Review Article

Review of Navigation Systems Used for Visually Impaired Individuals

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Abstract: Vision impairment affects a large number of individuals, necessitating support to carry out daily activities. With the advancement of technology, various devices have been developed to assist them in recognizing objects and obstacles, as well as facilitating navigation both indoors and outdoors. The working principles and functions of these devices serve as the basis for their classification. This article highlights modern and significant devices that offer key features such as obstacle detection, portability, navigation, and integration with mobile devices for users with visual impairments. Descriptions of standard operational procedures for various types of assistive technologies are provided, followed by a discussion of essential device features such as sensor types, operating time, response time, range, feedback modalities, coverage, weight, durability, and cost. Given the wide range of algorithms available to support assistive technologies, this article also reviews some of the most commonly used algorithms. The effectiveness of these devices is evaluated through a review of various systems developed for the visually impaired. The article also examines how assistive vision devices have undergone significant transformation by adapting to technological advancements over time and provides several recommendations for future research directions.

Keywords: Visually impaired, navigation systems, obstacle detection, assistive devices, visually impaired.

Citation: Wulandari, I. Y., Utomo, S., Prihantono, J. A., Alti, R. M., & Hidayat, R. (2025). Review of navigation systems used for visually impaired individuals. *Iota*, 5(3). https://doi.org/10.31763/iota.v5i3.956

Academic Editor: Adi, P.D.P

Received: June 12, 2025

Accepted: July 13, 2025

Published: August 01, 2025

1. Introduction

Vision loss can be categorized as either partial or total loss. Approximately 2.2 billion people worldwide experience visual impairment, whether at near or far distances, based on visual acuity levels (WHO, 2022). All individuals affected by this condition require regular care. The number of people with visual impairments, including blindness, continues to rise along with the global population, despite the availability of various treatment methods. Daily activities for individuals with visual impairments often present numerous challenges. These include difficulties in recognizing objects, identifying travel routes, crossing streets safely, and using public transportation. Additionally, they may struggle with reading printed documents, interacting with others, and navigating indoor environments (Kbar et al., 2016).

Unfortunately, the inconsistent availability of assistive technologies and the overall lack of standardized environmental design further exacerbate the existing issues (Tyagi et al., 2021). The environment for individuals with visual impairments should be equipped with adequate facilities to enable them to adapt and become independent by utilizing skills, mobility aids, and other assistive devices. This highlights the importance of raising public awareness, promoting environmentally friendly urban design, ensuring accessible transportation, and advancing inclusive technologies to enhance the overall well-being of individuals with visual impairments. Therefore, the objective of this study is to identify the significance of navigation systems for individuals with visual impairments (Akilandeswari et al., 2022).

Navigation systems are essential for enhancing the independence and mobility of individuals with visual impairments (Messaoudi et al., 2022). By providing real-time information about the surrounding environment and guiding users along their intended routes, these systems are expected to boost users' confidence and enable them to explore new or unfamiliar areas (El-Taher et al., 2021). In addition, navigation systems offer auditory cues and guidance, improving safety for visually impaired individuals and helping them avoid obstacles, such as when crossing streets or navigating complex public transportation routes, thereby reducing the risk of injury and accidents on the road (Atitallah et al., 2023; Afif et al., 2021).

2. Literature Review

2.1 Navigation Devices for the Visually Impaired

The advancement of assistive devices for the visually impaired has become a prominent topic of discussion, including during the pandemic period. Numerous studies have explored various aids and technologies designed for individuals who are blind or visually impaired (Kathiria et al., 2024). Key contributions have focused on popular keywords related to visual impairment, the development of assistive tools for the visually impaired, exploration of testing and experimentation in assistive device development, the most commonly used algorithms in creating such devices, and the innovation of assistive technologies for the visually impaired (Elmannai & Elleithy, 2017). This paper presents an in-depth investigation into these topics.

Many navigation applications and devices for the visually impaired offer customization options as technology advances, allowing users to tailor the interface and settings to meet their specific needs. These systems have become flexible and adaptable tools due to their ability to be personalized (Ponchillia et al., 2020; Chen et al., 2015). Navigation systems also promote continuous learning, helping visually impaired individuals to remember new routes they have taken and to become familiar with their surroundings. This ongoing learning process can enhance their independence and ability to navigate their environment (Ferah, 2025)

Navigation systems are highly beneficial for individuals with visual impairments, as they enable easier, safer, and more independent mobility, thereby enhancing their quality of life by facilitating interaction in public spaces (Ferah, 2025; Messaoudi et al., 2022). These systems are essential for improving the lives of people with visual impairments, increasing access to education and career opportunities, and fostering greater social engagement. However, several gaps have been identified concerning navigation systems for the visually impaired, giving rise to the following research questions:

- RQ1: What are the types of navigation systems for the visually impaired?
- RQ2: How do navigation systems integrate with mobility assistive technologies for the visually impaired?

The objective of this navigation system review is to analyze and compare various navigation systems designed for individuals with visual impairments.

2.2 Assistive Devices for Individuals with Visual Impairments

The history of assistive tools for individuals with visual impairments has undergone a long and evolving journey. It began with the use of guide dogs by visually impaired individuals for mobility, followed by the adoption of canes, the introduction of tactile alphabets for reading purposes, and eventually the use of technology to enhance daily efficiency (Guide dog, 2025; Huang et al., 2022). With advancements in technological innovation, traditional wooden aids have transformed into sophisticated devices powered by microcontrollers. Some of the technologies available today have even

supported researchers in developing solar-powered systems to produce more environmentally friendly products. These assistive tools can now adapt to emergencies and have proved particularly useful during the COVID-19 pandemic, such as for tracking COVID-19 cases among visually impaired individuals with limited sight (Apprey et al., 2022). Some studies examine the latest technologies developed for individuals with visual impairments by utilizing key features such as portability, navigation, detection, and advancements in mobile technology (Kim et al., 2016).

One of the devices that can be utilized in the development of detection tools is the sensor. Sensors, when combined with cameras, can support the activities of individuals with visual impairments. Various types of sensors function to measure the distance between visually impaired individuals and surrounding objects, while cameras capture images of these objects for further processing. Commonly used sensors in the development of assistive devices include Ultrasonic, RFID, GPS, BLE Beacons, IR, GSM, and LIDAR. According to Silva and Wimalaratne (2017), ultrasonic sensors play a significant role in supporting assistive tools for the visually impaired. Additionally, research by Madrigal et al. (2018) investigated the use of RFID in building corridors to detect objects. Chaccour and Badr (2016) proposed a GPS-based system, while Ton et al. (2018) introduced a LIDAR-based detection system concept that aids in spatial sensing and translates spatial data into sound with varying tones. Stereo sounds with respective pitch levels convey information about the angular orientation and horizontal distance of objects, thereby providing users with visual impairments an improved spatial perception of their surroundings and potential obstacles.

3. Method

We have made efforts to review and analyze articles sourced from reputable journals such as ScienceDirect, Taylor & Francis (Tandfonline), PubMed, and Google Scholar, published between 2013 and 2025, to ensure the relevance and validity of the information used in this study. Several reviews are presented to evaluate assistive tools and technologies that support individuals with visual impairments. The discussion is categorized based on the types of devices, the features and performance of assistive tools, the utilization of renewable energy in these devices, and recommendations for their further development. To date, technology has played a crucial role in the development of assistive devices for the visually impaired, enabling them to interact with their environment more independently and safely. These innovations help improve mobility, environmental awareness, and the overall quality of life for individuals with visual impairments. The contributions of technology cannot be overlooked, as highlighted by several researchers, as shown in Table 1.

Aspects directly related to assistive devices provide insights into how to select such tools based on their features under specific conditions. Most of the features are closely associated with hardware components; however, physical characteristics alone do not fully represent the device's overall functionality. Software plays a crucial role in determining the development approach of assistive devices according to specific user needs. Algorithms used in object detection, image classification, and segmentation, character recognition, feature extraction, and detection serve as key elements in developing assistive tools to achieve targeted objectives. Similarly, the utilization of renewable energy plays an important role in the advancement of assistive technologies for individuals with visual impairments.

Table 1. Contributions of Reviewed Papers to the Needs of Individuals with Visual Impairments.

Author (Year)	Classification of the device types	Device Features and Performance	Utilization of Renewable Energy	Development Recommendations
Islam et al (2019)	✓	✓	-	-
Calabrese et al (2020)	-	-	✓	-
Romlay et al (2021)	✓	✓	-	-
Zafar et al (2022)	✓	✓	-	-
Rizwan et al (2023)	✓	✓	✓	✓

4. Result and Discussion

4.1 Utilization of Technology as an Assistive Tool for Navigation

This article reviews the most recent and critical devices designed with key features such as portability, navigational capabilities, detection functions, and support for mobile devices to assist individuals with visual impairments. These devices are classified into four main categories, further differentiated based on their functions. The first discussion focuses on the classification of assistive technologies according to their level of portability, namely, wearable and non-wearable devices. Common technologies used by individuals with visual impairments include tools worn on the head, ears, waist, legs, and hands. These devices operate by collecting and analyzing information from the surrounding environment and then delivering feedback to the user through vibrations, sound, or wave reflections.

Various types of sensors are used to measure the distance between objects and users with visual impairments, while cameras function to capture object images for further processing. Several sensors commonly applied in the development of assistive devices include ultrasonic sensors, RFID, GPS, BLE beacons, infrared (IR), GSM, and LIDAR. Silva and Wimalaratne (2017) proposed an ultrasonic sensor–based system to support the mobility of visually impaired individuals. In a study by Madrigal et al. (2018), dark corridors in buildings were detectable using passive RFID technology. Chaccour and Badr (2016) introduced a GPS-based system, while Nair et al. (2018) designed a system using Bluetooth Low Energy (BLE) for positioning and navigation. Jafri et al. (2017) also developed a visual obstacle detection system utilizing infrared technology integrated with other technologies to enhance navigation system effectiveness. Setiadi et al. (2020) developed a proof-of-concept LIDAR (Light Detection and Ranging)–based detection system, known as LASS (LIDAR-Assisted Spatial Sensing), which gathers spatial information around the user using LIDAR sensors and converts it into stereo sound with pitch variations. Chaccour and Badr (2015) designed a system architecture using IP cameras to support the mobility of visually impaired individuals. Sivan and Darsan (2016) discussed a webcam-based detection system specifically intended for blind users.

The ability to respond in real time is a crucial feature that must be integrated into any assistive technology designed for individuals with visual impairments. Most devices today are capable of detecting and responding to obstacles immediately. For example, Prudhvi and Bagani (2013) developed a system in which a capacitive touch-based Braille keypad is used to send emergency requests, including the user's current location. Devices with real-time response capabilities exhibit slightly different characteristics compared to other tools. In certain cases, assistive devices are specifically designed for indoor use, while others are developed for outdoor navigation. For instance, Akilandeswari et al. (2022) proposed an indoor navigation system based on a Convolutional Neural Network (CNN) using an autoencoder approach. Conversely, Meliones et al. (2022) designed a wearable device for outdoor navigation that integrates ultrasonic sensors and a GPS module. In outdoor applications, environmental factors must also be considered, such as in the system developed by Vivek et al. (2022), initially designed to facilitate navigation in snowy terrain. On cloudy or rainy days, the device relies on battery power, whereas on sunny days, solar energy is utilized as the primary power source. Navigation becomes particularly challenging during heavy rain or snowfall. According to Rizzo et al. (2017), stereo camera devices show limited performance under extreme weather conditions such as rain or snow. However, system accuracy can be significantly improved through the addition of infrared (IR) sensors.

In the previous section, various key aspects directly related to assistive devices were discussed, including a summary of how to select such devices based on features suited to specific conditions. Generally, these features are closely tied to hardware components. Although the physical aspects of assistive tools were not elaborated in detail, it was highlighted that software plays a crucial role in the technological development process for individuals with visual impairments. The term "assistive device" encompasses both hardware and software components. Algorithms for object detection, image classification, and segmentation, character recognition, and feature extraction are essential elements in designing assistive technologies for specific functions (Anthony and Kusnadi, 2021). Character recognition technologies are particularly vital in assistive devices for the visually impaired. Moreover, the ability to detect objects and obstacles is also critical, making the application of technologies such as Convolutional Neural Networks (CNNs) for pattern recognition, image processing, and voice analysis highly relevant. Two versions of the "You Only Look Once" (YOLO) algorithm, YOLOv1 and YOLOv3, are widely employed in object detection processes. These algorithms have been extensively utilized in the development of assistive devices for individuals with visual impairments. Joshi et al. (2020) outlined a variety of algorithms used in object detection, image classification, image segmentation, character recognition, and feature extraction and detection.

4.2 Assistive Devices Utilizing Renewable Energy Sources

Recently, society has begun to shift toward renewable energy sources, as conventional batteries are increasingly considered outdated and potentially harmful to the environment. One of the most widely used sustainable energy sources is solar power. Numerous devices that integrate solar panels either as a primary power source or as a supplement to batteries have been extensively researched and implemented. Aymaz and Cavdar (2016) discussed the use of solar panels in an Ultrasonic Assistive Headset. Ramadhan (2018) examined a wearable smart system powered by solar energy. Midi et al. (2021) explored the development of a smart cane equipped with a solar power module, while Calabrese et al. (2020) designed a low-cost, solar-powered portable assistive device to support real-time object recognition for visually impaired individuals in their daily activities. The use of solar energy significantly reduces battery replacement costs and proves particularly beneficial in developing countries. Apprey et al. (2022) investigated

visual impairment issues in Ghana and proposed a solar-powered navigation cane equipped with a rechargeable battery to ensure a stable and affordable power supply.

4.3 Recommendations for Future Research Directions

The development of new assistive devices for individuals with visual impairments must continue to be encouraged. Although technology has advanced and various types of assistive tools are now available, the level of utilization remains relatively low (Gori et al., 2016). In the future, ongoing research on assistive technologies is essential to provide practical guidance for device designers, including considerations for the use of alternative energy sources. The use of solar panels or modules, either as replacements or supplements to batteries, is highly recommended due to their environmentally friendly nature. Researchers should further explore the broader application of renewable energy sources.

In addition to solar power, researchers are also encouraged to investigate other alternative energy sources. For example, Ramalingam et al. (2021) developed an IoT-based tracking system integrated into smart shoes that harnesses energy generated from foot movement. This illustrates the potential of utilizing human motion-based energy harvesting systems in assistive devices. Furthermore, Kassim et al. (2021) proposed a wireless charging system using energy harvesting techniques applied to wearable mobility aids for individuals with visual impairments.

5. Conclusion

This study discusses various issues related to the use of assistive devices for individuals with visual impairments in supporting their daily activities. Based on the analysis, it can be concluded that no single device can yet be considered truly optimal. Therefore, there is a need for the design of intelligent systems capable of integrating various essential features to provide maximum support for visually impaired individuals. This article is expected to serve as a useful reference for researchers and scientists interested in developing technological solutions in this field. Future researchers are encouraged to advance the work by formulating improved recommendations, as there are still relatively few genuinely effective devices. We also hope this paper will encourage developers to enhance collaboration with medical professionals, deepen their understanding of medical system requirements, and gain better insight into the conditions and needs of visually impaired users as the primary target of their products. Going forward, we recommend that assistive systems leverage technological advancements to deliver solutions that are widely accessible and capable of responding to emergencies. We believe that the analysis and recommendations presented in this paper can serve as a foundational starting point for further research in the field of assistive technologies for the visually impaired.

Acknowledgments: We would like to thank *Lembaga Penelitian dan Pengabdian kepada Masyarakat* (LP2M) or Institute for Research and Community Service, Nurtanio University, for internal research funding.

Author contributions: The authors are responsible for building Conceptualization, Methodology, analysis, investigation: **Wulandari, I. Y., Utomo, S., Prihantono, J. A., Alti, R. M., & Hidayat, R.** data curation, writing—original draft preparation, writing—review and editing, visualization: **Wulandari, I. Y., Utomo, S., Prihantono, J. A., Alti, R. M., & Hidayat, R.** supervision of project administration, funding acquisition: **Wulandari, I. Y., Utomo, S., Prihantono, J. A., Alti, R. M., & Hidayat, R.** and have read and agreed to the published version of the manuscript.

Funding: The study was conducted without any financial support from external sources.

Availability of data and Materials: All data are available from the authors.

Conflicts of Interest: The authors declare no conflict of interest.

Additional Information: No Additional Information from the authors.

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