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Smart Specs for Visually Impaired People Using ESP32

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Abstract
The continuous development of technology has resulted in unprecedented advancements in many fields with assistive technology for the visually impaired being a key area that has seen accelerated development. Of these, object detection technologies have seen a tremendous shift from rudimentary systems relying on human-engineered features and simplistic algorithms to sophisticated, real-time systems based on microcontrollers and computer vision. This development has facilitated more precise and reactive environmental perception aids, which have a direct influence on the autonomy and safety of the visually impaired. As a reaction to this development, the current project proposes "Smart Specs", a new, compact, and affordable wearable aid designed to enhance daily mobility for the visually impaired. Designed for simplicity and upgraded situational awareness, the smart specs incorporates the ESP32 microcontroller, which is the mind of the gadget, and facilitates both real-time computation and wireless connectivity. The ultrasonic sensors, camera module, and audio output elements join the ESP32 in conjunction to scan the surroundings of the user and provide timely responses.
One of the unique aspects of the system is its integration of OpenCV with Python to enable object and face detection based on image processing and computer vision. The detections are analysed onboard and translated into sound-based alerts or vibration signals, literally converting visual information into readable formats by visually impaired users. The dual-feedback mechanism thus builds user confidence and encourages independent navigation, even in new environments.
Smart specs provides a realistic and scalable solution that reconciles cost, precision, and usability, demonstrating how embedded systems and computer vision with AI can be used to create powerful, real-world assistive technology.

Keywords- Accessibility, Assistive device, ESP32 microcontroller, Navigation assistance, Smart specs, Versatile hardware, Visually impaired

INTRODUCTION

Technological advancement has been a major impetus in transforming the field of assistive technology, especially for the visually impaired. While the classic devices have been around for centuries as a requirement, they cannot provide instant, dynamic feedback regarding obstacles or the environment as a whole. These limitations hinder the visually impaired from navigating complex or unfamiliar environments with ease.
To address these limitations, the Smart Specs project offers a modern, smart, and cost-effective wearable solution that enables enhanced mobility and situational awareness. The system is developed with the ESP32

microcontroller, a low-power, high-performance controller with dual-core processing, Wi-Fi and Bluetooth connectivity, and support for real-time sensors. The ESP32 is the control module, which manages data collection from sensors, image processing from the onboard camera, and feedback mechanism control for the user.

The Smart Specs are designed to serve as an electronic travel aid, converting visual and spatial information into sound and touch feedback. Ultrasonic sensors built into the headband sweep the surroundings, detect objects nearby, and calculate their distance from the wearer. Meanwhile, a miniature camera module captures live images and processes them with OpenCV algorithms in Python. This enables the system to recognize specific objects, faces, or environmental markers, thereby expanding users' perception beyond the immediate area of a standard white cane.

The feedback system includes voice modules for presentation of the alert as speech and vibration motors for quiet alerting if ambient noise is present. The design modularity allows future features to be added to the system, such as GPS navigation, cloud storage, or interface with smartphone applications via Bluetooth or Wi-Fi.

PROBLEM STATEMENT

Smart Specs aims to create a smart, wearable assistive device that is specially attuned to the requirements of the visually impaired. The key functionalities are real-time obstacle detection, object recognition, and basic notification, on a low-power, tiny embedded platform. The key challenges are optimizing sensor fusion, battery life, comfort and miniaturization, and cost-effectiveness for accessibility. The solution attempts to balance traditional aids with emerging smart technologies such that users can navigate independently with increased security and confidence.

LITERATURE SURVEY

Recent developments in embedded systems, computer vision, and edge AI have significantly advanced assistive technologies for visually impaired individuals. Various sensor- and vision-based solutions have been proposed to improve real-time navigation, obstacle detection, and environmental awareness.

Annapurna et al. [1] presented an IoT-based vision alert system for blind individuals using ultrasonic sensors to detect obstacles and provide haptic feedback. Their work emphasizes low-cost and interdisciplinary approaches to enhance navigational assistance. Joans et al. [2] introduced an AI-based smart navigation system that integrates sensors with voice feedback for real-time obstacle detection and directional guidance. However, their use of simple threshold logic limited its adaptability in complex environments.

Kharat et al. [3] developed a computer vision-based obstacle detection system for the visually impaired using OpenCV. Their work marked a shift from purely sensor-based systems to hybrid approaches involving real-time image processing. Babu et al. [4] proposed smart blind glasses utilizing ultrasonic sensors and onboard image processing powered by OpenCV and Python. The system delivered audio alerts to enhance spatial awareness, combining both sensor and vision inputs effectively.

Rajesh et al. [5] designed an Arduino-based smart blind stick that provided obstacle detection through vibration feedback. While cost-effective and portable, the solution lacked dynamic visual interpretation, making it less effective in unfamiliar or crowded environments.

Ranaweera et al. [6] proposed an electronic travel aid integrating multiple sensors, providing early foundations for multimodal assistance. Das and Halder [7] implemented real-time face recognition on ESP32-CAM, showcasing the board’s potential for embedded AI applications in personal monitoring and navigation.

Tyagi et al. [8] reviewed various assistive navigation systems and stressed the significance of multimodal feedback, vibration, haptic, and audio to improve usability and user trust. Prathima et al. [9] presented “Smart Specs” that employed real-time object detection through embedded vision, utilizing ESP32-CAM to enable a fully portable, AI-driven wearable solution.

METHODOLOGY

Table 1: *The list of components used for smart specs.*

S.No.	Name	Quantity
1.	ESP32 Module	1
2.	FTDI Module	1
3.	Audio Amplifier	1
4.	Booster Module	1
5.	Charger Module	1
6.	Li ion Battery (3.7 V)	1

Table 1 presents a list of the various components used in the proposed system. The circuit diagram of smart specs using ESP32 is shown in Fig. 1.

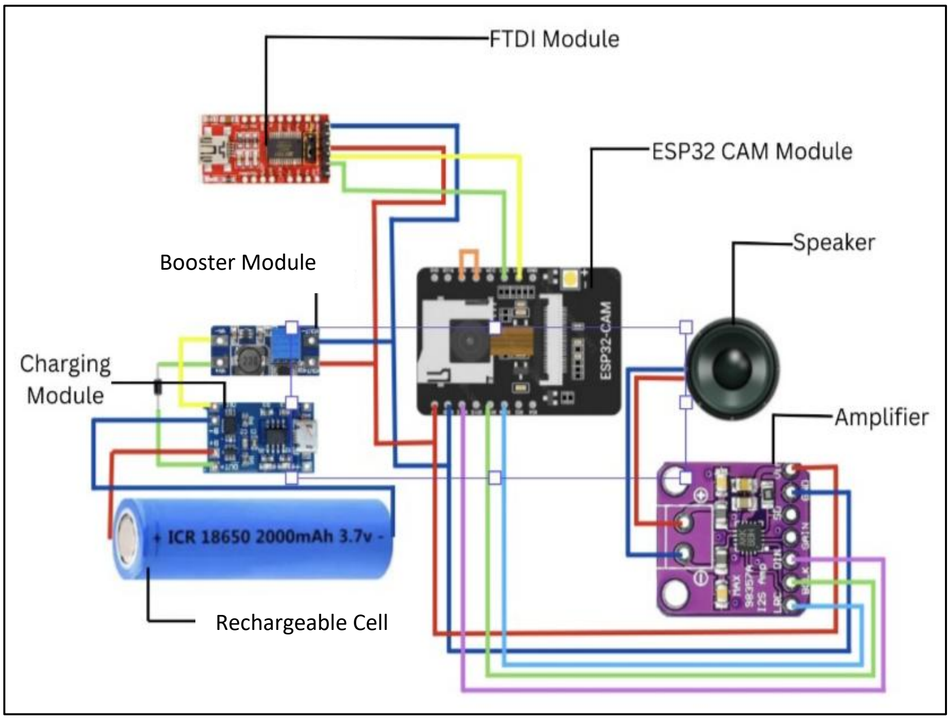

Figure 1: *Circuit diagram of smart specs using ESP32.*

Smart Specs is an impressive technological innovation in assistive devices for the blind. The project revolves around the collaboration of different hardware modules and embedded firmware programming to offer an effective, real-time obstacle detection system with respective auditory and vibratory feedback. The objective of the system is to enhance the mobility and situational awareness of users by enabling them to perceive their environment through non-visual perception.

The ESP32 microcontroller is at the heart of the Smart Specs system. ESP32 is a dual-core Wi-Fi and Bluetooth-powered microcontroller, and as a result, it is very well-suited to small, low-power wearable systems [10]. It provides the processing capability that enables the processing of sensor data from a set of sensors, execution of object detection algorithms, and control of user interface feedback mechanisms. The ability of the ESP32 to execute at high speeds and wirelessly transmit allows the system to react in real time to changing environmental conditions, a capability that is critical in delivering user safety and comfort.

For the purpose of programming and communication with a development platform by ESP32, an FTDI module is employed. The FTDI chip is a USB-to-serial bridge, and it allows the uploading of firmware, debugging of system functions, and observation of output via a serial interface. The module enables the development and iterative process at the initial stages of prototyping [11].

The most crucial part of the system is its auditory feedback mechanism. An audio amplifier is employed in the circuit for this reason. The audio amplifier is utilized to amplify the low-power audio signals produced by the ESP32 so that the user can hear them easily through attached speakers or earphones. The system is therefore able to provide audible and timely oral warnings whenever objects or known objects are in the environment. This feedback is very helpful in dynamic environments such as driving through congested areas or new areas.

Power management is achieved by the addition of a booster module and a charger circuit. Power is provided by a 3.7V lithium-ion battery, chosen because it is rechargeable and has high energy density. The booster module boosts the voltage to the operating standards needed by various components such as the ESP32, sensors, and the audio amplifier. This is to guarantee performance reliability despite the fluctuation of the battery voltage when in operation. The charger module protects against common battery problems such as overcharging, short circuits, and overheating. It provides safe and long-term operation of the device, especially under the scenario of continuous operation [12].

The development and deployment of the Smart Specs system is a four-stage process: hardware integration, software development, system calibration, and testing. Hardware integration is the stage where all the modules, ESP32, FTDI, ultrasonic sensors, audio amplifier, booster, and charger are assembled on a small platform, typically a spectacle frame or a light headband wearable. Physical form factor minimization and ergonomic comfort are the most important design considerations to enable long-term wear.

Custom firmware is flashed onto the ESP32 during the software development process in order to have continuous data acquisition from the ultrasonic sensors and ESP32-CAM. Real-time object detection is handled by Python scripts utilizing the OpenCV library with pre-trained models to identify faces and generic objects. Object proximity is sensed by the system via sensor feedback and initiates corresponding feedback mechanisms based on the identified distance and object type. Audio alarms and vibratory signals are initiated to guide the user to change course or alert the user to near obstructions.

The testing procedure entails rigorous testing under both controlled indoor and dynamic outdoor environments. The critical parameters include accuracy of obstacle detection, response time, voice clarity in noisy environments, and battery life on extended use. The data are analyzed to optimize the system for higher reliability, usability, and energy efficiency. This systematic approach has enabled the development of a useful, economic, and reproducible aid that greatly improves mobility and safety for the visually impaired.

The block diagram depicted in Fig. 2 summarizes the functional elements of the system. It is an illustrative image of the descriptions and interpretational aspects identified in the project.

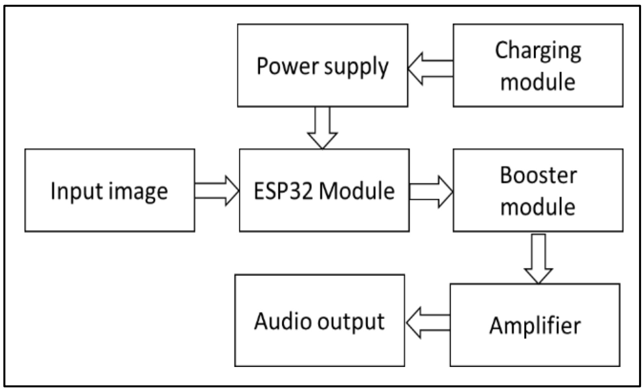

Figure 2: *Block diagram of smart specs using ESP32.*

To calculate the distance to an object using the ESP32 CAM module

$$d = \frac{f_l \times h_o}{h_i}$$

where, d =distance
f_l = focal length
h_o = actual object height
h_i =image height

RESULT

Fig. 3 shows the hardware model, and Fig. 4a and 4b show the output obtained while testing the model with an object (an Onion is used here for testing).

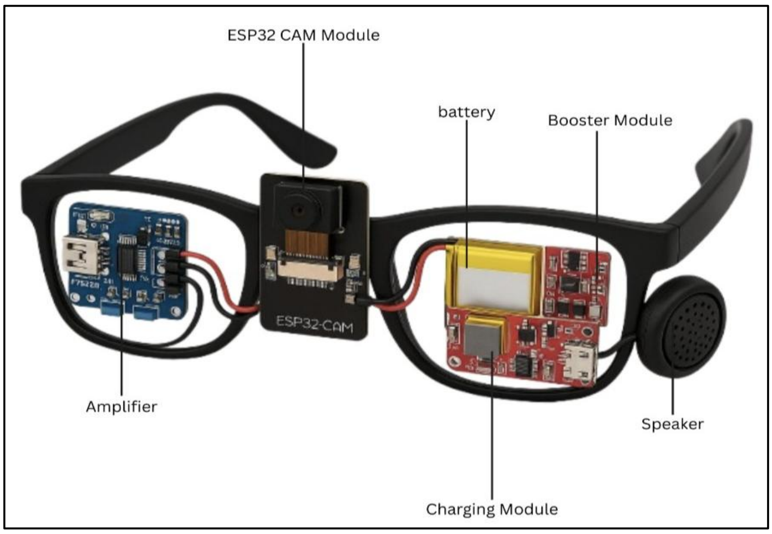

Figure 3: *Hardware model of the product.*

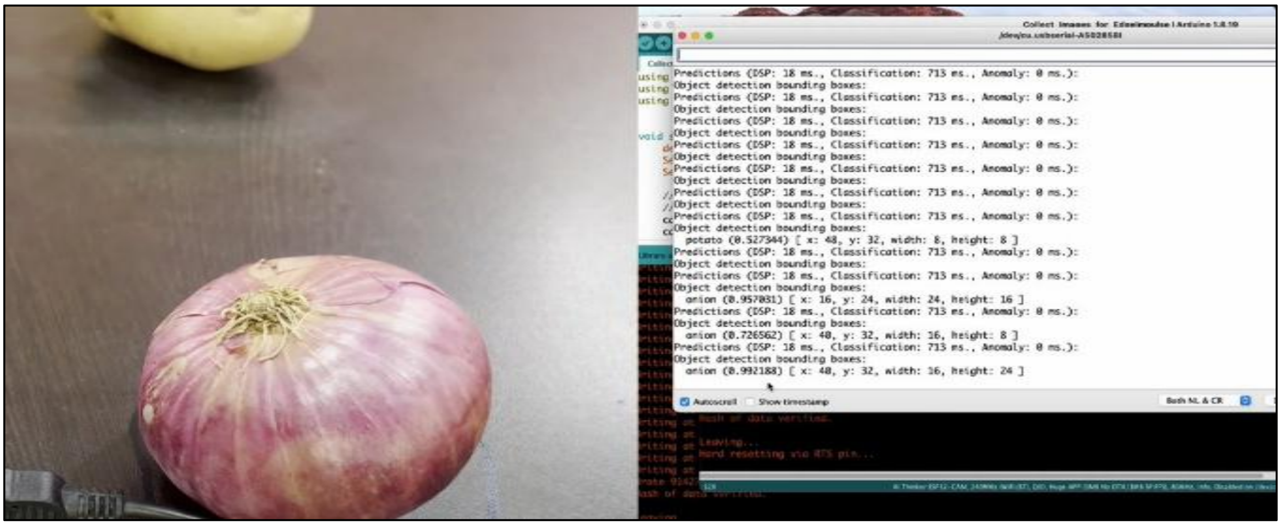

Figure 4(a): *Testing an object using smart specs.*

Figure 4(b): *Object identified as onions.*

CONCLUSION

The Smart Specs system, as a wearable aid for the blind, integrates the ESP32 microcontroller, ultrasonic sensors, and audio amplifier to provide real-time obstacle detection and auditory feedback. In experiments, the system showed reliable obstacle detection to 2 meters, with timely feedback through audio signals. Visual recognition capabilities were integrated through the ESP32-CAM module, allowing the device to detect and identify faces and everyday objects using pre-trained OpenCV-based models. The dual-mode feedback system comprising audio and vibratory feedback provided the users with a more intuitive and accessible way of environmental perception, significantly enhancing their mobility and confidence navigating in unfamiliar environments.

The system's behavior was normal in controlled laboratory settings and in dynamic real-world scenarios, demonstrating its practicability and viability as a scalable solution. While effective, it can be enhanced in a few areas, including enhancing sensor accuracy, enhancing object recognition algorithms under varying lighting and occlusion scenarios, and enhancing the audio feedback system's immunity to ambient noise.

Future advancements will include the integration of cutting-edge deep learning models such as YOLO (you only look once) and SSD (single shot multibox detector) to improve object detection accuracy. Also, the integration of a better text-to-speech (TTS) engine with more natural, expressive, and contextually aware voice outputs will come a long way in improving user interaction. All these functionalities will make Smart Specs an even better, more efficient, and user-friendly device for visually impaired users to carry out their daily tasks.

REFERENCES

1. T. Annapurna et al., "An IoT-based vision alert for the blind using interdisciplinary approaches," *E3S Web of Conferences, International Conference on Futuristic Trends in Engineering, Science & Technology (ICFTEST-2024),* vol. 507, Mar. 2024, doi: https://doi.org/10.1051/e3sconf/202450701047
2. S. M. Joans, A. R., M. Sam, S. C. Ranjane, and S. Subiksha, "Artificial intelligence based smart navigation system for blind people," *International Research Journal of Engineering and Technology (IRJET),* vol. 9, no. 7, pp. 2295–2302, Jul. 2022, Available: https://www.irjet.net/archives/V9/i7/IRJET-V9I7422.pdf
3. P. Kharat, T. Kumar, R. Sirsikar, R. Sawant, and V. Avhad, "Obstacle detection for visually impaired using computer vision," *International Research Journal of Engineering and Technology (IRJET),* vol. 10, no. 3, pp. 817–3820, Mar. 2023, Available: https://www.irjet.net/archives/V10/i3/IRJET-V10I3128.pdf
4. B. S. S. V. R. Babu, S. D. Basha, M. Chandrakanth, R. T. Teja and P. Hemanth, "Smart blind glasses using OpenCV Python," *2024 IEEE Wireless Antenna and Microwave Symposium (WAMS),* Visakhapatnam, India, 2024, pp. 01-04, doi: https://doi.org/10.1109/WAMS59642.2024.10527868
5. P. Rajesh, R. Sairam, M. D. Kumar, P. K. Eswar and Y. Keerthi, "Arduino based smart blind stick for people with vision loss," *2023 7th International Conference on Computing Methodologies and Communication (ICCMC),* Erode, India, 2023, pp. 1501-1508, doi: https://doi.org/10.1109/ICCMC56507.2023.10083752
6. P. S. Ranaweera, S. H. R. Madhuranga, H. F. A. S. Fonseka and D. M. L. D. Karunathilaka, "Electronic travel aid system for visually impaired people," *2017 5th International Conference on Information and Communication Technology (ICoIC7),* Melaka, Malaysia, 2017, pp. 1-6, doi: https://doi.org/10.1109/ICoICT.2017.8074700
7. B. Das and K. K. Halder, "Face recognition using ESP32-Cam for real-time tracking and

monitoring," *2024 International Conference on Advances in Computing, Communication, Electrical, and Smart Systems (iCACCESS)*, Dhaka, Bangladesh, 2024, pp. 01-06, doi: https://doi.org/10.1109/iCACCESS61735.2024.10499606
8. N. Tyagi, D. Sharma, J. Singh, B. Sharma, and S. Narang, "Assistive navigation system for visually impaired and blind people: A review," *2021 International Conference on Artificial Intelligence and Machine Vision (AIMV)*, Gandhinagar, India, 2021, pp. 1-5, doi: https://doi.org/10.1109/AIMV53313.2021.9670951
9. C. Prathima, G. N. Babu, B. R. Reddy, M. S. Kumar, S. Thousif and P. Vamsi, "Smart Specs: Real-time object detection through embedded vision," 2025 *International Conference on Data Science, Agents & Artificial Intelligence (ICDSAAI)*, Chennai, India, 2025, pp. 1-6, doi: https://doi.org/10.1109/ICDSAAI65575.2025.11011858
10. D. Workshop, "ESP32-CAM object detection with edge impulse," *DroneBot Workshop*, Jun. 25, 2023. https://dronebotworkshop.com/esp32-object-detect/
11. "ESP32-CAM AI-Thinker Pinout Guide: GPIOs Usage Explained | *Random Nerd Tutorials*," Mar. 10, 2020. https://randomnerdtutorials.com/esp32-cam-ai-thinker-pinout/
12. Arduino, "*Arduino Documentation*," docs.arduino.cc. https://docs.arduino.cc/

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