Grenze International Journal of Engineering and Technology, June Issue

Smart Assistance for Visually Impaired People - A Review

Swati Chandurkar[1], Aditya Kudale[2], Prasanna Kotkar[3], Ishan Pardeshi[4] and Surabhi Tilekar[5]
[1-5]Pimpri Chinchwad College of Engineering /Department of Computer Engineering, Pune, India
Email: swati.chandurkar@pccoepune.org, aditya.kudale22@pccoepune.org, prasanna.kotkar22@pccoepune.org, ishan.pardeshi23@pccoepune.org, surabhi.tilekar23@pccoepune.org

***Abstract*—Assistive technologies have developed rapidly for the blind and visually impaired, yet still face challenges in offering seamless navigation and mobility. In this paper, we review the latest technologies on navigation assistance systems in their integration with deep learning, sensor technologies, and mobile applications. Some of the current solutions such as YOLO-based models for real-time obstacle detection using ultrasonic sensors and AI localization provide spatial awareness and promote independence. Nevertheless, these innovations suffer from various limitations regarding their adaptability to several environments and seamless integration. Therefore, the survey presented in this article highlights critical gaps and possible future works in the gears of multifunctional, user-centric systems that are efficient, compact, and scalably deployable. The results justify the new emerging technologies' capability to transform assistive systems and, hence, contribute to catering to the need for inclusivity for visually impaired users.**

***Index Terms*— Real-Time Object Detection, Assistive Navigation, YOLOv3, styling, Ultrasonic Sensors.**

I. INTRODUCTION

Innovative assistive navigation technologies have focused on better mobility and safety of a visually impaired person, creating far clearer situational awareness via high-tech techniques based on deep learning, sensors integration, and smartphone application-based approaches. Since limited means of independence for those carrying around a guide dog or a white cane is realized, it is necessary to study these newer technologies. Messaoudi et al. discuss tools such as RFID, Bluetooth, GPS, and haptic and audio feedback for spatial awareness in Assistive Navigation Tools and Technologies for Individuals with Visual Impairments. Said et al. present NAS and FCOS-based real-time obstacle detection models optimized for low-power devices in Obstacle Detection System for Navigation Assistance Based on Deep Learning Techniques. Smartphone-based solutions are also available, including work by Kuriakose et al. for DeepNAVI; See et al.'s smartphone mobility assistant utilizing depth imaging, and Jain's Smart Eye, tailored for visually impaired users, which utilizes deep learning along with OCR and depth imaging for real-time audio feedback in terms of object detection and actual navigation. Other solutions include smart glasses with YOLO, and dual-sensor systems by Setiadi et al. that use LiDAR and cameras for obstacle detection, and audio cues by Najm et al. and Syahrudin et al. using the YOLO model in real time. Lavric et al., A Comprehensive Survey on Emerging Assistive Technologies for Visually Impaired Persons, summarize that the development of both AI and Visible Light Communications would make

Grenze ID: 01.GIJET.11.2.509_2

the accurate location determination inside the premises achievable. Such contributions in technology serve to reemphasize the value that could be created in helping persons who are visually impaired find increased independence and ability for tasks within more contexts of the physical world.

II. Literature Survey

One recent trend in assistive technology for navigation, in a literature review on visually impaired people, points towards replacement of traditional support mechanisms available in the past like dogs and white canes using innovative, technologically-advanced solutions. Advantages of RFID, Bluetooth, GPS, and haptic audio feedback systems provide the capacity to enhance spatial awareness among the visually challenged while ensuring more efficient real-time detection from obstacles using NAS and low-power optimized devices such as FCOS. Smartphone-based solutions integrate deep learning, OCR, and depth imaging to provide real-time object detection with audio feedback, thus making navigation safer. Other innovations include YOLO-based smart glasses and the use of dual sensors from LiDAR and cameras to enhance obstacle detection and AI and VLC for the accurate indoor localization. These developments highlight the transformative potential of deep learning, sensor fusion and mobile technologies to enable individuals with visual impairments to achieve greater autonomy and improved situational awareness.

Authors Hsieh et al. developed a wearable assistive system to increase the outdoor mobility of the visually impaired with safe navigation through the environment. This wearable assistive system integrates advanced hardware and deep learning techniques, assisting users in real-time audio-based guidance. It integrates the Nvidia Jetson AGX Xavier for AI-handling power and one ZED 2 binocular depth camera, able to capture higher resolution images and depth information of the surroundings. Hardware configurations such as this one are necessary for accurate environment perception and allow for smooth processing of visual data. It employed two convolutional neural network models: one was used for semantic segmentation with the FAST-SCNN model, while another was an object detection model using the YOLOv5s model to segregate and classify different features in the user environment.[1]

The authors further proposed that the device divides the captured images horizontally into seven segments, identifies the sidewalk and crosswalk areas and then calculates the "walkability confidence" in each segment. This type of segmentation allows the system to rate each section based on its walkability. Real-time obstacle detection using YOLOv5s and distance from the user are computed with the help of the depth data provided by the ZED 2 camera. Using this segmentation and obstacle detection, the system effectively assesses the surroundings, guiding the user through a connected headset with specific voice prompts, such as "move left" or "move right," in assisting him to avoid obstacles and choose the safest route. The authors conducted the testing in an MRT station in Taiwan, with a visually impaired participant successfully navigating sidewalks and crosswalks. A reported outcome of this experiment was that the participant felt much more confident and safe outside. [1]

Authors Darius Plikynas, Arūnas Žvironas, Marius Gudauskis, Andrius Budrionis, Povilas Daniušis, and Ieva Sliesoraityte have presented a full review on the latest developments in indoor navigation technologies intended to assist and aid the blindness through complex indoor spaces. The authors actually acknowledge that the GPS-based solutions become ineffective indoors because of signal limitations; on the other hand, they are focusing on other Electronic Traveling Aid systems, which employ other sensors, computer vision, or other alternatives to enable navigation in safe ways. Applying PRISMA methodology, they conducted a systematic review of current research and prototypes that stressed three main aspects: navigation technologies, sensor-based systems, and computer vision approaches. It highlights how differing ETA solutions provide for obstacles detection and places recognition, for instance, room numbers or location points like elevators and staircases.[2]

The authors further proposed categorizing navigation solutions for a blind user into three fundamental ways: First, vision-based systems employed live camera feeds or images to interpret surroundings, which, most often, makes use of image recognition for orientation. Non-vision-based systems relied on alternative sensors such as RFID tags, Bluetooth Low Energy (BLE) beacons, or ultra-wideband (UWB) technology to detect and communicate the user's location. Hybrid systems appear to combine the best of both worlds, vision-based and sensor-based approaches, to obtain higher accuracy. The authors discussed the merits and demerits of each approach and highlighted the benefits of a technology like UWB for localization and BLE for easy deployment. The authors have also identified a gap in the solutions that exist currently, where most of the prototypes realize obstacles, but they found fewer systems for robust guidance in complex environments. This review is beneficial to researchers by summarizing the progression of advances, challenges, and potential areas for improvement of indoor navigation technology for the visually impaired. [2]

The authors proposed a "MedGlasses" - a smart glasses-based system designed to enable the medication safety of chronically ill visually impaired individuals.[3] Since visually impaired patients, mainly aged, suffer from problems with correct identification and intake of medication, these are tackled in MedGlasses using deep learning for pill recognition and audio-based identification and reminding. This system includes wearables in smart glasses, the drug recognition box, a mobile application, as well as a cloud-based information management platform, engineered to ensure that the appropriate medication is received at the correct time for an improved safety level. The MedGlasses system achieves a high recognition accuracy of 95.1% [3], which helps decrease the rate of medication errors to promote safe independent medication use.[3]

The authors further proposed that MedGlasses may feature a dual structure with both local and remote processing to develop its functionality and experience. On local processing, smart glasses take photographs of drug pills, which are then processed by an AI-powered recognition box, plus gives instant voice feedback for the drug the user takes. The system remotely stores user data and history of their prescriptions in the cloud, which can be accessed through a mobile application by family members or caregivers. The setup enables caregivers to supervise the user's medication adherence and receive alerts, thus making them much more effective in support for users with needs. The authors carried out experiments to validate that the system indeed works in real-life applications, suggesting it as a reliable management tool for managing medicines by visually impaired patients in a safe and efficient manner. [3]

The two submitting authors, Mohd Heikal Husin and Yang Kwang Lim, reported that the smart white cane, "InWalker", is a novel device which applies IoT technology to improve the traditional white cane for the visually impaired. Assuming that traditional white canes have limitations, the InWalker incorporates multi-axes sensors to make the device easier and safer to apply while obstacle detection, GPS tracking and SMS messages are possible functions. All these features are controlled by an embedded board, which processes data from the sensors and then communicates it to the smartphone owned by a user through Bluetooth. It is in this setup that one can have real-time updates pertaining to any obstacles, routes, or location of the user: giving the device plenty of support, especially in scenarios where the users may face new unknown environments or may need help.[4]

The same authors further proposed that InWalker's design provides much improved usability in relation to common challenges visually impaired people face, especially concerning mobility and independence. Being equipped with ultrasonic sensors that recognize obstacles, InWalker offers alerts through vibration signals and audio clues that allow users to move more confidently across various environments. Moreover, the GPS tracking and SMS capabilities include security enhancement functions in which the caregivers or family members are allowed to see the location of the user and be alerted in case of any challenges in the environment. Initial trials with the visually impaired population proved that the device really meets its purpose, enhancing independence and safety. The authors state that InWalker holds great promise to enhance the lives of visually impaired people by providing easier and safer navigation.[4]

The system, as proposed by authors Vaibhav V. Mainkar, Hrushikesh R. Tamhankar, Tejashree U. Bagayatkar, Rahul G. Jadhav, Siddhesh K. Shetye, and Rahul S. Tendolkar, is a Raspberry Pi-based system which will help the visually impaired to read the text from images through audio output. The system captures images with a Raspberry Pi camera and processes them to improve readability; afterward, OCR with Tesseract is applied to extract the text. Such an extracted text from the images is further converted into voice using a Text-to-Speech (TTS) engine. Thus, the audio output facilitates the "audition" of the content by the visually impaired users. This, therefore, means that the printed documents could easily be converted into an accessible form-an audio information, in short.[5]

The system incorporates various modules for instance, the camera for capturing images, Imagemagick software for processing images, and the audio output mechanism for conveying the final audible result. In this work, the authors herein designed the assistive device to be compact, economical, and efficient while being independently usable by the visually impaired individuals. The main feature of such a device is that it is user-friendly and simple to operate, with minimal instruction or guidance. The use of open-source tools like Imagemagick for image sharpening and Tesseract for OCR ensures high accuracy in the recognition of text images - various formats used. The audio output created using Google Speech or e-speak synthesizers is amplified for clarity, thus providing accessibility for the visually challenged for real-world applications. Experimental testing of the system demonstrated satisfactory efficiency in text detection accuracy, signifying the actual usability and value of the system. The authors believe that the proposed Intelligent Reader on a Raspberry Pi basis can greatly enhance the quality of life for visually impaired people who will now enjoy accessibility to cheap, portable, and reliable means of reading printed text themselves.[5]

Riadh Ayachi, Mouna Afif, Yahia Said, and Abdessalem Ben Abdelali proposed a traffic sign recognition system especially tailored for ADAS applications with the use of a scaled Convolutional Neural Network. This system balances model size with computational efficiency to great high recognition accuracy, appropriate for an embedded application of an ADAS framework. Authors argue that traffic sign recognition plays an important role in the ADAS as it will enable them to interpret the signs in real-time, directly relating to safe navigation through vehicles. The CNN model scales down across three major parameters: depth, width, and resolution in the proposed system to decrease the computational overhead while maintaining robust detection performance. It will process visual data very efficiently while achieving a very desirable 99.3\% accuracy on the European traffic sign dataset and processing at a truly impressive speed of 250 FPS when deployed on a GTX960 GPU.[6]

To adapt the CNN model to embedded systems, several optimizations were applied. The authors reduced the number of convolutional layers and employed batch normalization to keep processing speed up without dropping accuracy. This adaptation will make sure the system can detect and classify real-time traffic signs on low power devices properly. In addition, the author reviews previous techniques for traffic sign recognition stating that although some of the models reach high accuracy in classification, they appear to be so computationally intensive as not to seem applicable to real-time practice in ADAS. The authors prove that when balancing the CNN parameters, their method shows a good compromise between speed and accuracy, and thus efficient and effective real-time processing, necessary for usage in ADAS applications, is achieved. This facilitates more accessible and more scalable models of traffic sign recognition, especially for lower-power hardware in vehicles where the real-time nature of object recognition must be ensured for greater safety of both drivers and pedestrians.[6]

To provide assistance to the visually impaired in detecting buses effectively, the authors have developed an improved version of YOLOv5.[21] This improved object detection model addresses the need for bus detection, while also delivering high accuracy and other desirable properties in terms of resource usage. End. The two dominant modules used in the model are GhostConv and C3Ghost, which significantly reduce the number of parameters and FLOPs, thus streamlining the model's computational efficiency. Additionally, the authors also used SimSPPF as the module inside the YOLOv5 backbone to streamline the process further while maintaining detection accuracy. With this lightweight model, a focus on reducing the model size and enhancement in detection speed, these models will be feasible to perform real time applications directly on the mobile or resource-limited devices.[7]

To improve the usability in the real world, authors tested the effectiveness of their improved model on mobile devices, found that the approach achieves a very high accuracy with fewer FLOPs and reduced memory usage than the standard YOLOv5. The method produced superior accuracy, recall, and mean Average Precision at 0.5 (mAP@0.5) metrics than the baseline YOLOv5, hence proving its effectiveness in real-time object detection in public transportation environments. An optimised model in this work thus empowers visually-impaired individuals to identify buses safely and reliably and thus promote safety and independence. The authors further elucidate that this improved model efficiency with the loss of accuracy can be more impactful beyond individuals with visual impairments towards enabling infrastructure for smart cities and autonomous transport systems. This is because it will make real-time feedbacks possible since the mechanism for detection is on edge devices, reducing usage of cloud resources and thus making the system reachable for such visually impaired persons in such sophisticated cities.[7]

Muiz Ahmed Khan et al. developed a low-cost wearable visual assistance for the blind with a mixture of camera and ultrasonic sensors based on Raspberry Pi 3 Model B+. It employs TensorFlow SSDLite-MobileNet for object detection and Tesseract OCR and eSpeak for voice output. In comparison to the white cane, assessed in 60 blind volunteers, it was more frequently used for increased mobility and convenience. Despite being efficient, it performed poorly under low lighting and with complicated text patterns. Despite the absence of GPS and wet surface detection, because of its modularity, it holds promise for improvement in the future and is a thrilling aid to independence and safety.[8]

The authors Bineeth Kuriakose, Raju Shrestha, and Frode Eika Sandnes did an analysis of tools and technologies for navigation for the blind and visually impaired. The review analyzed several kinds of assistive technologies that exist both indoors and outdoors as well as mixed environments. Such tools fall under categories like visual imagery systems, non-visual data systems, and smartphone-based solutions. Their review highlights that though many systems provide navigation assistance by using technologies like stereo cameras, LiDAR, Bluetooth beacons, and ultrasonic sensors, they mostly lack core features of fully independent navigation. Major device-related issues include their size, a high learning curve in portability, and too much information overload, which disallow its widespread adoption. These should be introduced with real-time object detection, multimodal feedback options, reduced training requirements, and privacy-focused data handling. The ideas as presented here should highlight the future direction of design considerations under an emphasis of a user-centered approach toward developing practical and effective assistive tools that can assure mobility and safety in navigation for the visually impaired.[9]

The authors Mallikarjuna Gowda C.P., Raju Hajare, and P.S.S. Pavan suggested an affordable cognitive IoT system that can support visually impaired people in object recognition and navigation by integrating machine learning and Embedded technologies[10]. Image capture is accomplished using a camera, processing through a CNN that has been trained on certain classes of objects, as well as auditory feedback that labels identified objects to the user. The whole setup is compact and transportable to enable a visually impaired user to roam difficult environments, say a bus or train station environment, in detecting obstacles, vehicles, and more. Based on Raspberry Pi 3, the system uses TensorFlow. The algorithm uses multiple CNN layers that include pooling and fully connected layers for maximum accuracy in recognition and a speed of classifying each image within just seconds.[10]

The authors tested the system with no problems, and noted that it might be a more accessible alternative to full canes or to expensive robots, although one is limited to daytime use due to camera functionality. Future work would be in developing a "bionic eye" capability, enhancing the system's application toward artificial vision solutions that can potentially interpret more environments and conditions for visually impaired persons. This paper presents the potential of IoT and machine learning in restructuring assistive technology for visually impaired persons to achieve more independence and security through the augmented perception system.[21],[10]

The authors Yunjia Lei, Son Lam Phung, Abdesselam Bouzerdoum, Hoang Thanh Le, and Khoa Luu took a step forward to introduce an assistant navigation system based on pedestrian lane detection, aiming at enhancing mobility along with safety for the visually impaired. Because most techniques have fallen short in presenting an unstructured diversity of pedestrian scenes, an overall survey and comparison are conducted with a blend of traditional approaches and more advanced deep learning techniques. These are the color and edge-based methods that involve the usage of predefined color models and edge detection to detect lanes in images, which still fail in pedestrian paths due to different lane shapes and texture. For example, the authors implemented modern deep learning models based on convolutional neural networks and semantic segmentation to enable learning visual features automatically from large-scale datasets. They performed a high number of experiments on the PLVP3 data set customised to pedestrian lane detection; it happens to contain several lane textures and lighting conditions. Results found high accuracy and robust improvement of methods under different environments by using deep learning over traditional methods; they gained high performance in walkable regions with challenging lighting conditions. Such developments are, therefore, an integral part of the design of a truly robust real-time assistive system that can support the visually impaired for enabling safe and efficient navigation.[11]

Raihan Bin Islam, Samiha Akhter, Faria Iqbal, Md. Saif Ur Rahman, and Riasat Khan implemented an affordable assistive technology to enable totally blind individuals with real-time environmental awareness and detection of obstacles. It employs TensorFlow object detection API using SSDLite MobileNetV2, which has been trained on the MS COCO dataset that runs on a Raspberry Pi 4B using a Pi Camera for real-time video capture. The system provides real-time audio feedback through the Google Text-to-Speech (gTTS) service. An ambiance mode uses weather datasets to sense situations such as clouds, rain, mist, or sunlight. Realism is improved using particle swarm optimization for identifying and fine-tuning the layers of MobileNetV2. Finally, it is put together with an ultra-light head cap having a power-efficient microcontroller and headphones for everyday use. Users rated it 4.675, liking the fact that it improved safety and independence.[12]

The authors, Md. Asif Adnan, Nazmul Alam, Foysal Ahammed, Imtiez Ahmed Prince, Mohammad Faijur Rahman, and Md. Tanzim Ahamed designed a smart blind stick to help a visually impaired person navigate. It coupled Raspberry Pi 4, MobileNetV3-SSD, ultrasonic sensors, and a soil moisture sensor to detect obstacles, stairs, and wet surfaces, thus giving audio alerts. With the internal GPS and GSM module, the device can be tracked, and in an emergency, an SOS button automatically sends the location of the user. Tested successfully indoors as well as outdoors, this gadget enhances mobility and independence. Future upgrades may include improved object detection and traffic light recognition for safer navigation.[13]

Muhamad Nurnajib Rithuan, 'Aini Syuhada Md Zain, and Norizan Mohamed Nawawi designed an indoor blind navigation system using VLC-based Li-Fi technology. LED lights send location information to a receiver on the user's device, interpreting it as audio messages such as "You are in the kitchen." Ultrasonic sensors provide obstacle detection, returning warning sounds that increase in pitch as objects approach. Constructed using Arduino boards, an ISD1820 voice module, and a buzzer, the system reduces electromagnetic interference while maintaining high data rates. Experiments produced accurate data transmission up to 90 cm, with reliable wall, chair, and person detection. GPS and GSM could be added in the future to facilitate tracking and emergency reporting, further improving independent mobility.[14]

Jakob Kilian, Alexander Neugebauer, Lasse Scherffig, and Siegfried Wahl created the open-source sensory substitution device called Unfolding Space Glove. This glove improves spatial navigation for the blind by translating 3D time-of-flight camera data into haptic feedback on a 3×3 grid on the back of the hand, so that the user can sense his surroundings through touch. It is a self-contained, portable device that can work in all lighting conditions. In experiments, blind and blindfolded participants learned to cross obstacle courses using the glove. Although they did so at a slower pace than with a white cane, this result indicates the potential of the glove as a complementary or alternative navigation aid for the visually impaired.[15]

The authors Yahia Said, Mohamed Atri, Marwan Ali Albahar, Ahmed Ben Atitallah, and Yazan Ahmad Alsariera designed this obstacle detection system for visually-impaired people navigation. In this system, it uses deep learning techniques with NAS. It utilizes, here, a baseline of the FCOS detector that is added with an efficientNet backbone to use on embedded devices. This has an anchor-free model known as the FCOS framework, supporting real-time object detection while requiring fewer computations. An improved NAS approach in the form of reinforcement learning optimizes both FPN and the prediction head in a way that improves detection accuracy with additional computational efficiency. Experimental evaluation on the COCO and IODR datasets for Indoor Object Detection and Recognition shows that the system does recognize well indoor and outdoor obstacles with higher precision compared to the baseline FCOS model but is still feasible for mobile deployment.[16]

III. SUMMARY OF FINDINGS

TABLE I: SUMMARY OF FINDINGS IN ASSISTIVE TECHNOLOGY FOR VISUALLY IMPAIRED

Common Findings	Gaps	Algorithms / Citations
Assistive Navigation and Independence: Most systems support visually impaired individuals in achieving safer and more independent navigation, covering indoor, outdoor, and public spaces.	Limited adaptability across different environments (e.g., indoor, outdoor) or applications (e.g., object recognition only), indicating a need for integrated solutions for comprehensive navigation support.	FAST-SCNN, YOLOv5, Ultrasonic sensors, IoT, FCOS with EfficientNet, VLC, SSDLite-MobileNet, CNN, LiDAR [1], [2], [3], [4], [9], [10], [11], [12], [13], [14], [15], [16]
High Accuracy in Detection and Recognition: Achieving high accuracy in specific tasks such as obstacle detection, object recognition, and lane detection ensures reliable assistive support for visually impaired users.	Focused on specific detection scopes (e.g., only objects or lanes) and may not cover broader requirements, such as general surroundings or diverse indoor and outdoor environments.	Tesseract OCR, CNN, YOLOv5, MobileNet SSD, FCOS with EfficientNet, SSDLite-MobileNetV2, NAS [1], [5], [6], [7], [8], [9], [10], [12], [13], [15], [16]
Affordability and Portability: Designed with accessible hardware like Raspberry Pi, smartphones, or wearable devices, making the systems economical and portable for visually impaired users seeking independent mobility.	Portability may be affected by hardware requirements or environmental constraints, such as limited depth range or restricted functionality under certain lighting conditions.	Tesseract OCR, Raspberry Pi, TensorFlow Lite, ARCore Depth Lab, VLC, Ultrasonic Sensors, MobileNetV3-SSD [1], [4], [7], [8], [9], [10], [12], [13], [14]
Real-Time Object and Obstacle Detection: Real-time detection using efficient algorithms, such as YOLOv5 and CNN models, facilitates rapid feedback, crucial for navigating complex environments and alerting users to nearby obstacles.	May struggle in challenging conditions such as crowded or noisy spaces, limiting the effectiveness of audio or gesture-based controls, or have reduced accuracy in low-light environments.	YOLOv5 with GhostConv, C3Ghost, SimSPPF, CNN, MobileNetV2, NAS, FCOS with EfficientNet, VLC [1], [3], [6], [7], [8], [9], [10], [11], [14], [15]
Application-Specific Constraints and Environmental Limitations: Systems perform well within their intended scopes but may face limitations adapting to broader contexts, such as diverse lighting, weather conditions, or complex indoor and outdoor environments.	Scope limitations in each system (e.g., specific object types, weather or lighting conditions) suggest a need for more adaptable, multifunctional solutions that can be utilized in varied environments.	FAST-SCNN, IoT with GPS, Ultrasonic Sensors, VLC, LiDAR, SSDLite-MobileNet, NAS [2], [3], [4], [5], [9], [10], [11], [13], [14], [16]

IV. CONCLUSION

This survey shows the prospect of advanced technologies that overcome the challenges of mobility and independence in people with visual impairments. These assistive systems, based on deep learning, sensor fusion, and smartphone-based solutions, are showing tremendous improvements in real-time object detection, obstacle avoidance, and spatial awareness. Innovations such as YOLO-based smart glasses, ultrasonic sensors, AI-driven navigation, and IoT systems have promised to offer cheap, ortable, and efficient solutions suited to various environments. However, current systems have limitations in terms of adaptability, environmental constraints, and full integration of features. Future developments should therefore focus on the development of multifunctional solutions that will integrate both indoor and outdoor capabilities without losing the friendly interfaces to the users. These will improve the independence of blind people and pave the way for a more inclusive society based on technology.

REFERENCES

[1] Hsieh, I.-H.; Cheng, H.-C.; Ke, H.-H.; Chen, H.-C.; Wang, W.-J. "A CNN-Based Wearable Assistive System for Visually Impaired People Walking Outdoors." Applied Sciences, 2021, 11, 10026. DOI: 10.3390/app112110026.

[2] Likynas, D.; Žvironas, A.; Gudauskis, M.; Budrionis, A.; Daniušis, P.; Sliesoraitytė, I. "Research Advances of Indoor Navigation for Blind People: A Brief Review of Technological Instrumentation." IEEE Instrumentation and Measurement Magazine, 2020, pp. 22-29. DOI: 10.1109/MIM.2020.9126068.

[3] Chang, W.-J.; Chen, L.-B.; Hsu, C.-H.; Chen, J.-H.; Yang, T.-C.; Lin, C.-P. "MedGlasses: A Wearable Smart-Glasses-Based Drug Pill Recognition System Using Deep Learning for Visually Impaired Chronic Patients." IEEE Access, 2020. DOI: 10.1109/ACCESS.2020.2967400.

[4] Husin, M. H.; Lim, Y. K. "InWalker: Smart White Cane for the Blind." Disability and Rehabilitation: Assistive Technology, 2019, pp. 1-7. DOI: 10.1080/17483107.2019.1615999.

[5] Mainkar, V. V.; Tamhankar, H. R.; Bagayatkar, T. U.; Jadhav, R. G.; Shetye, S. K.; Tendolkar, R. S. "Raspberry Pi-Based Intelligent Reader for Visually Impaired Persons." Proceedings of the Second International Conference on Innovative Mechanisms for Industry Applications (ICIMIA 2020), IEEE, 2020. ISBN: 978-1-7281-4167-1.

[6] Ayachi, R.; Afif, M.; Said, Y.; Abdelali, A. B. "Traffic Sign Recognition Based on Scaled Convolutional Neural Network for Advanced Driver Assistance System." 2020 IEEE 4th International Conference on Image Processing, Applications, and Systems (IPAS), IEEE, 2020. DOI: 10.1109/IPAS50080.2020.9334944.

[7] Arifando, R.; Eto, S.; Wada, C. "Improved YOLOv5-Based Lightweight Object Detection Algorithm for People with Visual Impairment to Detect Buses." Applied Sciences, 2023, 13, 5802. DOI: 10.3390/app13095802.

[8] Khan, M. A.; Paul, P.; Rashid, M.; Hossain, M.; Ahad, M. A. R. "An AI-based Visual Aid with Integrated Reading Assistant for the Completely Blind." IEEE Trans. Human-Machine Systems, 2020, 50(6). DOI: 10.1109/THMS.2020.3027534.

[9] Kuriakose, B.; Shrestha, R.; Sandnes, F. E. "Tools and Technologies for Blind and Visually Impaired Navigation Support: A Review." IETE Technical Review, 2020. DOI: 10.1080/02564602.2020.1819893.

[10] Gowda, M. C. P.; Hajare, R.; Pavan, P. S. S. "Cognitive IoT System for Visually Impaired: Machine Learning Approach." Materials Today Proceedings, 2021. DOI: 10.1016/j.matpr.2021.03.666.

[11] Lei, Y.; Phung, S. L.; Bouzerdoum, A.; Le, H. T.; Luu, K. "Pedestrian Lane Detection for Assistive Navigation of Vision-Impaired People: Survey and Experimental Evaluation." IEEE Access, 2022. DOI: 10.1109/ACCESS.2022.3208128.

[12] Islam, R. B.; Akhter, S.; Iqbal, F.; Rahman, M. S. U.; Khan, R. "Deep Learning-Based Object Detection and Surrounding Environment Description for Visually Impaired People." Heliyon, 2023. DOI: 10.1016/j.heliyon.2023.e16924.

[13] Adnan, M. A.; Alam, N.; Ahammed, F.; Prince, I. A.; Rahman, M. F.; Ahamed, M. T. "Raspberry Pi-Powered IoT Device for Blind Navigation Using MobileNetV3-SSD Image Processing." Proceedings of the International Conference on Information Communication Technology for Sustainable Development (ICICT4SD), 2023. DOI: 10.1109/ICICT4SD59951.2023.10303636.

[14] Rithuan, M. N.; Zain, A. S. Md.; Nawawi, N. M. "Indoor Navigation System for Vision Impairment People through Visible Light Communications." Proceedings of the 1st International Symposium on Engineering and Technology (ISETech), IOP Conf. Series: Materials Science and Engineering, 2020, vol. 767. DOI: 10.1088/1757-899X/767/1/012057.

[15] Kilian, J.; Neugebauer, A.; Scherffig, L.; Wahl, S. "The Unfolding Space Glove: A Wearable Spatio-Visual to Haptic Sensory Substitution Device for Blind People." Sensors, 2022, 22(5). DOI: 10.3390/s22051859.

[16] Said, Y.; Atri, M.; Albahar, M. A.; Ben Atitallah, A.; Alsariera, Y. "Obstacle Detection System for Navigation Assistance of Visually Impaired People Based on Deep Learning Techniques." Sensors, 2023, 23(11). DOI: 10.3390/s23115262.

[17] Lin, J.-Y.; Yao, C.-C.; Chiang, C.-L.; Chen, M.-C. "Smart Glasses Application System for Visually Impaired People Based on Deep Learning." Proceedings of the IEEE International Conference on Computer Science and Information Engineering, 2020. DOI: 10.1109/ICCSIE49998.2020.000.

[18] See, A. R.; Sasing, B. G.; Advincula, W. D. "A Smartphone-Based Mobility Assistant Using Depth Imaging for Visually Impaired and Blind." Applied Sciences, 2022, 12, 2802. DOI: 10.3390/app12062802.

[19] Syahrudin, E.; Utami, E.; Hartanto, A. D. "Enhanced Yolov8 with OpenCV for Blind-Friendly Object Detection and Distance Estimation." J. Rekayasa Sist. Teknol. Inf., 2024, 8(2), pp. 199-207. DOI: 10.29207/resti.v8i2.5529.
[20] Messaoudi, M. D.; Menelas, B.-A. J.; Mcheick, H. "Review of Navigation Assistive Tools and Technologies for the Visually Impaired." Sensors, 2022, 22(20), 7888. DOI: 10.3390/s22207888.
[21] Lakhani, N.; Lakhotiya, H.; Mulla, N. "Be My Eyes: An Aid for the Visually Impaired." Proceedings of the 2022 IEEE 3rd Global Conference on Advanced Technologies (GCAT), Oct. 7-9, 2022. DOI: 10.1109/GCAT55367.2022.9972160.
[22] Gladis, K. P. A.; Srinivasan, R.; Sugashini, T.; Raj, S. P. A. "Smart-YOLO Glass: Real-Time Video-Based Obstacle Detection Using Paddling/Paddling SAB YOLO Network." Alexandria Engineering Journal, 2023, 77. DOI: 10.1016/j.aej.2023.11.017.