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Assistive Technologies for the Visually Impaired: A Review

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Abstract

Assistive technologies for the visually impaired have evolved from simple hardware-based tools to advanced artificial intelligence-powered systems that enhance independence, safety, and quality of life. This review systematically analyzes 80 studies and commercial products published between 2000 and 2025, identified through IEEE Xplore, PubMed, Scopus, and Google Scholar. The methodological framework ensures comprehensiveness and reproducibility by classifying technologies into visual imagery systems, non-visual data systems, map-based solutions, 3D sound systems, smartphone-based applications, and commercial products. Findings highlight the increasing role of deep learning, multimodal integration (encompassing vision, hearing, and touch), and wearable devices in enhancing navigation and accessibility. Policy implications emphasize the need for affordable, inclusive, and user-centered designs, particularly in low-resource settings. This study provides a foundation for future innovations in smart glasses, haptic devices, and artificial intelligence-powered navigation aids, bridging the gap between research and real-world deployment.

Categories: Accessibility, AI applications, Human-Computer Interaction (HCI) in Graphics
Keywords: wearable robotics, independence for visually impaired, assistive technology, human performance augmentation, artificial intelligence (ai), human-computer interface

Introduction And Background

Introduction

Effective and safe navigation is one of the most important human needs in all periods of history. Routing is done for various purposes, such as traveling, working, shopping, or rather for all the actions we do routinely in life. Besides transportation means, which facilitate our relocations, it can be said that the sense of sight is at the highest level of importance. Being aware of what is happening around us, and what obstacles are in our path and threatening us, is possible only by relying on the sense of sight. Considering all this, moving around in unfamiliar environments without vision is difficult. Vision impairment occurs when an eye condition affects the visual system and its vision functions. Everyone, if they live long enough, will experience at least one eye ailment throughout their lifetime that will require adequate care. According to the World Health Organization [1] globally, at least 2.2 billion people have some form of visual impairment or complete blindness. The comparative ratio of all types of vision problems is shown in Figure *1*, Table *1*, and Figure *2* [2]. Being blind or partially sighted does not mean losing the independence to go wherever we want. People who are blind or have limited vision can travel independently daily with devices that are suitable for them. So far, various navigational aids such as white cane [3], guide dog [4], trained volunteers [5], echo (using sound waves) [6], signs and clues [7], sense of hearing or smell, tactile pavements [8], and orientation and mobility are available [9]. Today, with the advancement of technologies, assistive tools, which are listed in Tables *2* and 3, enable them to overcome various barriers to independent living.

According to Figure *1* and Table *1*, Asia has the largest population of people with visual impairment, due to its large population size and high prevalence of eye diseases such as diabetic retinopathy and cataracts. These diseases are particularly prevalent in areas with limited access to early diagnosis and treatment. The disparity in medical resources between urban and rural areas exacerbates this challenge, as many people in remote communities lack access to specialized eye care.

Africa ranks second in terms of the prevalence of blindness, largely driven by inadequate health care infrastructure and the persistent impact of preventable infectious diseases such as trachoma. Meanwhile, Europe and North America experience lower rates of vision loss due to developed health care systems that emphasize preventive measures and early treatment. Oceania, while reporting fewer cases overall, faces particular challenges, particularly among indigenous populations, where limited access to health care leads to visual impairment.

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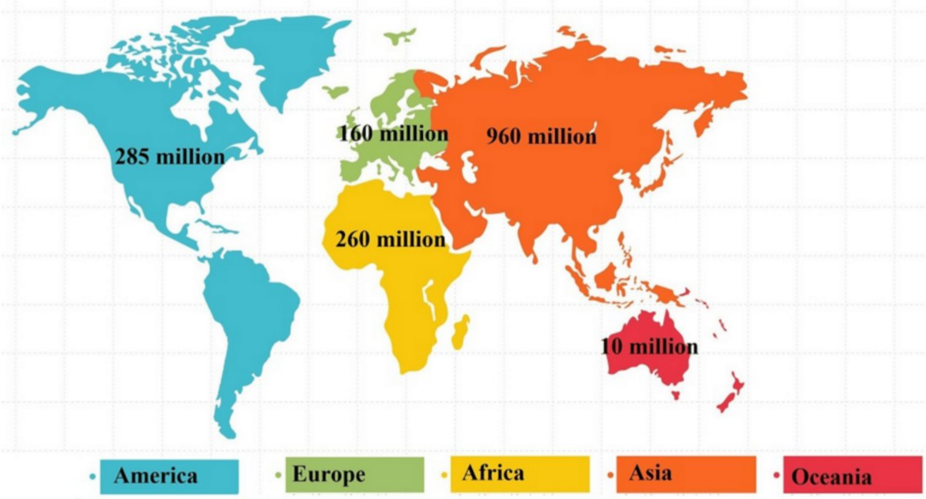

FIGURE 1: Global prevalence of blindness and visual impairment by continent

Continent	Population (Million)	Primary Causes of Blindness	Healthcare Accessibility	Key Challenges	Access to Assistive Technologies
Asia	960	Diabetes, glaucoma, cataracts, diabetic retinopathy	Moderate to high (in developed countries)	Disparities in healthcare access between urban and rural areas	Moderate (advanced in developed regions)
Africa	260	Cataracts, trachoma, vitamin A deficiency	Low	Shortage of medical infrastructure and sustainable treatment programs	Low (minimal access to advanced tools)
Europe	160	Age-related macular degeneration, cataracts, diabetes	High	Rising prevalence of vision impairment due to aging	High (significant progress in smart glasses and sensory aids)
Americas	285	Diabetes, aging-related vision loss, macular degeneration	Moderate to high	Inequality in healthcare access between urban and rural areas	High (advanced AI-powered assistive solutions like OCR and smart sensors)
Oceania	10	Genetic disorders, diabetes, ocular trauma	Limited	Lack of sufficient healthcare infrastructure	Low (restricted availability of advanced visual aids)

TABLE 1: Factors that affect visual impairment

Source: [2]

OCR, Optical Character Recognition

Figure *2* provides an overview of the global prevalence of blindness and visual impairment by continent. Four main categories of visual impairment are identified in this table: Near Vision (Near VI), Mild Vision (Mild VI), Moderate to Severe Vision (Moderate to Severe VI), and Blindness. Different factors affect the prevalence of blindness, and countries with stronger health systems tend to experience lower rates of visual impairment. Vitamin A deficiency can be a contributing factor to blindness, and lack of early screening and timely treatment can also cause many cases of blindness.

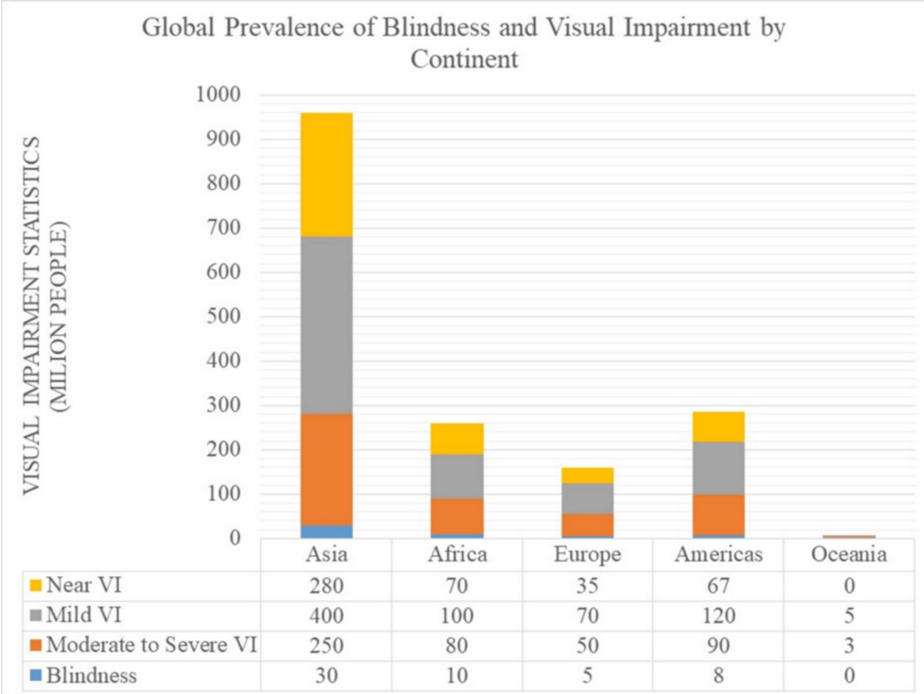

FIGURE 2: Global distribution of people with vision problems

VI, Visual Impairment

Global South and digital divide

The persistence of visual impairments in the Global South is shaped by multiple dimensions:

• Limited access to early diagnosis and treatment for cataracts, diabetic retinopathy, and trachoma [10]. High costs of artificial intelligence (AI)-powered assistive devices restrict accessibility for low-income populations [11], as well as lack of rehabilitation centers, trained personnel, and distribution networks for assistive technologies. Weak regulatory frameworks and limited government support hinder large-scale adoption.

• The digital divide further compounds these challenges: Limited internet access in rural areas prevents the use of cloud-based assistive solutions [12]. Smartphones, augmented reality (AR) glasses, and AI-powered devices remain out of reach for many users. Lack of training in using advanced devices reduces adoption rates.

Bridging this gap requires subsidized or low-cost assistive devices designed for low-resource environments, as well as creating offline-capable AI systems that do not rely solely on cloud connectivity and developing community-based educational programs to increase digital literacy among visually impaired people.

Theoretical framework

The adoption and effectiveness of assistive technologies for visually impaired individuals can be better understood through established theoretical models. These frameworks provide insights into how users perceive, accept, and integrate such technologies into their daily lives:

Technology Acceptance Model (TAM): TAM emphasizes perceived usefulness and perceived ease of use as key determinants of technology adoption [13]. In the context of assistive AI tools, visually impaired users are more likely to adopt smart glasses or navigation systems if they believe these devices significantly enhance independence and are easy to operate.

Unified Theory of Acceptance and Use of Technology: This theory extends TAM by including social influence and facilitating conditions [14]. For visually impaired individuals, community support, affordability, and institutional backing (e.g., healthcare systems, NGOs) play a critical role in adoption.

Diffusion of Innovation: This theory [15] explains how innovations spread through populations. Assistive technologies often face slower diffusion in the Global South due to infrastructural and economic barriers. Early adopters, such as rehabilitation centers and advocacy groups, play a vital role in accelerating acceptance.

Human-Computer Interaction and Accessibility Theories: These frameworks highlight the importance of inclusive design, multimodal feedback (audio, haptic, AR), and user-centered evaluation . They ensure that assistive devices are not only technologically advanced but also socially and culturally adaptable.

By applying these frameworks, this study situates smart glasses, haptic devices, and AI-powered navigation aids within a socio-technical context, offering deeper insights into adoption challenges, user satisfaction, and sustainability.

Objectives

According to Table *2*, this study aims to classify, analyze, and evaluate assistive technologies for visually impaired people with a particular focus on electronic navigation aids, position-finding devices, and electronic travel aids. The study pursues the following objectives:

• To systematically classify assistive technologies based on functional capabilities, sensor integration, and navigation methods.

• To assess the advantages and limitations of different systems, including camera-based solutions, Global Positioning System (GPS)-equipped devices, and sensor-based navigation tools.

• To examine the role of input units in assistive devices and assess their impact on usability, accuracy, and adaptation to environmental obstacles.

• To compare commercial and research solutions, identifying gaps between technological advances and the needs of visually impaired users.

These objectives help establish a scientific foundation for future innovations to guide the development of smart glasses and wearable technologies that enhance the independence, safety, and quality of life of people with visual impairments.

To explore and systematically classify assistive technologies and commercial solutions for visually impaired individuals, with a focus on smart glasses and navigational tools. This comprehensive review aims to analyze current innovations, evaluate commercial products, and address the diverse needs of visually impaired communities to improve their independence, safety, and quality of life while providing a foundation for the design of future assistive technologies.

Type	Electronic Orientation Aids	Position Locator Devices	Electronic Travel Aids
Function	Camera and various sensors	Based on GPS and GIS	Sensor Technology
Disadvantages	Overweight	GPS signals obstacles	The input unit(s)

TABLE 2: Assistive systems

GPS, Global Positioning System; GIS, Geographic Information System

Table *3* illustrates, sensors used in environment and obstacle detection each have their advantages and limitations that must be carefully evaluated depending on the application conditions. Conventional cameras are capable of producing high-resolution images, but do not provide depth information, while depth-sensing cameras do this but do not perform well in bright light conditions [16]. Light Detection and Ranging (LiDAR) technology enables precise distance measurements by sending short laser pulses, but its large size can limit its use in some cases [17]. Radio-frequency identification (RFID) systems enable data transfer between Near Field Communication chips; however, their signal accuracy can fluctuate due to environmental factors [18]. Similarly, Bluetooth beacons allow data to be transferred over short ranges, but they are expensive to install [19]. Ultrasonic sensors, on the other hand, measure distance using ultrasound waves, but they cannot detect obstacles and, in some cases, require GPS [20]. Infrared (IR) sensors use optical signals to measure distance, but their installation costs are relatively high [21]. This set of technologies represents a wide variety of applications. There are many different methods of measurement and data transmission, and their selection should be based on functional requirements, expected accuracy, and environmental conditions. As a result, a comprehensive evaluation of each sensor's characteristics for specific applications allows for optimization of system capabilities and reduction of operational limitations.

Types	Pros	Cons	Ref.
General cameras	High-quality images	Do not provide the depth information	[16]
Depth camera	Provide depth	Does not function in intense light	[16]
Light Detection and Ranging	Short laser pulse measurement	Excessive size	[17]
Radiofrequency identification	Transfer information between NFCs	Fluctuating signal accuracy	[18]
Bluetooth beacon	Transmit less data over a smaller range	High installation costs	[19]
Ultrasonic sensor	Uses ultrasonics to measure the distance	Cannot recognize the type of obstacles/GPS required	[20]
Infrared sensor	Measurement by the IR signal	High installation costs	[21]

TABLE 3: The input unit(s)

NFC, Near Field Communication; IR, Infrared; GPS, Global Positioning System

Review

Methods

A systematic literature search was conducted across major databases, including IEEE Xplore, PubMed, Scopus, and Google Scholar. The initial search yielded 311 records. After removing duplicates (n = 17), 294 records remained for screening. Titles and abstracts were reviewed, and 173 records were excluded due to irrelevance or lack of technical depth.

The full texts of 121 articles were assessed for eligibility. Of these, 41 were excluded for reasons such as insufficient methodological detail, outdated technology focus, or lack of peer review.

Finally, 80 studies were included in the qualitative synthesis. This review uses a structured and systematic approach to classify, analyze, and evaluate assistive technologies designed for people with visual impairments, with a particular focus on smart glasses, wearable navigation systems, and sensor-equipped devices. The methodological framework is designed to ensure comprehensiveness, reproducibility, and relevance to scientific research and practical applications.

Study Selection Strategy

A multi-step selection process was used to identify studies, prototypes, and commercial products related to assistive technologies for the blind, which included the following:

A comprehensive search of scientific literature, including peer-reviewed articles, conference proceedings, and technical reports from 2000 to 2025, and inclusion of commercial product documentation and white papers to bridge the gap between academic research and market-ready solutions. Additionally, a manual review of the reference lists of key articles was conducted to identify other relevant studies.

This review was conducted in scientific databases such as IEEE Xplore, ScienceDirect, SpringerLink, and Google Scholar, as well as product repositories and official websites of assistive technology manufacturers.

Keywords and Boolean Strategy

To maximize resource coverage, the following combinations with Boolean operators were used:

("assistive technology" OR "navigation aid") AND ("visually impaired" OR "blind")

("smart glasses" OR "wearable devices") AND ("object recognition" OR "text-to-speech")

("ultrasonic sensor" OR "RGB-D camera" OR "LiDAR") AND ("navigation" OR "obstacle detection")

("YOLO" OR "deep learning") AND ("assistive system" OR "AI-powered glasses")

Searches were limited to English-language resources and products published or documented between 2000 and 2025.

Inclusion and Exclusion Criteria

To ensure the relevance and quality of resources, the following criteria were applied: The inclusion criteria included only studies, prototypes, or commercial products that were specifically designed for blind or visually impaired people. These technologies had to have AI-based capabilities such as object recognition, optical character recognition (OCR), or speech processing. Also, the selected resources had to have a documented evaluation and were published in the form of research articles, technical reports, or authoritative documentation. Another inclusion condition was the presence of some kind of sensory feedback (visual, auditory, or haptic) in the technologies to facilitate user navigation and interaction.

In contrast, resources that fell into one of the following categories were excluded from the review: general wearable technologies that were not specifically designed for visual impairments; devices that lacked any intelligent processing or sensory feedback; non-peer-reviewed sources such as notes or editorials that lack sufficient technical detail; as well as systems that focus solely on medical diagnosis and lack assistive functionality for blind or visually impaired users.

Data Extraction and Classification

Each selected study or product was analyzed and classified based on the following dimensions:

• Functional domain: visual systems, non-visual data systems, map-based systems, 3D audio systems, smartphone-based solutions, and commercial products

• Sensor and processing technologies: types of cameras (red, green, and blue [RGB], depth, stereo), LiDAR, ultrasonic, infrared, BLE, RFID, etc.

• Integration of AI: use of deep learning models (e.g. YOLO [You Only Look Once]), OCR, speech recognition, and multimodal data fusion

• Type of user interaction: audio feedback, haptic feedback, visual overlays, or hybrid interfaces

• Hardware features: portability, ergonomics, power consumption, and real-time processing capability

This classification allowed for a comparative analysis of the strengths, limitations, and innovation gaps in different technological approaches.

Quality Assessment

To maintain methodological rigor, each study or product was assessed against the following criteria:

• Technical feasibility: accuracy, latency, and robustness in real-world conditions

• Usability: user-centered design, accessibility, and adaptability to different environments

• Level of innovation: innovation in integrating sensors, AI algorithms, or interaction patterns

• Ethical considerations: data privacy, algorithmic bias, and compliance with accessibility standards

Integration and Comparative Framework

The extracted data were integrated into thematic categories aligned with the review objectives. A comparative matrix (Table *4*) was developed to compare research and commercial solutions across dimensions including AI capabilities, hardware design, and user experience. This framework helped identify technological trends (e.g., multimodal sensors, deep learning integration), gap between research examples and market-ready products, and future innovation opportunities in inclusive and intelligent design.

Comparative Performance in Real-Life Scenarios

While the classification framework provides a structured overview of technological categories, it is equally important to assess how these systems perform in real-world environments. For example, OrCam MyEye demonstrates high accuracy in indoor text recognition but faces limitations in bright outdoor conditions. The WeWALK Smart Cane performs reliably in urban areas with strong GPS coverage but shows reduced accuracy in rural regions. YOLO-based smart glasses achieve rapid object detection, yet their high energy consumption reduces battery life and long-term usability. By highlighting these practical trade-offs, the review underscores that technological sophistication does not always translate into seamless real-life performance.

As it is illustrated in Figure 3, this methodology provides a structured assessment of assisted navigation technologies and provides insights into commercial and research innovations. In this study, we categorized the variety of technologies for navigational support utilized in smart glasses into five major parts [8].

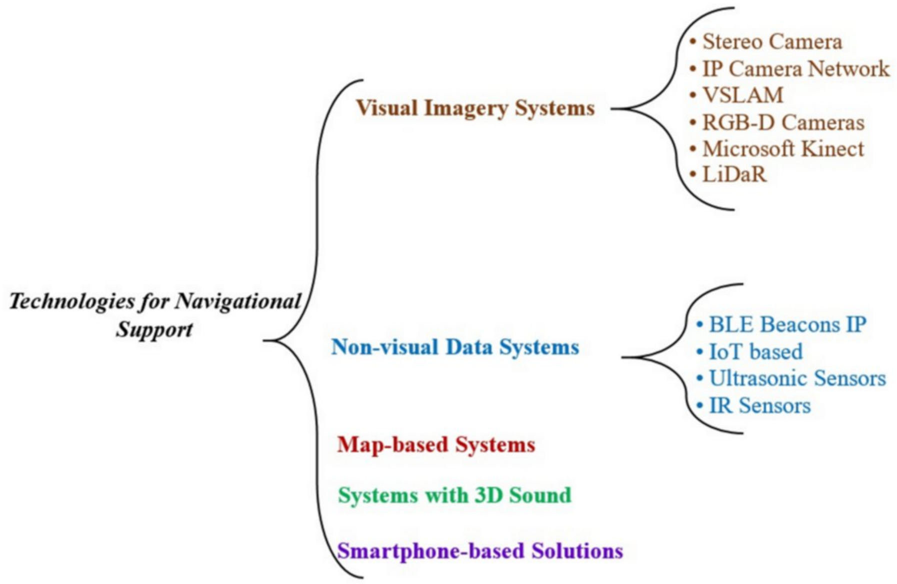

FIGURE 3: Diversity of technologies for navigational support

IP, Internet Protocol; VSLAM, Visual Simultaneous Localization and Mapping; RGB-D, Red Green Blue-Depth; LiDAR, Light Detection and Ranging; BLE, Bluetooth Low Energy; IoT, Internet of Things; IR, Infrared

Visual imagery systems

Analyzing the image of the surroundings can help a lot in safe navigation for the visually impaired. A stereo camera is a navigation method used by an intelligent assistant called Tyflos. Tyflos system receives surrounding information using photos or videos. It then converts those images into verbal descriptions [22]. An Internet Protocol camera network is a navigation system using Internet Protocol cameras like the system proposed by Chaccour and Badr [23]. The photos are analyzed by remote processing, and then by using a mobile application, the user can reach the destination. Visual Simultaneous Localization and Mapping is a technology that can be used for relocation using visual inputs from only one camera and sensor [24]. Bai et al. [25] proposed an indoor routing solution that uses its algorithm. A cyber-physical system using Red Green Blue-Depth (RGB-D) sensors for object detection and scene perception was proposed by Xiao et al. [26]. Intelligent Situational Awareness and Navigation Assistance (ISANA) [27] was an electronic smart cane prototype that used the Google Tango tablet [28] as its mobile computing platform. Microsoft Kinect is an RGB-D camera that has sparked a lot of research interest in its application in building navigation systems for the visually impaired [29]. Sain [30] presented a method that uses an algorithm that accepts input data from the Microsoft Xbox Kinect 360 [31]. The LiDaR Assist Spatial Sensing technology suggested by Ton et al. [32] detects barriers and converts them into stereo sound using a LiDaR sensor. AR glasses are innovative intermediaries for the informal, enabling dynamic interaction with the environment. AiGet, an AI assistant built with this technology, analyzes the user's gaze, environmental data, and personal profile to provide contextual knowledge without interrupting core activities. The system uses advanced language models to shift from reactive to proactive, so that users are presented with relevant and engaging information without having to consciously search for it. Laboratory studies and practical surveys show that such technologies not only enhance curiosity and connect people with their surroundings, but also transform the informal [33]. Also, Xie et al. [34] proposed a multi-sensory guidance system for the visually impaired that can provide tactile and auditory advice using ORB-SLAM and YOLO techniques. Mukhiddinov and Cho [35] presented a smart glasses system for blind and visually impaired people that facilitates independent movement in low-light and night-time environments by utilizing image processing techniques and deep learning models. The system consists of four main models: low-light image enhancement, object recognition and audio feedback, salient object recognition, and text-to-speech with haptic graphics. Its capabilities include image contrast enhancement, voice guidance for users by recognizing 133 audio categories, and visual information display through text and salient object recognition [35]. Wang et al. [36] examined the role of artificial intelligence in diagnosing eye diseases and developing assistive devices for people with visual impairments. Digital advances have had a significant impact on improving the quality of life of these people, and deep learning technology is increasingly being used in diagnosing eye diseases and developing smart devices. They categorized recent research into two areas: deep learning methods for diagnosing eye diseases and smart devices to assist people with low vision in daily activities [36]. Matov [37] developed a software called DataSet Tracker, which is designed for real-time analysis and can be run on computers, smartphones, and smart glasses, especially in environments with limited computing resources, such as microscopes without Internet connectivity. The system is optimized to simplify complex cellular analyses, including the investigation of cytoskeletal networks and vesicular pathways. The proposed computational platform enables high-content investigation and screening of new drugs in the early stages of development and, by analyzing the mechanisms of action of drugs, helps to design effective treatment regimens with minimal side effects [37]. De Silva et al. [38] developed a smart glasses system based on YOLOv8 and the Internet of Things to support students with visual impairments. The system enables independent learning in areas such as science, mathematics, and financial transactions by providing real-time object recognition and comprehensive voice feedback. By integrating text-to-speech and speech-to-text technologies, this technology plays an important role in inclusive education, reducing learning barriers, and increasing interest in science and technology among visually impaired students [38]. Kurbis et al. [39] developed StairNet, a deep learning-based system to improve visual perception of complex motion environments, especially stairs, in human-robot interactions. The system uses self-centered perspective to recognize the environment before physical interaction and evaluates the performance of different neural network models, training methods, and implementations using a large dataset of 515,000 labeled images. Results show that StairNet can provide remarkable performance in image classification with high accuracy (up to 98.8%) and provides a balance between human-centered design and efficiency with an inference speed of 2.8 ms on GPUs and 1.5 s on CPU-based smart glasses [39]. Kim et al. [40] developed a clinical skills assessment system based on first-person video through smart glasses and examined its usability and effectiveness. Using two cameras (smart glasses and webcam), video analysis was performed to assess the performance of nursing students. Usability tests with quantitative and qualitative questionnaires assessed the usefulness and acceptability of the system. Data from standard checklists of three clinical skills (intramuscular injection, endotracheal suction, and Levine tube feeding) were used to examine inter-rater reliability using Fleiss' Kappa coefficient analysis. The results showed that this assessment system, with an average Fleiss' Kappa coefficient of 0.592, performed well and could play an effective role in the teaching and learning process. However, hardware improvements and specific guidelines for the roles of assessors and students are still needed [40].

Non-visual data systems

Nair et al. [41] presented a hybrid location and navigation system that leverages the capabilities of both Bluetooth Low Energy (BLE) beacons and Google Tango while minimizing their drawbacks. A smartphone was utilized in the Guide Beacon system [42] to communicate with Bluetooth-based beacons. The Internet of Things (IoT) is the interconnection of multiple technologies that may transport data across a network without requiring any type of human or machine intervention [43]. Indriya [44] is a portable gadget that works with a smart cane. Navigation systems based on ultrasonic sensors are a popular choice in design following camera solutions. This technique is used in combination with electronic boards such as the Raspberry Pi or Arduino [45]. Sen et al. [46] described an ultrasonic blind stick with configurable sensitivity using an ultrasonic proximity sensor and a GPS module. Using ultrasonic sensors, the NavGuide [47] can classify barriers and surrounding environment circumstances. Infrared sensors have a lower power consumption and cost than ultrasonic sensors [48]. Hekal et al. [49] described a smart assistive stick based on IR. Introduces an assistive system based on Raspberry Pi 4 Model B+ and ESP32-CAM to support visually impaired people. The system uses YOLOv4-tiny for object recognition, a hybrid model for face recognition, and MobileNetV2 for currency recognition. In addition to image processing capabilities, the system includes speech-to-text, text-to-speech, haptic feedback with ultrasonic sensors and vibration motors. The technology is designed to increase independence, improve the quality of life, and promote social participation of blind people [49]. Gamage [50] explored the use of AI-powered smart glasses to assist people with severe visual impairments. Using a design thinking and collaborative design approach, prototypes of smart glasses applications have been developed through case studies to better understand user needs. Their goal is to provide a software architecture for seamless access to environmental information and improve user interaction with the technology [50]. Hnoohom et al. [51] presented a ResNet-SE model for classifying driving activities based on signal data received from smart glasses. The proposed model, by combining residual networks and channel attention, outperforms CNN and LSTM, providing more accurate classification in real traffic conditions.

Map-based systems

One of the disadvantages of them is the inability to change the map content. Accessible interactive maps have been designed by Ducasse et al. [52]. Albouys-Perrois et al. [53] conceived and produced an AR map that can be utilized in O&M classes using a participatory design method. Götzelmann and Winkler [54] presented SmartTactMaps, a smartphone-based strategy to assist blind people in exploring tactile maps. Liu et al. [55] describe a 3D environment map created with an RGB-D sensor, which assists visually challenged persons in navigating at home. LucentMaps [56], a 3D-printed audio-visual tactile map, was also proposed. The VizMap system [57] collects data from interior spaces using computer vision and crowdsourcing.

Systems with 3D sound

The Sound of Vision system described by Caraiman et al. [58] is a wearable sensory replacement device that aids VIs in navigation by producing and transmitting an aural and tactile representation of their surroundings. Stereo Vision-based Electronic Travel Aid (SVETA) is a type of electronic travel aid that includes a headpiece with stereo cameras and ear buds. Each musical sound relates to some information about the characteristics of the obstacle that the user is confronted with [59].

Smartphone-based solutions

Smartphone-based navigation solutions provide consumers with mobility and ease. NavCog3, an indoor navigation system that gives users audible feedback [60]. The ActiVis project provides a multimodal user interface that transmits navigational information to the target user via audio and vibration signals with an Android app based on a Tango device [61].

Commercial products

Until now, various research laboratories and companies have produced examples of assistive devices for the use of the low-sighted. By combining some of these methods, each of these laboratories and companies has different models of smart gadgets suitable for a specific section of the visually impaired community. Table *4* presents a comparative analysis, performance evaluation, and the possibility of integrating existing technologies, also, a comparison of assistive technologies for visually impaired individuals.

Row	Company / Research	Product	Primary Function	AI Integration	Hardware & Build Quality	Sensor & Processing Technology	Year
1	Talking Atomic Watches	Talking Atomic Watches	Audible time announcements	No AI integration	Compact, durable	Basic timekeeping functionality	2000
2	Colorino Color Identifier [62]	Colorino Color Identifier	Color detection and identification	Basic AI-Powered color recognition	Compact, portable	AI-powered color detection	2010
3	Be My Eyes [63]	AI-powered Be My Eyes	Remote assistance by sighted users	AI-assisted image processing	Smartphone-based	AI-Powered image enhancement	2015
4	Lechal Smart Shoes [64]	Smart Shoes Lechal	Vibrational navigation feedback	AI-supported path analysis	Lightweight, wearable	AI-Powered path tracking, vibration feedback	2016
5	Universiti Teknologi PETRONAS [65]	Smart Glasses for the Visually Impaired	AI-powered text recognition, Raspberry Pi integration	AI-Powered OCR and environmental analysis	Lightweight, wearable	AI-powered text recognition	2016
6	IrisVision [66]	IrisVision Live 2.0	OCR, magnification, voice commands	AI-Powered text and object recognition	Lightweight, ergonomic	High-resolution camera, fast processing	2017
7	NuEyes [67]	NuEyes Pro	Voice control, magnification	AI-powered text and barcode recognition	Lightweight, portable	AI-Powered text recognition, QR scanning	2017
8	OrCam MyEye [68]	OrCam MyEye	AI-powered text reading and object recognition	AI-powered reading, and gesture detection	Lightweight, wearable	AI-Powered text recognition, facial identification	2018
9	Acesight (Zoomax) [69]	Acesight	AR-enhanced magnification	AI-based augmented reality	Moderate weight, comfortable fit	Augmented reality overlays, real-time enhancement	2019

10	WeWALK Smart Cane [70]	Smart Cane WeWALK	Smart navigation via ultrasonic sensors	AI-assisted mobility tracking	Durable, ergonomic	Ultrasonic sensors, GPS tracking	2019
11	eSight [71]	eSight 4	Bioptic vision enhancement	AI-enhanced live image processing	Compact, wearable	High-speed image processing	2020
12	Deep Learning Smart Glasses (Gachon University) [36]	Smart Glass System Using Deep Learning	Object recognition and auditory feedback	AI-Powered enhancement for navigation	Lightweight, wearable	AI-Powered object detection, low-light enhancement	2021
13	Envision [72]	Envision Glasses	AI-powered environmental analysis	AI-powered OCR, real-time navigation	Lightweight, ergonomic	AI-Powered text recognition, facial identification	2021
14	Florida Institute of Technology [73]	Smart Glasses Assisting Visually-Impaired People	AI-powered speech & object detection, face recognition, navigation	AI-Powered environmental analysis	Lightweight, wearable	AI-powered speech and object recognition	2021
15	NoorCam [74]	NoorCam	Object and face recognition	AI-Powered facial and object identification	Compact, wearable	AI-powered facial recognition, object detection	2021
16	XRAI Glass [75]	XRAI Glass	Speech-to-text conversion	AI-assisted transcription and recognition	Lightweight, wearable	AI-Powered speech recognition, real-time text overlay	2022
17	Seleste Smart Glasses	Seleste Smart Glasses	AI-powered object recognition and video calls	AI-powered processing for object identification	Lightweight, ergonomic	AI-Powered object recognition, real-time video streaming	2023
18	AI-Based Smart Glasses (Ajay Kumar) [76]	AI-Based Smart Glasses	YOLOv5-based object detection	AI-Powered sensor processing	Lightweight, wearable	AI-Powered object detection, temperature sensing	2024
19	IJRASET Smart Glass [77]	AI-Powered ultrasonic navigation	Deep learning-based object detection, OCR integration	AI-enhanced image and text processing	Lightweight, wearable	AI-Powered ultrasonic sensors, OCR detection	2024
20	Artificial Skin (University of Georgia) [78]	Artificial Skin with Sensors	Tactile sensory feedback	AI-assisted tactile signal processing	Flexible, wearable	AI-Powered tactile response	2025
21	AI-powered smart glasses at Google I/O 2025	Smart Glasses for the Visually Impaired	AI-powered text recognition, Raspberry Pi integration	AI-Powered OCR and environmental analysis	Lightweight, wearable	AI-powered text recognition	May 20, 2025

TABLE 4: Comparison of assistive technologies for visually impaired individuals

AI, Artificial Intelligence; AR, Augmented Reality; GPS, Global Positioning System; OCR, Optical Character Recognition; YOLO, You Only Look Once

Discussion

Rapid advances in assistive technologies for the visually impaired have led to the development of a wide range of smart glasses and wearable navigation devices, each designed with AI-based features to improve accessibility. The comparison of Table *4* presented in this article provides a comprehensive view of the design, performance, and technological capabilities of some of these products. The AI integration in these products varies significantly. Some, such as the Envision glasses [72] and OrCam MyEye [68], focus on text recognition and environmental analysis, while the Gochon University smart glasses [36] and the AI-based smart glasses [76] focus on object recognition and sensory feedback through machine learning algorithms. The emergence of technologies such as YOLO-based object recognition in the IJRASET smart glasses [77] indicates the growing role of deep learning in improving real-time scene interpretation. Additionally, speech recognition and speech-to-text technologies like XRAI Glass [75] have helped break down communication barriers, expanding the role of AI from enhancing vision to enhancing voice interaction. Devices like the Seleste smart glasses, which support live video calls, represent a shift toward remote access solutions that enable real-time assistance from sighted people. Hardware ergonomics play a critical role in user adoption and long-term use. Products like the IrisVision Live 2.0 [66] and eSight 4 [71] focus on lightweight, wearable designs for everyday comfort, while the Intel Smart Backpack System offers an advanced navigational aid framework and uses AI processing for navigation in a multi-tasking wearable form factor. These design differences represent a trade-off between portability and real-time processing power, where researchers must balance wearability with real-time processing speed.

A different example is artificial skin (University of Georgia) [78], which uses a haptic feedback mechanism to simulate skin sensitivity. Unlike vision enhancement solutions, this technology takes a sensory substitution approach and examines accessibility from a neurological and physiological perspective. As privacy is a key issue in the use of AI-based assistive technologies, products that use cloud computing (Be My Eyes [63], NoorCam [74], XRAI Glass [75]) raise ethical concerns about data security and surveillance, while models that use local processing (OrCam MyEye, Florida Institute of Technology research model [73]) emphasize on-device computing to minimize external vulnerabilities. Given the increasing use of facial recognition technology in smart glasses (NoorCam [74], Envision [72]), discussions about data protection, algorithmic bias, and consent-based user controls are essential for future regulation. The distinction between commercial and research models reflects the industry's direction in this area. Products such as Acesight, NuEyes, and Envision Glasses are designed for the consumer market and emphasize broad accessibility, while research examples (Florida Institute of Technology, University Technology PETRONAS, IJRTE studies) have pushed the boundaries of experimental AI applications that have not yet been translated into consumer technologies. This division shows that research funding and product development cycles play a decisive role in the transition of assistive technologies from research laboratories to the consumer market.

At the latest event in this area, at Google I/O 2025, Google unveiled AI-powered smart glasses integrated with Gemini AI. The technology includes text recognition, environmental analysis, and OCR processing, helping to improve the independence of people with visual impairments. The lightweight design and integration with Raspberry Pi allow for haptic feedback, speech processing, and AR analytics. These glasses could revolutionize assistive devices by combining multiple technologies.

To better understand the current landscape, three major trends have emerged from our comparative analysis:

Trend 1: Deep Learning and Multimodal Integration. The comparative analysis reveals that deep learning algorithms (e.g., YOLO, OCR, speech recognition) and multimodal integration (vision, hearing, touch) are now central to innovation. Devices such as IJRASET smart glasses and Envision Glasses exemplify this convergence, enabling real-time scene interpretation and multimodal feedback.

Trend 2: Combined Sensory Approaches. Increasingly, assistive devices combine multiple sensory channels to enhance navigation and interaction. Examples include haptic feedback in artificial skin prototypes, auditory cues in 3D sound systems, and visual overlays in AR-based glasses. This multimodal design improves safety, independence, and user satisfaction.

Trend 3: Ethical and Privacy Considerations. The integration of AI raises critical ethical issues. Cloud-based solutions, such as Be My Eyes and NoorCam, raise concerns about data security, while on-device processing models (e.g., OrCam MyEye) mitigate these risks. To ensure equitable adoption, future designs must address algorithmic bias, informed consent, and compliance with accessibility standards. According to these ethical insights, we propose the following policy recommendations to guide future development:

1) Prioritizing device processing to protect user privacy and reduce dependence on cloud connectivity.

2) Training AI models on diverse datasets to minimize algorithmic bias across cultural, gender, and geographic contexts.

3) Implementing government subsidies and NGO partnerships to ensure affordability in low-resource settings.

4) Establishing international design standards for accessibility and inclusiveness, ensuring that devices are user-centered and resource-friendly.

Future studies should focus on optimizing processing power, improving real-time response rates, and reducing hardware costs to increase accessibility. In addition, clinical trials and user experience studies should evaluate the effectiveness of assistive technologies, so that these tools are technically advanced and usable in everyday applications. As a result, the convergence of computer vision, AI ethics, human-computer interaction, and accessibility research will shape the next generation of intelligent assistive technologies. By addressing the challenges of cost, privacy, compatibility, and technical performance, researchers and developers can create intelligent, inclusive, and sustainable assistive solutions for people with visual impairments.

Conclusions

Over the past two decades, assistive technologies for the visually impaired have progressed from basic hardware tools to intelligent, AI-powered systems integrating vision, sound, and touch. Current innovations such as AR-based glasses, ultrasonic navigation, and tactile feedback devices demonstrate the potential of multimodal solutions. This study has systematically classified and analyzed 80 studies and commercial products, highlighting both the technological progress achieved and the persistent challenges that remain.

Future research should move beyond the development of individual assistive devices and focus on creating an integrated, modular ecosystem that combines multiple technologies, such as computer vision, haptic feedback, speech recognition, and augmented reality, within a unified platform. Instead of isolated solutions, a flexible framework could allow researchers and developers to add or refine modules according to user needs and environmental contexts. This approach would not only enhance adaptability and personalization but also reduce costs through shared infrastructure. To ensure real-world impact, this ecosystem should be validated through long-term clinical trials and user experience studies to validate effectiveness. Designing low-cost, offline-capable devices for low-resource environments, also enhancing multimodal integration (vision, hearing, touch) for natural interaction, and addressing ethical concerns such as privacy, algorithmic bias, and equitable access should be considered. By bridging technological innovation with user-centered design and ethical considerations, the next generation of assistive technologies can provide inclusive, sustainable, and impactful solutions for visually impaired individuals worldwide.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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