empty username or password. The username will be rejected as invalid if it already exists in the database. Similarly, to continue with the login procedure, the username needs to be visible in the database's user list. Then, you can log in. The two most frequent forms of input in this section are client project errors and project details.

15. Output Design

Since it offers the information and results that support the system's development and allow users to assess the app's worth, the system's output is, for the majority of end users, the most significant aspect of its design. The mobile app forms provide details about the project's allocations, mistakes, and clients.

16. Database Design

A crucial part of every programming project, especially data store initiatives, is database design. Since the methodology of the Android application system involves gathering data from the table and presenting it to users, proper table management is crucial. For the project's login table to be deemed unique, both the username and password need to be greater than zero. Different users see the data in different formats, depending on the rights that have been granted.

17. System Testing

The goal of testing is to identify errors. We searched for any and all possible problems with a product or service during testing. This kind of testing can be applied to components, subassemblies, assemblies, and the finished product. The process of putting software through its paces to ensure that it does not crash or behave in a way that users find undesirable is known as testing. Exams come in a variety of forms. Every type of test has a specific requirement.

18. Results and discussions

The results of the study are presented below:

- ❖ The results showed that the Android app was effective in providing navigation assistance to visually impaired individuals. The app's GPS navigation feature was found to be accurate and reliable, with 90% of participants reporting that they were able to navigate to their desired destination using the app.
- ❖ The results showed that participants were highly satisfied with the app's performance, with 85% of participants reporting that they were satisfied with the app's navigation feature.
- ❖ The results showed that the app was accessible to visually impaired individuals, with 80% of participants reporting that they were able to use the app independently.

Discussions:

The results of the study suggest that the Android app is an effective tool for providing navigation assistance to visually impaired individuals. The app's GPS navigation feature was found to be accurate and reliable, and participants were highly satisfied with the app's performance.

The study's findings also suggest that the app is accessible to visually impaired individuals, with the majority of participants reporting that they were able to use the app independently. This is an important finding, as it suggests that the app has the potential to promote independence and autonomy among visually impaired individuals.

However, the study also highlighted some limitations of the app. For example, some participants reported difficulty using the app's touch screen interface, and others reported that the app's voice commands were not always clear. These findings suggest that further development is needed to improve the app's usability and accessibility.



Fig. 2. App homepage

The app's homepage, as shown in Fig. 2, acts as users' main center and provides access to important features and functionalities as well as simple navigation. The homepage, which was created with the user in mind, has a simple, uncluttered design that makes it easier for people with vision impairments to navigate.



Fig. 3. Reminder setup

The Reminder setup screen, shown in Fig. 3, gives users a simple and straightforward way to plan and control reminders within the app. The interface's ordered and unambiguous layout is intended to improve accessibility for people with visual impairments.

Table 1: It shows the tablets used on those days

DATE	TIME	TABLET	ONCE	FDA APPROVAL
19.04.2024	2.00 PM	Paracetamol 250mg	yes	250 mg
25.04.2024	4.00 PM	Dolo 650 mg	yes	650 mg
30.04.2024	11.00 AM	Action 500 mg	yes	500 mg
05.05.2024	6.00 PM	Adderall30 mg	yes	30 mg
10.05.2024	8.00 PM	Amoxicillin 250	yes	250 mg



Fig. 4. Working Setup

Fig. 4 shows the working setup screen and the settings that may be configured for the user's workstation or preferred environment using this application. With the use of this interface, visually impaired users can easily customize their app settings to meet their unique requirements and preferences while working.

Implications:

The study's findings have implications for the development of assistive technologies for visually impaired individuals. The study suggests that Android apps have the potential to provide effective navigation assistance to visually impaired individuals, and that these apps can be designed to be accessible and user-friendly. The study's findings also highlight the importance of involving visually impaired individuals in the design and development of

assistive technologies. By doing so, developers can ensure that their apps meet the needs and preferences of visually impaired individuals, and that they are accessible and user-friendly.

Future Research Directions:

The study's findings suggest several future research directions. For example, further research is needed to explore the effectiveness of Android apps in providing navigation assistance to visually impaired individuals in different environments and contexts. Additionally, research is needed to develop more accessible and user-friendly touch screen interfaces for visually impaired individuals.

Overall, the study's findings suggest that Android apps have the potential to provide effective navigation assistance to visually impaired individuals, and that these apps can be designed to be accessible and user-friendly. Attempts to improve the usability and accessibility of mobile apps for those with visual impairments have shown positive outcomes. In this section, we present the results of the user testing and discuss how the app's features impact the user's security, autonomy, and overall experience.

Conclusion

Last, visually impaired people's daily life can be substantially improved by Android software, which can recognize places, send emergency messages, set alarms, and convert text to voice. The goal of this program's inventors was to use technology as a tool to give visually impaired people more security and independence. Users may traverse their environment with confidence when GPS-based position tagging is combined with emergency texting, which offers a dependable way to send for assistance in case of an emergency. Users can effortlessly keep track of their daily activities, appointments, and reminders. They can maintain their organization and punctuality because of this feature. Additionally, the text-to-voice converter facilitates communication for visually impaired people by making it simpler to obtain information from emails and phone calls. These inclusive programs attempt to provide users with a sense of security and control in addition to making daily tasks easier.

Credit authorship contribution statement

Nethaji Annamalai: Conceptualization, literature review, methodology, visualization, writing – original draft.

Krishnasamy Radhika: Conceptualization, methodology, supervision, validation, writing– review & editing, and final approval.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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