Artificial Intelligence Based Solution for Navigating Vision Impaired Individuals: A Review

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***Abstract*— Vision Impaired individuals face difficult situations while they are traveling independently. The major issues include difficulty in reach the destination location independently. This review aims to evaluate current solutions and propose an innovative solution to enhanced the navigation of vision impaired individuals. This research aims to systematically evaluate existing literature on assistive technologies for vision impaired individuals and to introduce a novel solution with emerging technologies to enhance the navigation of them. According to the PRISMA guidelines a comprehensive literature search was conducted by using multiple academic databases such as IEEE Xplore, Google scholar, IJEECS and MDPI. Studies were found for their relevance, focusing on assistive device, technologies and applications designed to aid the vision impaired individuals. Data were gathered and analyzed for identify the gaps. This review found the wide variety of technologies such as wearable devices, mobile applications and mobility aids. However, still there are significant gaps remaining in integration of real-time navigation and personalized assistance. According to the findings, we proposed the new solution that combines computer vision (CV) and artificial intelligence (AI) based personalized assistant to create real-time navigation system for visual impaired individuals. The proposed solution aims to bridge the gaps in existing solutions and future studies should focus on implementing this technology in real-world.**

Keywords— Assistive Devices, Vision Impaired Individuals, Object Detection, Navigation, Assistive Software

I. Introduction

Vision is one of the most important senses of human life. That allows humans to observe and interact with the world. Millions of people suffer different types of vision impairments globally [1]. Which varies from partial loss of vision to complete loss of vision. Based on the World Health Organization (WHO) statistics at least 2.2 billion people have vision impairment globally. Of these 36% of people with distance vision impairment and 17% of people with vision impairment due to cataract [2]. Based on the WHO statistics these numbers are growing year by year that highlight the global challenge of the vision impaired people face their daily lives, especially in navigating urban areas, circumventing obstacles and reaching their destination location without getting help from other people [3].

There are many assistive and guiding devices developed for vision-impaired individuals to face those challenges. Vision- impaired individuals use white canes traditionally. That white cane can detect obstacles within a limited range in front of them[4]. Smart sticks are developed utilizing ultrasonic sensors[5], a Global positioning system (GPS) and Global System to Mobile Communication (GSM) module for provide alerts to the guardian and detect obstacles from greater distances[6]. More recently, smart glasses have been developed to provide superior assistance to the vision impaired individuals by utilizing the camera module, obstacle detection sensors, GPS, GSM modules and machine learning algorithms (ML)[7], [8].

Despite these advances, no any devices are able to provide a comprehensive autonomous real-time guiding system. Vision Impaired people are still facing the difficulty of getting the safest and easiest path to reach their destinations without getting other's guidance. Compared to the autonomous car system, vision-impaired people are facing the same kind of situation. The self-driving car has a sensor based autonomous system that depend on real-time sensor data to detect objects, circumvent obstacles, and make the navigation [9]. This is an ideal solution for vision-impaired individuals to reach their destination location without getting any external assistance. This review addresses the gap by finding the technologies to implement the comprehensive autonomous system to assist vision- impaired individuals. The primary aim of this review paper is to introduce an AI-based solution for navigating vision- impaired individuals. Additionally, find the existing technologies and limitations which are used to develop assistive devices.

The rest of this paper is as follows. Section II critically examines the tools and technologies used in the existing devices. Also, evaluate the limitations and accuracy of these devices. Section III explores the methodology of this review paper with a diagram. Section IV describes the results of this review paper. The last section V concludes by highlighting the proposed solution for this problem and highlighting the technologies and methodology included in the proposed solution.

II. Literature Review

Current assistive navigation systems for the vision impaired are discussed within this literature review of existing technologies and methods employed. Relevant studies which consider , cameras and sensors, software technologies, devices and hardware, and obstacle feedback systems were analyzed to ensure inclusion.

A. Cameras and Sensors

The research [10] have been implemented smart glass using Raspberry Pi camera for capturing the real time visuals, Two Ultrasonic sensors detect 2cm – 400cm distance obstacles Withing 90º and 30º degrees. NEO 6M GPS sensor gets the latitude and longitude of the user's location. NEO 6M GPS sensor location is little different than the actual location error percentage is 0.0009% to 0.004%. That device is responsive for only 400cm. The research [11] developed the hand held smart glass by using millimeter -wave (MMW) radar and RGB–depth (RGB-D) sensor camera. RGB-D camera provide better details of the obstacles such as spatial and color information. MMW radar detect the obstacle in long distance. According to the fig. 2 RGB-D camera has the IMU unit that unit consist the accelerometer and gyroscope that measure the motion and orientation to enhance the capturing vision for navigate the vision impaired individuals. Combination of RGB-D camera and MMW radar can detect multiple objects withing the 80m. The research [12] developed the system for detecting the stairs and pedestrian crosswalks by using RGB-D camera. Crosswalks and stairs are detected by using the RGB channels and utilizes depth data to detect the parallel lines of the crosswalks and stairs. The study [13] implemented the real-time crosswalk detection algorithm integrated into a smart glass.

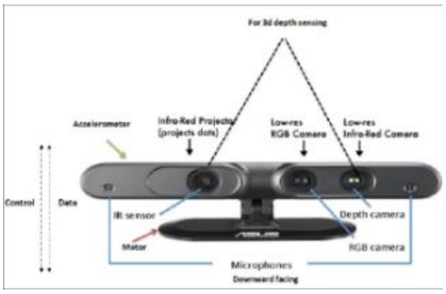

Fig. 2. Example of RGB_D camera [14]

The research [15] have been used binocular vison camera (Stereo vision camera) for capturing the visual feed. According to the fig. 1. right camera will detect the particular point of the object and left camera accept that point referred by the right camera [16].Also to calculate the distance OpenCV algorithm such as Semi-Global Block Matching(SGBM) is used.

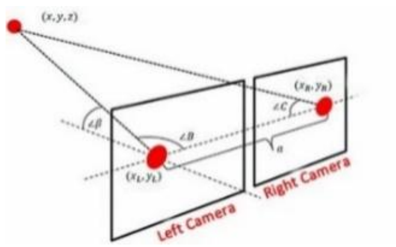

Fig. 1. A Standard Stereo Vision System [16]

B. Software Technologies

The research [17] have been used Android application for navigating the visual impaired individuals. Google map API is integrated in to that application. User can select their destination by voice assistance. The research [18] have been used mobile application for detect objects and face recognition using deep learning model (DL). This operates in two modes such as walking mode and reading mode. The research [19] have been used a mobile application for assist the visually impaired individuals. That mobile app includes the real-time object detection, read text (OCR), face recognition and text to speech translation facilities. To detect objects and recognize text, Google Vision and Frits AI are used.

C. Devices and Hardware

To navigate vision impaired individuals there are many assistive devices have been implemented in past years. By considering these devices there are two types of devices available in the world. Such as wearable devices and mobility aid devices. The research [10],[3] have been implemented the smart glass for vision impaired individuals which used Raspberry Pi 3 board for processing unit. NVIDIA Jetson Nano board is used by the research [15]. That NVIDIA Jetson board is more compatible with the more complex machine learning models [15]. The research [7] have been used Raspberry pi and ESP 8266 board for processing unit. The ultrasonic sensors are interfaced with the ESP 8266 (Node MCU) and ESP 8266 board to the raspberry pi board. The research [17] have been implemented the smart cane for blind individuals which used Arduino uno R3 board for processing unit. GPS, GSM, Ultrasonic sensor, water sensor and RF module connected to that board. RF module is used for find the cane if it is lost.

Board	CPU/ GPU	RAM	Connectivity
Raspberry Pi 4 [5]	Quad-core 1.5 GHz	1GB to 8GB	WIFI, Bluetooth, USB, HDMI
NVIDIA Jetson nano [15]	Quad-core ARM Context-A57, Maxwell GPU with 128 CUDA cores	4 GB LPDDR 4	USB 3.0, HDMI, Gigabit Ethernet
Arduino Uno R3[17]	8bit AVR @ 16 MHz	2KB SRAM	No built-in connection can add

Table 1. Comparison of the Processing Board for Assistive Technology

D. Objects Detection Models

The Research [10] have been used Google TensorFlow it contains millions of objects data and Faster Region CNN (Faster R-CNN). That TensorFlow library is used with the Raspberry pi. Camera grabs the video frame and detect the particular point and match with the image database which is already trained. Then If match with the detected point object match with the database. Faster R-CNN used for family member recognition. For instance, some research papers have been used You Only Look Once (YOLO) versions for real time object detection. The research [15] have been used YOLOv3 model. Neural network of YOLO model divides the captured image into smaller regions, bounding boxes and probability for each box. YOLOv5 mode with Microsoft Common Object in Context (MSCOCO) have been used to implement the Smart Stick [5]. That model can recognize 80 objects and additional 8 newly trained objects within a 2-meter range. 1600 images are used to train the model. Object detection accuracy in YOLOv3 model achieves 87.71%, while the YOLOv5 achieves 93.33%. The research [18] have been used SSD MobileNet V2 for the objects detection and face recognition in the mobile application.

E. Obstacle Feedback System

The research [5] smart stick have been used pre-defined instructions to provide the feedback to the vision impaired individuals. These instructions are only can be used for some common scenarios. “Turn left, Turn right” commands provide to the user via headphone according to the detected object position. Pyttsx3 library is used for convert the text to speech. The research [7] have been used audio feedback to alerted if the obstacle is more closed. Voice assistance used for communicate with the user by developed speech recognition system. User can talk with the smart glass by using inbuild microphone. That can recognize the user’s commands as speech. The research [17] smart cane have been used vibration for feedback system. That can detect the object by using ultrasonic sensors and when the sensor detects objects in-front of the user then the feedback system vibrates the smart cane. Also in this smart cane use google map to navigate the user to their specific location by using voice assistance integrated with the google map.

Ref	Objective(s)	Methodology	Limitation(s)
[3]	Navigate and avoid the obstacle	Used camera module and RNN for object detection	Users are not able to reach any location individually, Power consumption
[7]	Detect Objects, Read text	Used DL and Computer vision	Users are not able to reach any location individually, poor detection in low-light
[15]	Detect obstacles, get the distance to the objects	Use binocular camera to get distance to the object. Give tactile feedback	Users are not able to reach any location individually, Power consumption
[17]	Navigate using google map, object detection	Google map support for find the way and object detection with ultrasonic sensor	Less accuracy in object detection
[12]	Detect stair cases and crosswalks	To detect that support vector machine integrate in to the RGB-D camera	Only can detect the crosswalks and stairs
[18]	Object detection using mobile app	ESP32 cam connect to the mobile app and detect objects	Users are not able to reach any location individually

Table .2. Summary of the literature review

This literature review has looked at the major technological aspects that are in the assistive devices for the vision impaired individuals; the hardware aspect, the sensory technology, the software solutions and finally the obstacle feedback. Consequently, this analysis has revealed important developments and limitations of existing solutions, for instance potential issues with real-time guidance and how effectively assist the vision impaired individuals. In doing so, these studies highlight the need for improving and linking these components to support the development of better, independent navigation systems. In the next section on methodology, we present the framework we employed in conducting this review, under the heading of identification, screening, eligibility and inclusion.

III. Methodology

This review is structured according to PRISMA guidelines that aims at providing an in-depth examination of the existing literature concerning the most recent developments in assistive technologies for Vision impaired people, especially in hardware and sensory subsystems, software technologies, and obstacle feedback components. The methodology adhered to four key stages: The following criteria were applied: Identification, screening, eligibility, and inclusion that would allow the accumulation of the most significant studies only for a more detailed analysis of the subject area.

The identification phase was an extensive search of various academic databases of IEEE Xplore, Google scholar, IJEECS and MDPI. The aim was to gain a diverse collection of research hitting 2012 to 2024 in order to review all the most recent advances in technology available. Certain keywords, including “Assistive Devices, Vision Impaired Individuals, Object Detection, Navigation, Assistive Software” were used to cover a wide range of assistive software application and device aspects. An initial broad search strategy yielded wide range of studies. All of which had insights regarding at least one aspect of assistive technology for vision impaired individuals.

A first refinement was then done at the screening stage to guarantee relevance and quality. This was accomplished by performing systematic duplicate removals and removal of articles for which the methods lacked rigor or were lacking relevance to vision impaired navigation technology. In this process, the number of studies considered was reduced to around 40 studies explicitly targeting hardware, sensors, software, or feedback mechanisms with assistive navigation.

The reading of the full text of each research paper took place in the eligibility phase to determine its suitability toward the aims of the review. Specific papers were selected that focus on navigation aids for vision impaired individuals in areas such as object detection, obstacle avoidance or route guidance. After this thorough review, the pool was whittled down to 30 studies with the potential to contribute unique insights for how we use technologies and methods to create assistive navigation systems.

The last stage, inclusion, was a complete qualitative analysis in which the last studies were reviewed in detail to extract what contribution they made to the field. We looked at each of the studies' unique technology architecture (sensors, processing units, etc.), as well as any advanced algorithms that aided in navigation accuracy. Studies were also analyzed regarding their reported limitations, such as navigate in dynamic environments, obstacle feedback system and real time processing capacity. Finally selected the 21 studies for my review. This analysis focused on the identification of these studies which offered claims of substantial evidence for the status of Assistive Technology today.

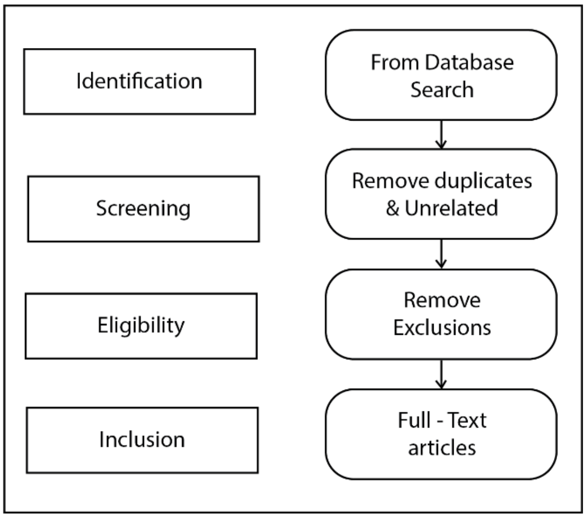

Fig. 3. Summary of the methodology

IV. Result and Discussion

This section discusses the results of reviewed studies and presents a detailed analysis on the fundamental strengths and weaknesses of existing assistive technologies for vision impaired individuals. The discussion is organized into three core areas: Advantages and Limitations of Hardware Technologies of assistive devices, Effectiveness of Object Detection Models and Devices, and Enhancement Obstacle Feedback System. Each subsection focuses on evaluating the specific contributions and limitations of these technologies as they relate to functionality.

A. Advantages and Limitations in Hardware Technologies for Assistive Device

The Review of the literature provide the more details of limitations and advantages of hardware components used for the assistive devices. Such as processing power real-time performance and hardware compatibility with the AI models. According to the Table 1 Raspberry Pi 4 has Quad-core 1.5Ghz CPU and 1 GB to 8 GB RAM. Raspberry Pi 4 has more processing power compared to the other processing board. NVIDIA Jetson Nano has Quad-core ARM A57 CPU and 4 GB LPDDR4 RAM. Compared with the Raspberry Pi 4, NVIDIA Jeston board has more processing power. Arduino uno is the basic processing board for the assistive devices. They have 8-bit AVR 16 MHz CPU, by compared to Raspberry Pi and NVIDIA Jetson, Arduino Uno has insufficient processing power. Also Raspberry Pi 4 has capability to run AI models but not more complex AI models. NVIDIA Jetson Nano has capability to run More complex AI models rather than Raspberry Pi 4. Also Raspberry Pi and NVIDIA Jetson are capable to run and accurate for voice assistance. But compared with the Raspberry Pi 4 and NVIDIA Jetson, Raspberry pi 4, cost is less than the NVIDIA Jetson. According to the literature review results, Raspberry Pi cameras, stereo vision cameras, RGB-D cameras and ESP 32 cameras and , MMW radar have been used to capture the vision. Compared with other cameras, Pi camera can only detect the 62o angle and can detect 1m distance. RGB-D camera can detect 0.5m to 6m range and Binocular depth camera can detect the 10 m to 20m range. But binocular depth camera used SGBM algorithm for object detection. Compared with the RGB-D camera, binocular depth camera method is not much accurate. To capture the vision feed of the autonomous vehicle have been used camera with IMU combined with LiDAR system[20]. As result of the literature review, RGB-D or stereo vision camera has IMU for the depth perception and better object recognition. For implement the better solution for vision impaired individuals can be used that IMU integrated camera. According to the literature review result, compared with the Binocular vision camera, RGB-D camera is the best camera for capture the vision. To detect the ground area of the user that cannot covered by the camera can be used ultrasonic sensor.

B. Effectiveness of Objects Detection Models

When compared to the mobile phone object detection application smart glass [10] are more accurate. The research [19] have been integrated Google vision and Frist AI into mobile application. That mobile application can only detect the object in-front of the user that mobile application cannot provide additional details such as distance to the object. Because that mobile application used the mobile phone camera. But research [18] have been used ESP 32 camera with the mobile application. To detect obstacles SSD MobileNet V2 have been used in the mobile application. But the model mean average precision was 60%. According to the literature review result, research [5] have been used YOLO V5 model for smart stick. That YOLO V5 model achieved 93.33% in detection objects. YOLO V3 model achieved 87.71%. Compared with the MobileNet model, YOLO V5 achieved more accuracy. YOLO,CNN and RCNN models have been used for object detection in autonomous vehicle system. YOLO is a CNN based model[9]. According to the literature review YOLO v5 is the best accurate model for object detection. Using the YOLO latest model can be achieved better solution for the vision impaired people.

C. Enhancement of Obstacle Feedback System

The success of an assistive device for vision impaired individuals is also determine by the quality an accuracy of the feedback system. According to the literature review the research [5] have been used pre-defined commands. That pre-defined command can only be used for some common scenarios. Commands can't be change according to the real-time environment change. That pre-defined command can provide the command according to the position of object detect. Some of studies have been used voice assistant integrated with the Google map and vibration system as feedback system. Many of assistive device used those feedback technology and few of developments have been used Natural Language Processing (NLP) for voice assistant. According to the literature review result, NLP technology into voice assistant is the best way to navigate the user. Also the feedback technology can be improved like this. When a user asked about the surrounding environment information using voice commands. System should be able to provide the details to the user using Natural Language Generation (NLG). Also NLG is a subfield of AI. NLG can automatically provide human-readable text or speech from structured data or other form of input [21]. That NLG can be integrated into the chatbot and image to speech conversion.

V. Conclusion

This review paper analyzed the present situation of the assistive devices and technologies to proposed the innovative solution for vision impaired individuals. In this review focused on the hardware components such as processing board, camera and other sensors, object detection models, obstacle feedback system in existing studies.

Additionally this review discussed about the research gaps in the existing studies such as limitations, challenges and accuracy to enhanced the real-time navigation of vision impaired individuals. According to the discussion section, in autonomous vehicle also available this kind of system to automate the vehicle movements according to the user's requirements. For this task autonomous vehicle use cameras, radar, lidar ultrasonic actuators and AI, ML and DL combined algorithm for image processing task [9].

As a solution to the research problem for the independent navigation of a vision-impaired person, a combination of CNN-based YOLO with an RGB-D camera and MMW radar provides reliable object and environment perception. YOLO is accurate and greatly can distinguish obstacles in real-time, while RGB-D and MMW radar provide accurate depth input and position. This integration guarantees one to be guided through dynamic environments for effective provision of services. Furthermore, an NLP based voice assistant with google map integration with Natural Language Generation (NLG) technology improves the existing guidance system by providing situation aware, real time, routing information. All of these components entail form a communicative and coherent system that provides accurate localization and orientation, enhancing the level of independency for vision impaired individuals as far as their mobility is concerned. Hope this review will guide for further advancements in assistive devices for vision impaired individuals.

Reference

[1] P. Barapatre, N. Bhosage, M. Gaikwad, R. Pawar, and K. Kamble, "A Review Paper on AIoT as Vision Aid for Visually Impaired People," in *2024 IEEE 9th International Conference for Convergence in Technology (I2CT)*, Pune, India: IEEE, Apr. 2024, pp. 1–4. doi: 10.1109/I2CT61223.2024.10543443.

[2] "Vision impairment and blindness." Accessed: Oct. 08, 2024. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment

[3] Information Technology, Parul University, Vadodara, India., N. Satani, S. Patel, Information Technology, Parul University, Vadodara, India., S. Patel, and Information Technology, Parul University, Vadodara, India., "AI Powered Glasses for Visually Impaired Person," *Int. J. Recent Technol. Eng. IJRTE*, vol. 9, no. 2, pp. 316–321, Jul. 2020, doi: 10.35940/ijrte.B3565.079220.

[4] M. A. Williams, A. Hurst, and S. K. Kane, "'Pray before you step out': describing personal and situational blind navigation behaviors," in *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility*, Bellevue Washington: ACM, Oct. 2013, pp. 1–8. doi: 10.1145/2513383.2513449.

[5] W. A. Abir, S. H. Tosher, N. A. Nowrin, Md. Z. Hasan, and M. A. Rahaman, "A Computer Vision and IoT Based Smart Stick for Assisting Vision-Impaired People," in *2023 5th International Conference on Sustainable Technologies for Industry 5.0 (STI)*, Dhaka, Bangladesh: IEEE, Dec. 2023, pp. 1–6. doi: 10.1109/STI59863.2023.10465144.

[6] S. Bhorge, M. Kasodekar, A. Karmalkar, and V. Kulkarni, "Smart Blind Stick: Object Detection & GPS

Integration for Enhanced Mobility," in *2024 3rd International Conference on Applied Artificial Intelligence and Computing (ICAAIC)*, Jun. 2024, pp. 1653–1658. doi: 10.1109/ICAAIC60222.2024.10575880.

[7] S. G. Gollagi, K. D. Bamane, D. Manish Patil, S. B. Ankali, and B. M. Akiwate, "An innovative smart glass for blind people using artificial intelligence," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 31, no. 1, p. 433, Jul. 2023, doi: 10.11591/ijeecs.v31.i1.pp433-439.

[8] A. R, H. S, and H. P. P, "Customized Smart Glasses for Needy Blind People," *Int. J. Online Biomed. Eng. IJOE*, vol. 16, no. 13, pp. 33–44, Nov. 2020, doi: 10.3991/ijoe.v16i13.18527.

[9] D. Parekh *et al.*, "A Review on Autonomous Vehicles: Progress, Methods and Challenges," *Electronics*, vol. 11, no. 14, p. 2162, Jul. 2022, doi: 10.3390/electronics11142162.

[10] Md. T. Islam, M. A. Rashid, M. Ahmad, A. Kuwana, and H. Kobayashi, "Design and implementation of smart guided glass for visually impaired people," *Int. J. Electr. Comput. Eng. IJECE*, vol. 12, no. 5, p. 5543, Oct. 2022, doi: 10.11591/ijece.v12i5.pp5543-5552.

[11] N. Long, K. Wang, R. Cheng, K. Yang, W. Hu, and J. Bai, "Assisting the visually impaired: multitarget warning through millimeter wave radar and RGB-depth sensors," *J. Electron. Imaging*, vol. 28, no. 01, p. 1, Feb. 2019, doi: 10.1117/1.JEI.28.1.013028.

[12] S. Wang and Y. Tian, "Detecting stairs and pedestrian crosswalks for the blind by RGBD camera," in *2012 IEEE International Conference on Bioinformatics and Biomedicine Workshops*, Philadelphia, USA: IEEE, Oct. 2012, pp. 732–739. doi: 10.1109/BIBMW.2012.6470227.

[13] R. Cheng, K. Wang, K. Yang, N. Long, and W. Hu, "Crosswalk navigation for people with visual impairments on a wearable device," *J. Electron. Imaging*, vol. 26, no. 05, p. 1, Oct. 2017, doi: 10.1117/1.JEI.26.5.053025.

[14] K. Tychola, I. Tsimperidis, and G. Papakostas, "On 3D Reconstruction Using RGB-D Cameras," *Digital*, vol. 2, pp. 401–423, Aug. 2022, doi: 10.3390/digital2030022.

[15] J. R. B. Da Silva, J. V. B. Soares, L. R. Gomes, and J. R. Sicchar, "An approach to the use of stereo vision system and AI for the accessibility of the visually impaired," in *2024 International Conference on Control, Automation and Diagnosis (ICCAD)*, Paris, France: IEEE, May 2024, pp. 1–6. doi: 10.1109/ICCAD60883.2024.10553945.

[16] E. Dandil and K. K. Cevik, "Computer Vision Based Distance Measurement System using Stereo Camera View," in *2019 3rd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT)*, Ankara, Turkey: IEEE, Oct. 2019, pp. 1–4. doi: 10.1109/ISMSIT.2019.8932817.

[17] F. Ahmed, Z. Tasnim, M. Rana, and M. M. Khan, "Development of Low Cost Smart Cane with GPS," in *2022 IEEE World AI IoT Congress (AIIoT)*, Seattle, WA, USA: IEEE, Jun. 2022, pp. 715–724. doi: 10.1109/AIIoT54504.2022.9817322.

[18] T. Rizan, V. Siriwardena, M. Raleen, L. Perera, and D. Kasthurirathna, "Guided Vision: A High Efficient And Low Latent Mobile App For Visually Impaired," in *2021 3rd International Conference on Advancements in Computing (ICAC)*, Colombo, Sri Lanka: IEEE, Dec. 2021, pp. 246–251. doi: 10.1109/ICAC54203.2021.9671191.

[19] A. Chuttergoon and L. Nagowah, "Eye Guide: An Assistive Mobile Technology for Visually Impaired Persons," in *2020 3rd International Conference on Emerging Trends in Electrical, Electronic and Communications Engineering (ELECOM)*, Balaclava, Mauritius: IEEE, Nov. 2020, pp. 198–203. doi: 10.1109/ELECOM49001.2020.9296992.

[20] M. Martínez-Díaz and F. Soriguera, "Autonomous vehicles: theoretical and practical challenges," *Transp. Res. Procedia*, vol. 33, pp. 275–282, 2018, doi: 10.1016/j.trpro.2018.10.103.

[21] D. Tripathi and A. Tamrakar, "Natural Language Generation: Algorithms and Applications," *Turk. J. Comput. Math. Educ. TURCOMAT*, vol. 9, pp. 1394–1399, Dec. 2018, doi: 10.61841/turcomat.v9i3.14597.