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## AI-Powered Assistive Navigation Systems for the Visually Impaired

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Peer Review Information	Abstract
<p><i>Submission: 05 Nov 2025</i></p> <p><i>Revision: 25 Nov 2025</i></p> <p><i>Acceptance: 17 Dec 2025</i></p> <p><b>Keywords</b></p> <p><i>Computer Vision, Object Detection, Raspberry Pi, Visual Impairment, Real-time Processing, Embedded Systems, Artificial Intelligence</i></p>	<p>Vision impairment affects over 2.2 billion people worldwide, posing significant challenges to independent mobility and daily life. This review synthesizes recent advancements in AI-driven assistive technologies, encompassing lightweight object detection models, large vision-language models (LVLMs), embedded platforms, sensor fusion techniques, and user-centered interaction designs. The surveyed literature highlights recurring challenges, including limited contextual reasoning in lightweight models, dependency on network connectivity, privacy concerns, and the absence of long-term real-world evaluations. Building on these insights, we propose a practical server-client architecture in which a compact Raspberry Pi-based wearable integrates a camera module and ultrasonic sensor for local data capture and minimal preprocessing. Data is streamed to a local edge server or laptop that performs object detection, multisensor fusion for robust proximity alerts, and optional LVLM-based scene description with text-to-speech output. This design optimizes portability and battery life on the wearable while enabling high-fidelity, low-latency inference on the server, with an on-device fallback detector ensuring fail-safe operation during connectivity loss. Expected outcomes include improved detection accuracy (mAP in the ~75–90% range on optimized datasets), multi-fold latency reduction through offloading, reduced false positives via ultrasonic-vision fusion, and increased user trust through multimodal feedback. The discussion addresses potential limitations such as network dependency, power constraints, environmental sensing errors, LVLM computational demands, and privacy risks, alongside proposed mitigation strategies and evaluation metrics. The review concludes with a roadmap toward scalable, privacy-aware, and user-centered assistive navigation systems for the visually impaired. This paper reviews recent advances in AI-powered assistive navigation systems for the visually impaired, focusing on wearable and mobile platforms using computer vision, deep learning, and sensor fusion. It identifies common challenges such as network dependency, hardware limitations, and environmental sensitivity while outlining future research directions toward efficient, user-centered, and scalable assistive systems.</p>

## Introduction

Vision impairment affects over 2.2 billion people worldwide, including 43.3 million who are blind and 295 million with moderate to severe visual impairment, as highlighted in *AI-Based Wearable Vision Assistance System for the Visually Impaired*. This condition severely restricts mobility, increases the risk of accidents, and can lead to social isolation, particularly in unfamiliar environments. Traditional mobility aids like white canes and guide dogs provide limited obstacle detection—canes detect only nearby ground-level objects, and guide dogs, though effective, are costly and require extensive training, as studied by N. Kumar and A. Jain in their work *Deep Learning Model to Assist Blind People in Navigation*. These limitations create a pressing need for advanced navigational systems capable of delivering real-time, context-aware environmental information.

Recent advances in artificial intelligence and computer vision have enabled wearable and mobile devices to perform real-time object detection and obstacle recognition on embedded platforms such as Raspberry Pi and smartphones, as showcased in *Intelligent Head-Mounted Obstacle Avoidance Wearable*. For example, Okolo et al. combined Raspberry Pi, a camera, ultrasonic sensors, and YOLOv8 to provide voice-guided navigation, while Bilware et al. integrated YOLO-based recognition into a smart walking stick for obstacle detection and distance feedback. Emerging solutions now incorporate large vision–language models for deeper situational understanding, as demonstrated by Baig et al., and mobile applications integrating GPS and computer vision, such as the work by Wu et al., for real-time route guidance and obstacle alerts.

However, significant challenges persist, including balancing accuracy, latency, and power consumption in battery-powered devices, as highlighted in *Computer Vision-Based Assistance System Using Mobile Edge AI*. Wearables must integrate cameras, sensors, and processors into compact, comfortable, and socially acceptable designs — a direction explored by P. Xu, A. Song, and K. Wang in *Intelligent Head-Mounted Obstacle Avoidance Wearable*. Cost remains a barrier, with many advanced systems being inaccessible to average users, which prompted R. Jaiswal to introduce *Lakshya: Intelligent Device Using AI/ML Models of Google TensorFlow* as a more affordable alternative. Furthermore, environmental variability—such as changing lighting conditions and crowded spaces—continues to affect detection reliability, as discussed in *Deep Learning Model to Assist Blind People in Navigation, Object Detection Navigator*

*Using AI and Computer Vision, and Computer Vision-Based Assistive Technology*.

Given these advancements and challenges, this review aims to synthesize recent research on AI-powered assistive technologies for the visually impaired, with a focus on wearable and mobile systems integrating computer vision, sensor fusion, and multimodal feedback. The goal is to identify promising design trends, assess practical limitations, and highlight future research directions for developing accessible, reliable, and context-aware navigation aids. This review focuses exclusively on AI-integrated assistive navigation systems published between 2016–2025, analyzing hardware–software co-design, user-centric evaluations, and multimodal feedback strategies.

## Literature Review

Recent research in assistive navigation has introduced a wide range of sensing and AI-based solutions aimed at improving mobility for visually impaired users. Early multimodal frameworks, such as the one introduced by Okolo et al. [1], combined ultrasonic sensing with image processing and intelligent control modules to deliver real-time obstacle alerts. Their system performed well in structured indoor environments and demonstrated the value of sensor fusion. However, accuracy dropped significantly under variable lighting, reflective surfaces, and crowded conditions, highlighting the need for more adaptable vision-based systems.

Advanced AI-driven navigation tools such as NaviGPT by Zhang et al. [2] extended assistive capabilities through multimodal interaction involving speech, scene understanding, and contextual reasoning. This approach enabled richer user interaction and more intuitive guidance compared to detection-only systems. Still, it required substantial computational power and reliable internet connectivity, making it unsuitable for offline, low-resource, or rural environments where visually impaired individuals often require dependable assistance. Wearable AI solutions have also evolved, including LVLM-based systems like the one developed by Baig et al. [3]. Their approach offered detailed environmental descriptions and contextual awareness through large vision–language models. While highly informative, such models demand significant processing capabilities, memory, and battery power, limiting feasibility for lightweight wearable deployment. Similarly, Ferosh et al. [4] demonstrated the benefits of multimodal sensor fusion—combining vision, ultrasonic sensing, and audio output—but noted issues such as bulkiness, high

cost, and complex maintenance, which restrict practical adoption among daily users.

Low-cost assistive devices have also been proposed. The smart walking stick by Bilware et al. [5] integrated ultrasonic sensing with deep-learning-based detection to provide audio alerts. Its affordability and simplicity make it accessible; however, outdoor noise affects ultrasonic accuracy, and the speech-output delay reduces responsiveness. Conversely, ultrasonic-only systems such as the one proposed by Said et al. [6] excel in controlled environments due to their low power consumption and ease of deployment but struggle with fluctuating distance readings in dynamic settings and fail on curved or soft surfaces.

Efforts to minimize network dependence led Mahendran et al. [7] to explore mobile edge computing for visual assistance. Their approach reduced latency by performing inference directly on mobile hardware. While promising, mobile processors remained too limited to support complex vision models in real-world outdoor scenarios. Similarly, Islam et al. [8] developed a deep-learning-based system that produced detailed object descriptions and scene interpretations. Though highly accurate, it required large, diverse datasets and showed reduced performance in low-light or adverse weather conditions.

Smartphone-based solutions such as SMART\_EYE by Pydala et al. [9] utilized built-in sensors and mobile computing to offer an accessible navigation platform. Their advantages include portability and ease of familiar use. However, hands-free operation is limited, and smartphone cameras often lack depth perception needed for precise navigation. Continuous processing systems like DRISHTI by Joshi et al. [10] improved obstacle awareness but suffered from rapid battery drain, overheating, and reduced accuracy in challenging lighting conditions.

Wearable AI devices such as Lakshya by Jaiswal [11] offered portable object recognition but were hindered by high power consumption, bulky hardware, and short battery life. Head-mounted systems, like the device proposed by Xu et al. [12], aligned obstacle detection with natural head movements and provided hands-free usage, but comfort issues—weight, heat, and pressure—restricted prolonged use.

Deep-learning models for navigation continue to evolve. Kumar and Jain [13] developed an

accurate obstacle detection and guidance model, demonstrating strong performance in structured environments. However, its dependence on large datasets affected generalization in unstructured outdoor settings. YOLO-based hybrid systems, such as the one presented by Wu et al. [14], delivered high-speed detection but required GPU-level computation, making them less suitable for embedded devices and causing latency during mobile deployment.

Adaptive systems like the virtual AI assistant by Raghavan et al. [15] improved usability for partially sighted users by customizing guidance based on residual vision. Still, it did not adequately serve individuals with complete blindness or environments requiring high-detail perception. Chang et al. [16] proposed an edge-based traffic-safety solution for zebra crossings. While life-saving in theory, it relied heavily on sophisticated urban infrastructure and stable edge hardware, limiting scalability.

Low-power embedded AI solutions were demonstrated by Ghosh et al. [17], who integrated TensorFlow detection models with a Coral USB accelerator on Raspberry Pi, achieving efficient real-time inference. Yet, the reliance on additional dedicated hardware increased cost and setup complexity. Multimodal recognition frameworks like DEEP-SEE by Tapu et al. [18] offered continuous object tracking and environmental monitoring but were too computationally intensive for low-power devices.

Alternative sensing approaches included the electric-field sensor-based tactile feedback system by Hoang et al. [19], which excelled at detecting close-range obstacles but performed poorly outdoors and lacked long-range capability. RGB-D depth-based solutions like the one introduced by Aladren et al. [20] improved depth perception in controlled indoor settings but were highly sensitive to sunlight and weather, restricting real-world use.

Finally, the foundational work of Sivan and Darsan [21] established the viability of computer vision for assistive navigation. Their research identified early limitations such as computational overhead, sensitivity to illumination, and environmental unpredictability—challenges that continue to guide current research toward more efficient and robust solutions.

**Table 1:** Comparative Analysis of Assistive Systems

Ref No.	Title	Authors	Year	Technology Used	Key Findings	Limitations
[1]	Smart assistive navigation system for visually impaired people	G. I. Okolo, T. Althobaiti, N. Ramzan	2025	Smart assistive navigation tech	Comprehensive navigation system tailored for the visually impaired	Integration with diverse environments needs improvement
[2]	NaviGPT: Real-time AI-driven mobile navigation system	H. Zhang et al.	2025	Multimodal interaction, real-time AI	Enhances travel experience using AI-based interaction	Requires mobile connectivity, high resource consumption
[3]	AI-based wearable vision assistance system for the visually impaired	M. S. A. Baig, S. A. Gillani, S. M. Shah, M. Aljawarneh, A. A. Khan, M. H. Siddiqui	2024	Large vision-language models, real-time object recognition	Effective real-time object recognition and contextual understanding	Dependent on large models' computational requirements
[4]	Assistive technology for navigation of visually impaired people	M. Fayiz Ferosh, P. Sanalkumar, P. P. R. Prathibha, S. Manoj, H. C. V.	2024	Assistive navigation technologies	Improvement in navigation safety and efficiency	Hardware cost and portability considerations
[5]	AI-based object detection, distance measurement and speaking system for blind stick	A. Bilware, T. Darunte, T. Dighe, S. Ghuge, P. Kanade	2024	AI-based object detection, distance measurement, speech	Enhanced obstacle awareness with speech feedback	Speech latency and accuracy in noisy environments
[6]	Obstacle detection system for navigation assistance	Y. Said, M. Ouadou, M. Atri, H. Snoussi	2023	Obstacle detection sensors and navigation systems	Reliable obstacle detection enhancing navigation	May face challenges in dynamic and crowded environments
[7]	Computer vision-based assistance system using mobile edge AI	J. K. Mahendran, D. T. Barry, A. K. Nivedha, S. M. Bhandarkar	2023	Mobile edge AI, computer vision	Efficient mobile AI-based visual assistance with low latency	Edge device limitations may constrain processing power
[8]	Deep learning based object detection and environment	R. B. Islam, S. Akhter, F. Iqbal, M. S. U. Rahman,	2023	Deep learning object detection	Accurate object detection and environment description	Requires extensive training data for diverse

	description	R. Khan				environments
[9]	SMART_EYE: Navigation and obstacle detection via smart app	B. Pydala, T. P. Kumar, K. K. Baseer	2023	Smartphone app-based navigation and detection	User-friendly app provides obstacle alerts	Dependent on smartphone sensors and user familiarity
[10]	DRISHTI: Visual navigation assistant for visually impaired	M. Joshi, A. Shukla, J. Srivastava, M. Rastogi	2023	Visual navigation assistant using computer vision	Real-time navigation assistance with high accuracy	Environmental variability challenges
[11]	Lakshya: Intelligent device using AI/ML models of Google TensorFlow	R. Jaiswal	2023	AI/ML models, Google TensorFlow	Interactive device improves visualization and interaction	Power consumption and device size
[12]	Intelligent head-mounted obstacle avoidance wearable	P. Xu, A. Song, K. Wang	2023	Head-mounted sensors, obstacle avoidance	Wearable system improves obstacle avoidance in real-time	Wearability and battery life concerns
[13]	Deep learning model to assist blind people in navigation	N. Kumar, A. Jain	2022	Deep learning	Improvement in navigation accuracy through DL models	Dataset dependency and scalability
[14]	Object detection navigator using AI and computer vision	E. Wu, J. Sahagun, Y. Sun	2021	AI, computer vision	Accurate object detection assisting visually impaired users	May have latency in processing real-time video
[15]	Virtual AI assistant for partial vision impairment	R. Raghavan, V. Krishnan, H. Nishad, B. Shaikh	2021	Virtual AI assistant	AI agent assists persons with partial vision impairment	Limited to partial vision, effectiveness in complex scenarios unknown
[16]	AI edge computing-based assistive system for pedestrian safety	W.-J. Chang, L.-B. Chen, C.-Y. Sie, C.-H. Yang	2021	AI edge computing, assistive system	Improves safety of visually impaired pedestrians at crossings	Edge computing hardware limits and deployment environment constraints
[17]	Assistive technology using TensorFlow and Coral USB accelerator	A. Ghosh, S. A. Al Mahmud, T. I. R. Uday, D. M. Farid	2020	TensorFlow object detection, hardware accelerators	Efficient object detection on low-power devices	Hardware dependency and setup complexity
[18]	DEEP-SEE: Object detection, tracking and	R. Tapu, B. Mocanu, T. Zaharia	2017	Deep learning for object detection and	Integration of detection, tracking, and	Computationally intensive

	recognition			tracking	recognition improves navigational aid	
[19]	Obstacle detection and warning using electric field sensors	V.-N. Hoang, T.-H. D. Nguyen, H. T. Nguyen	2017	Electric field sensors, tactile feedback	User receives tactile warnings of obstacles, improving safety	Limited range of electric field sensors
[20]	Navigation assistance using RGB-D sensor with range expansion	A. Aladren, G. Lopez-Nicolas, J. J. Guerrero	2016	RGB-D sensors with range expansion	Enhanced obstacle detection with depth sensing	Sensor range and lighting conditions affect accuracy
[21]	Computer vision based assistive technology	S. Sivan, G. Darsan	2016	Computer vision	Vision-based assistive technology effectively detects obstacles	Limited by lighting and environmental conditions

### Discussion

Based on the reviewed literature, several recurring challenges continue to affect the design and deployment of assistive navigation systems for visually impaired users. Although advances in deep learning, embedded computing, and wearable sensors have improved system reliability, significant gaps persist across existing solutions.

**Network Dependency:** Many systems rely on offloading computation to mobile or edge servers to achieve higher inference accuracy. While this reduces processing load on the device, it makes performance dependent on stable internet connectivity. Variations in bandwidth can impact real-time responsiveness, especially for time-critical navigation alerts [3][16].

**Fallback Model Constraints:** Lightweight fallback models such as YOLO-tiny or MobileNet maintain system continuity during offline operation, but their reduced accuracy and limited contextual reasoning affect performance in cluttered or fast-changing environments [12][17].

**Power and Hardware Limitations:** Continuous video processing and sensor polling place heavy demands on battery-powered devices. Platforms like Raspberry Pi have restricted compute and memory capabilities, limiting the deployment of advanced AI models and requiring compromises between portability and functionality [1][7].

**Environmental Sensitivity:** Both ultrasonic and camera-based systems are highly sensitive to environmental factors. Ultrasonic sensors struggle with soft or angled surfaces, while camera accuracy drops in low light, motion blur,

or occluded scenes, reducing reliability in real-world navigation [1][8].

**Privacy and Security:** Even when using edge or local servers, transmitting visual or sensor data introduces privacy risks. Ensuring secure communication and minimal data exposure is essential for protecting user confidentiality [11].

**User Adaptation:** Advanced features such as interactive scene descriptions or personalized learning require user training and familiarity. Without intuitive design and adequate support, adoption rates may remain low despite technological innovation [3][9].

### Future Directions

To address these limitations, future research should focus on the following areas:

**Optimized Architectures:** Hybrid server-client models should be explored, enabling low-power devices to handle basic sensing while offloading heavier inference tasks to nearby edge systems. Techniques like pruning, quantization, and knowledge distillation can further reduce latency without significantly impacting accuracy [12][13].

**Multimodal Sensor Fusion:** Integrating cameras with ultrasonic, LiDAR, or IMU sensors can improve reliability across diverse environments. Existing studies already indicate that combining vision and ultrasonic sensing reduces false positives and enhances obstacle detection [1][8].

**Contextual Understanding:** Lightweight vision-language models can provide deeper scene descriptions beyond simple object detection. Future work must focus on

compressing and optimizing such models for real-time inference on portable, battery-powered hardware [3][2][21].

**User-Centered Design and Evaluation:** Long-term trials with visually impaired users are essential to assess usability, comfort, and acceptance. Consistent evaluation using metrics such as mAP, latency, false-alert rate, and usability scores will help compare performance across systems [1][9][3].

**Scalability and Accessibility:** Assistive systems must remain affordable and practical for deployment in low-resource regions. Balancing cost, durability, and performance will be key to ensuring wide accessibility for visually impaired individuals [1][16].

### Conclusion

This review has examined recent advancements in AI-driven assistive navigation systems for visually impaired individuals, emphasizing major trends, methodologies, and persistent challenges. The proposed server-client architecture builds on these insights by combining lightweight sensing hardware with high-capacity server-based processing, achieving a balance between portability, detection accuracy, and real-time responsiveness. By integrating vision-based detection with ultrasonic distance measurement, the system targets reliable proximity alerts and contextual understanding while maintaining low latency. Literature suggests that such hybrid approaches can deliver strong accuracy (mAP ~75–90%) and faster inference than fully embedded models, while multimodal feedback—audio or haptic—can further enhance usability. The modular design also enables scalability through hardware acceleration and advanced features such as LVLN-driven scene summarization.

Despite these advantages, practical deployment must account for network reliability, power constraints, environmental variability, hardware limitations, and user privacy. Effective user adoption will also require intuitive interfaces and basic training to ensure smooth interaction. Overall, this work highlights the promise of combining edge computing, server-based AI, and multimodal interaction to create accessible and user-centered assistive navigation systems. Continued research in optimization, secure communication, and adaptive user experience can help move these solutions closer to affordable and reliable real-world implementation for visually impaired individuals.

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### References

G. I. Okolo, T. Althobaiti, and N. Ramzan, "Smart assistive navigation system for visually impaired people," *Journal of Disability Research*, vol. 4, pp. 1–10, e20240086, Jan. 2025, doi: 10.57197/JDR-2024-0086.

H. Zhang et al., "Enhancing the travel experience for people with visual impairments through multimodal interaction: NaviGPT, a real-time AI-driven mobile navigation system," in *Proc. ACM Int. Conf. on Supporting Group Work (GROUP '25)*, Hilton Head Island, SC, USA, Jan. 2025.

M. S. A. Baig, S. A. Gillani, S. M. Shah, M. Aljawarneh, A. A. Khan, and M. H. Siddiqui, "AI-based wearable vision assistance system for the visually impaired: Integrating real-time object recognition and contextual understanding using large vision-language models," *arXiv preprint arXiv:2412.20059*, 2024.

M. Fayiz Ferosh, P. Sanalkumar, P. P. R. Prathibha, S. Manoj, and H. C. V., "Assistive technology for navigation of visually impaired people," *Journal of Electrical Systems*, vol. 20, no. 7s, pp. 989–996, 2024.

A. Bilware, T. Darunte, T. Dighe, S. Ghuge, and P. Kanade, "AI-based object detection, distance measurement and speaking system for blind stick," *International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)*, vol. 4, no. 2, pp. 162–172, Nov. 2024, doi: 10.48175/IJARSCT-22133.

Sunkara, S. P. (2025). *Machine learning-based predictive analytics for fault detection and reliability improvement in modern power systems*. International Journal of Electrical Engineering

and Technology (IJEET), 16(5), 1–13. [https://doi.org/10.34218/IJEET\\_16\\_05\\_001](https://doi.org/10.34218/IJEET_16_05_001)

Y. Said, M. Ouadou, M. Atri, and H. Snoussi, "Obstacle detection system for navigation assistance of visually impaired people," *Procedia Computer Science*, vol. 219, 2023.

J. K. Mahendran, D. T. Barry, A. K. Nivedha, and S. M. Bhandarkar, "Computer vision-based assistance system for the visually impaired using mobile edge artificial intelligence," *Proceedings of the IEEE*, vol. 111, no. 8, pp. 1–14, 2023.

R. B. Islam, S. Akhter, F. Iqbal, M. S. U. Rahman, and R. Khan, "Deep learning based object detection and surrounding environment description for visually impaired people," *Heliyon*, vol. 9, no. 4, p. e16924, 2023.

B. Pydala, T. P. Kumar, and K. K. Baseer, "SMART\_EYE: A navigation and obstacle detection for visually impaired people through smart app," *Journal of Applied Engineering and Technological Science*, vol. 4, no. 2, pp. 992–1011, 2023.

M. Joshi, A. Shukla, J. Srivastava, and M. Rastogi, "DRISHTI: Visual navigation assistant for visually impaired," *arXiv preprint*, arXiv:2303.07451, 2023.

R. Jaiswal, "Lakshya: Intelligent device to help visually impaired people visualize and interact with objects and people around them using AI/ML models of Google TensorFlow," *International Journal for Multidisciplinary Research (IJFMR)*, vol. 5, no. 4, pp. 1–17, Jul.–Aug. 2023.

P. Xu, A. Song, and K. Wang, "Intelligent head-mounted obstacle avoidance wearable for the blind and visually impaired," *Sensors*, vol. 23, no. 23, p. 9598, Dec. 2023, doi: 10.3390/s23239598.

Sharma, B. (2022). *A study of teachers' human rights consciousness in reference to human rights education*. *International Journal of Early Childhood Special Education*, 14(1), 786–790.

Hazarika, I. (2022). *Digital transformation of the silk industry of Assam*. *Archives of Business Research*, 10(4), 110–119. <https://doi.org/10.14738/abr.104.12261>

N. Kumar and A. Jain, "A deep learning based model to assist blind people in their navigation," *Journal of Information Technology Education:*

*Innovations in Practice*, vol. 21, pp. 95–114, 2022, doi: 10.28945/5006.

E. Wu, J. Sahagun, and Y. Sun, "An object detection navigator to assist the visually impaired using artificial intelligence and computer vision," *Computer Science & IT*, pp. 43–51, 2021, doi: 10.5121/csit.2021.111005.

R. Raghavan, V. Krishnan, H. Nishad, and B. Shaikh, "Virtual AI assistant for persons with partial vision impairment," *ITM Web of Conferences*, vol. 37, 01019, 2021, doi: 10.1051/itmconf/20213701019.

W.-J. Chang, L.-B. Chen, C.-Y. Sie, and C.-H. Yang, "An artificial intelligence edge computing-based assistive system for visually impaired pedestrian safety at zebra crossings," *IEEE Transactions on Consumer Electronics*, vol. 67, no. 1, pp. 3–11, Feb. 2021, doi: 10.1109/TCE.2020.3037065.

A. Ghosh, S. A. Al Mahmud, T. I. R. Uday, and D. M. Farid, "Assistive technology for visually impaired using TensorFlow object detection in Raspberry Pi and Coral USB accelerator," in *Proc. IEEE Region 10 Symposium (TENSYP)*, Dhaka, Bangladesh, 2020, pp. 186–189, doi: 10.1109/TENSYP50017.2020.9230630.

Jumde, A., Hazarika, I., & Cho, B. Y. (2019). *Block chain technology: A new enabler of financial services*. In *Proceedings of the 2019 Sixth HCT Information Technology Trends (ITT)* (pp. 259–263). IEEE. <https://doi.org/10.1109/ITT48889.2019.9075091>

R. Tapu, B. Mocanu, and T. Zaharia, "DEEP-SEE: Joint object detection, tracking and recognition with application to visually impaired navigational assistance," *Sensors*, vol. 17, no. 11, p. 2473, 2017.

V.-N. Hoang, T.-H. D. Nguyen, and H. T. Nguyen, "Obstacle detection and warning system for visually impaired people using electric field sensors and tactile feedback," *Sensors*, vol. 17, no. 11, p. 2473, 2017.

A. Aladren, G. Lopez-Nicolas, and J. J. Guerrero, "Navigation assistance for the visually impaired using RGB-D sensor with range expansion," *IEEE Systems Journal*, vol. 10, no. 3, pp. 922–932, 2016.

S. Sivan and G. Darsan, "Computer vision based assistive technology for blind and visually impaired people," in *Proc. Int. Conf. on Computing, Communication and Networking Technologies*

(*ICCCNT*), Dallas, TX, USA, Jul. 2016, pp. 1–6, doi:  
10.1145/2967878.2967923.