



Third Eye: AI and IoT-Based Smart Navigation and Safety System for Visually Impaired People — A Comprehensive Review

Kawade Sanskruti Avinash, Prof. Bangar Abhishek Popat,

Prof. Bhosale Sachin Bajirao, Prof. Karad V.A.

Dept. of Computer Engineering

Jaihind College of Engineering, Pune, India

Abstract. Visual impairment restricts independent mobility and exposes people to collisions, falls and unsafe road situations. White canes and guide dogs remain the main aids, but they give little information about what an obstacle is, how far away it is, or when the user needs help. Artificial intelligence (AI) combined with wearable sensing and the Internet of Things (IoT) is increasingly proposed as a route to smart navigation and safety systems that perceive the scene, guide the user by audio or touch, and alert caregivers in an emergency. This paper presents a focused narrative review of five verified studies, published between 2018 and 2026 in IEEE, MDPI and River Publishers outlets, that cover sensor-based safety alerting, RGB-D and deep-learning navigation, machine-learning smart cane and glasses, edge-TPU indoor navigation, and an AIoT eyewear system with LiDAR ranging and an SOS function. The review examines sensing, AI perception, feedback and IoT integration. The literature shows that recent systems report object-detection accuracy of about 95 % and centimetre-level distance error in controlled tests, and that low-cost edge hardware such as the Raspberry Pi with a Google Coral TPU can run navigation models on the wearable itself. However, evidence is dominated by small prototypes, controlled or indoor settings, heterogeneous metrics and limited testing with visually impaired users, and few systems join navigation, perception and caregiver-facing safety in one design. The paper contributes a comparative analysis of the studies, a proposed conceptual “Third Eye” architecture that links wearable sensing, edge AI, IoT safety alerts and field validation, and a prioritised agenda of research gaps and directions.

Keywords: Visually Impaired, Smart Navigation, Obstacle Detection, Deep Learning, Internet of Things, Edge Computing, Assistive Wearable

I. Introduction

Independent travel depends on perceiving obstacles, surfaces, signs and moving traffic. For people with visual impairment this information must come from other channels, and mistakes carry a physical cost: collisions, falls, getting lost, or entering a roadway. Traditional aids such as the white cane and guide dog are valued but limited: a cane detects only what it touches, and neither tells the user what an object is or notifies anyone if something goes wrong [1], [6], [9]. Three developments now converge. First, compact cameras, depth sensors, LiDAR and inertial units are cheap enough to wear. Second, deep-learning detectors and classifiers can run on smartphones and on embedded boards with accelerators [2], [4]. Third, IoT connectivity



moves alerts and location from the device to a phone, a cloud service or a caregiver [1], [5]. Together they make a “third eye”: a wearable that senses, interprets, guides and, when needed, calls for help.

This review examines how far the published evidence supports that vision. It asks which sensing and AI methods have been demonstrated, how feedback is delivered, how IoT and safety functions are integrated, and what is still missing before field deployment. It then proposes a conceptual architecture that responds to the weaknesses identified.

II. Review Methodology and Literature Selection Criteria

A focused search was made across IEEE Xplore, MDPI, Elsevier, Springer, River Publishers, PubMed/PMC, Crossref and OpenAlex metadata, and institutional repositories, using combinations of visually impaired, blind, navigation, obstacle detection, wearable, smart glasses, deep learning, YOLO, IoT, edge computing and SOS or emergency alert. Priority was given to 2018–2026 work.

Inclusion criteria. A study was included as a core study when it (i) was published in a peer-reviewed journal or conference proceeding from a recognised publisher (IEEE, MDPI or River Publishers here); (ii) described a working wearable or portable assistive prototype for navigation or safety of visually impaired people; (iii) used machine learning, deep learning or embedded intelligence, or an IoT or alerting component; and (iv) reported an evaluation. Surveys were used for context only, and arXiv preprints were used only as supporting context and are labelled as such.

Verification. Each core study was checked against a publisher page, DOI record or institutional repository (volume, pages, authors and DOI). Quantitative results are quoted from the published abstracts and record pages; full-text confirmation of all metrics is still advisable before submission. Scopus and Web of Science could not be queried directly, so the review is narrative rather than systematic, only five core studies are analysed, and study counts are not reported.

III. Literature Review

1. Sensor-Based Safety and Caregiver Alerting

Ramadhan [1] describes a wearable smart system built from a microcontroller board, several sensors, cellular and GPS modules and a solar panel. Sensors track the path and warn the user of obstacles ahead. The system also alerts people nearby when the user stumbles or needs help, and sends the alert together with the system location as a phone message to registered family members and caregivers. This is an early example of the safety function that later AI systems often omit, although the approach is sensor-driven rather than learning-based.

2. RGB-D Sensing with Deep-Learning Perception

Bai et al. [2] present an eyeglasses-shaped travel aid with a consumer RGB-D camera and an inertial measurement unit. Because ground height is continuous across adjacent frames, the device separates ground from obstacles, computes a walkable direction, and signals it through converted beep sounds. A convolutional neural network on a smartphone, combined with depth-based detection, names obstacles and locates them, and speech announces the result. Twenty visually impaired participants wore the device in an office and were able to avoid collisions and find their way in complicated scenarios. Related work from the same research line also uses RGB-D input and semantic maps for obstacle avoidance and scene perception [10].



3. Machine-Learning Smart Cane and Glasses

Keshara et al. [3] combine a smart cane with wearable smart glasses. Their system detects obstacles and potholes, supports walk-lane navigation so that the user stays off the main road, recognises road signs to help with crossing, and detects faces and emotions to identify familiar people. The breadth of functions is notable, covering ground hazards, traffic context and social awareness in one proposal, but the abstract reports no quantitative accuracy figures.

4. Edge-TPU Indoor Navigation

Loresco et al. [4] build 3D-printed glasses with a Raspberry Pi camera and a processing unit made of a Raspberry Pi 4B and a Google Coral Edge TPU. Deep-learning models handle localisation, navigation, obstacle detection and obstacle avoidance, and audio guidance reaches the user. In a controlled indoor environment the models achieved high accuracy, precision, recall and F1-score, and user tests with the System Usability Scale suggested the device is promising for independent navigation. The study shows that useful navigation inference can run on low-cost wearable hardware without a server. A related preprint takes the edge idea further by using a smartphone camera, a nearby Raspberry Pi and an on-device language model to give turn-by-turn spoken indoor directions while keeping images inside the building [11].

5. AIoT Eyewear with Ranging and SOS

Nanda et al. [5] use an ESP32-CAM for real-time detection with YOLO, a TF-Luna LiDAR for distance, and a Bluetooth neckband for audio feedback. Datasets were prepared and trained with Roboflow. The system adds night-time navigation and an emergency alert. Reported results are an object-detection accuracy of 94.93 %, a mean absolute error of 0.34 cm and a root mean square error of 0.44 cm in distance estimation, and a 100 % response rate for the SOS alert. Among the five studies it comes closest to joining perception, ranging and safety in a single AIoT design.

6. Surveys and Context

Surveys of wearable and navigation aids for visually impaired people [6]–[9] describe a long list of devices but also stress open problems: user acceptance, weight and cost, reliability outdoors, and the lack of common evaluation methods. These observations are consistent with the gaps identified in Section VI.

IV. Comparative Analysis of Existing Studies

Table I summarises the five core studies in chronological order. Values are not directly comparable because tasks, environments, participants and metrics differ.

Table 1: Comparison of Representative AI and Iot-Based Navigation and Safety Studies

Author, year	Objective	Sensing / method	Major reported findings	Limitations (as reported or evident)
Ramadhan, 2018 [1]	Safe walking and help-seeking	Microcontroller, obstacle sensors, GPS, cellular, solar panel	Obstacle alerts; stumble and help alerts sent with location to family and caregivers	Sensor-driven, no learning-based recognition described; prototype
Bai et al., 2019 [2]	Navigation plus obstacle recognition	RGB-D + IMU; ground segmentation; smartphone CNN	Walkable direction by beeps; object names by speech; 20 visually impaired users avoided collisions	Tested in an office; no IoT or caregiver channel described

Author, year	Objective	Sensing / method	Major reported findings	Limitations (as reported or evident)
Keshara et al., 2022 [3]	Obstacle, road and social awareness	Smart cane + smart glasses; machine learning	Obstacle and pothole detection, walk-lane navigation, road signs, face and emotion	Abstract gives no quantitative results
Loresco et al., 2024 [4]	Indoor navigation with obstacle avoidance	3D-printed glasses; Raspberry Pi 4B + Coral Edge TPU; deep learning	High accuracy, precision, recall, F1; usability assessed with SUS	Controlled indoor setting only
Nanda et al., 2026 [5]	Detection, ranging and emergency alert	ESP32-CAM + TF-Luna LiDAR; YOLO; Bluetooth neckband	Accuracy 94.93 %; MAE 0.34 cm; RMSE 0.44 cm; SOS 100 %	Abstract reports no trial with visually impaired users; lighting-condition tests

Observations. Three patterns emerge. (i) Capability has moved from threshold-based sensing [1] to deep-learning perception on the wearable itself [2], [4], [5]. (ii) Ranging and perception are increasingly paired, as with LiDAR and YOLO [5], while RGB-D depth plays the same role in [2]. (iii) Only [1] and [5] include an explicit emergency or caregiver path, and only [2] and [4] report any structured testing with people (visually impaired participants in [2] and a usability scale in [4]).

V. Proposed Conceptual Architecture (Third Eye)

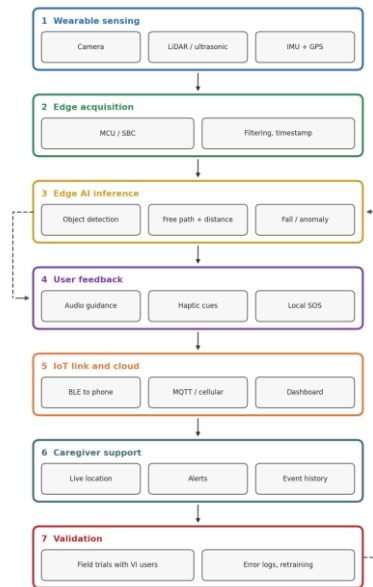


Fig. 1. Proposed conceptual Third Eye architecture (conceptual, not experimentally validated). Dashed lines show the offline local alert path (left) and the validated model-update path (right).



Fig. 1 shows a conceptual architecture assembled from the functions demonstrated in the reviewed studies. It is not experimentally validated. Layer 1 combines a camera, a distance sensor (LiDAR or ultrasonic) and an inertial unit with GPS, because ranging and recognition complement each other [2], [5]. Layer 2 timestamps and filters the signals on a microcontroller or single-board computer. Layer 3 runs detection, free-path and distance estimation and fall or anomaly detection on the device, using an accelerator where available [4], and attaches a confidence value to each output. Layer 4 delivers audio guidance and haptic cues and holds a local SOS path that keeps working without connectivity. Layer 5 links the wearable to a phone by Bluetooth and onward by MQTT or cellular to a dashboard [1], [5]. Layer 6 gives caregivers location, alerts and event history, following the caregiver messaging idea in [1]. Layer 7 closes the loop through field trials with visually impaired users, error logging and retraining only after independent re-testing.

VI. Research Challenges and Identified Gaps

Gaps supported by the reviewed evidence. (i) Fragmented capability: few studies combine navigation, scene perception and caregiver-facing safety alerts [1], [5]. (ii) Controlled settings: evidence comes from an office [2], a controlled indoor space [4] and lighting-condition tests [5], not from busy streets. (iii) Limited user evidence: participant numbers are small or not reported, and the abstracts of [3] and [5] report no user trial. (iv) Heterogeneous metrics: accuracy, F1, distance error and usability scores cannot be compared across studies. (v) Weak reporting of safety outcomes such as missed obstacles, false alarms and alert latency.

Challenges noted from surveys and design reasoning. Battery life and weight, comfort and social acceptance, performance at night and in rain, dependence on mobile connectivity, and the privacy of camera images and location streams are recurrent concerns [6]–[9]. These are design observations rather than findings of the five core studies, and they need dedicated testing.

VII. Proposed Research Directions

Priorities that follow from the gaps are: multi-environment field trials, including outdoor roads and crossings, with visually impaired participants and reported collision, miss and false-alarm rates; a shared benchmark and common metrics for navigation aids; offline-first operation with edge inference and a local SOS, with the cloud used for updates and caregiver views; privacy-preserving processing that keeps images on the device [11]; multi-sensor fusion of camera, ranging and inertial data with calibrated confidence and out-of-distribution detection; fall and distress detection tied to caregiver alerts; and co-design with users to reduce weight, cost and stigma.

VIII. Conclusion and Future Scope

AI and IoT-based aids for visually impaired people have moved from sensor-based alerting to deep-learning navigation on low-cost edge hardware, with recent systems reporting detection accuracy near 95 % and centimetre-level ranging error in controlled tests. The evidence base is still small and prototype-centred, with limited user trials, mostly controlled environments and no common metrics, and few designs join navigation with emergency communication. The proposed Third Eye architecture shows how those pieces can be combined and where validation is required. Future work should build and test such a system with visually impaired users in real settings, compare edge and cloud inference for latency and privacy, and report safety outcomes rigorously.



References

1. A. J. Ramadhan, "Wearable smart system for visually impaired people," *Sensors*, vol. 18, no. 3, Art. no. 843, 2018, doi: 10.3390/s18030843.
2. J. Bai, Z. Liu, Y. Lin, Y. Li, S. Lian, and D. Liu, "Wearable travel aid for environment perception and navigation of visually impaired people," *Electronics*, vol. 8, no. 6, Art. no. 697, 2019, doi: 10.3390/electronics8060697.
3. S. R. D. S. Keshara, W. R. J. M. Weragoda, S. Chandrasiri, J. Ellankovan, and W. A. Madushan, "Real-time smart navigation system for visually impaired people," in *Proc. 4th Int. Conf. Advancements in Computing (ICAC)*, Colombo, Sri Lanka, 2022, pp. 476–481, doi: 10.1109/ICAC57685.2022.10025323.
4. P. J. M. Loresco, R. J. C. Cruz, K. Z. Ramones, J. A. D. Zafra, and K. R. G. Ramirez, "Indoor navigation glasses for the visually impaired with deep learning and audio guidance using Google Coral Edge TPU," in *Proc. TENCON 2024 – IEEE Region 10 Conf.*, 2024, pp. 842–845, doi: 10.1109/TENCON61640.2024.10902929.
5. P. Nanda, S. R. Samal, S. Bandopadhyaya, D. P. Pradhan, A. Ivanov, and V. Poulkov, "AIoT smart eyewear with real-time object and audio recognition for visually impaired users," *J. Mobile Multimedia*, vol. 22, no. 1, pp. 41–62, 2026, doi: 10.13052/jmm1550-4646.2212.
6. R. Tapu, B. Mocanu, and T. Zaharia, "Wearable assistive devices for visually impaired: A state-of-the-art survey," *Pattern Recognit. Lett.*, vol. 137, pp. 37–52, 2020.
7. W. Elmannai and K. Elleithy, "A highly accurate and reliable data fusion framework for guiding the visually impaired," *IEEE Access*, vol. 6, pp. 33029–33054, 2018.
8. P. Kathiria, P. Parmar, D. Kothari, A. Patel, and P. Solanki, "Assistive systems for visually impaired people: A survey on current requirements and advancements," *Neurocomputing*, vol. 606, Art. no. 128284, 2024.
9. M. H. Abidi, A. N. Siddiquee, H. Alkhalefah, and V. Srivastava, "A comprehensive review of navigation systems for visually impaired individuals," *Heliyon*, vol. 10, no. 11, Art. no. e31825, 2024.
10. Y. Lin, K. Wang, W. Yi, and S. Lian, "Deep learning based wearable assistive system for visually impaired people," *arXiv:1908.03364*, 2019 (preprint).
11. S. Srinivasaiah, S. K. Nekkanti, and R. R. Nedhunuri, "Turn-by-turn indoor navigation for the visually impaired," *arXiv:2410.19954*, 2024 (preprint).