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Smart Cane: A Safety and Mobility Enhancement Tool for the Elderly and Visually Impaired

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Abstract

The Smart Cane project introduces an advanced mobility aid designed to enhance safety and independence for the visually impaired and elderly. It features obstacle detection using an ToF sensor, LED illumination for dark areas, and an emergency alert system that sends real-time location notifications to family or close contacts. It also includes water detection to prevent slips on wet surfaces. Unlike conventional mobility aids, this device integrates assistive technology that gives haptic feedback through vibrations when obstacles are detected. The Smart Cane bridges the gap between traditional aids and the growing needs of users in today's dynamic world.

1. Introduction

The visually impaired and the elderly face mobility and security issues to a great extent. Most of them encounter daily challenges in relation to moving around obstacles, walking during low-light conditions or even during an emergency where they cannot act in a timely manner [1]. Conventional canes do not have obstacle awareness, light, and emergency signaling capabilities. As per World Health Organization, many individuals lead their lives with mobility and visual impairment which prompts the necessity to have superior and accessible assistance devices [2]. Investigations demonstrated that user awareness and safety can be significantly enhanced by integrating ultrasonic or Time-of-Flight (ToF) sensors, vibration feed-back and emergency communication interactions [3].

Blindness or old age could reduce the number of chances of an individual noticing the danger, rather in unfamiliar territory or in the not well-developed place. Conventional canes will give only floor-based feedback and fail to warn against onward or raised objects. This is even more dangerous in dim, busy or even less lighted areas, and there is a higher possibility of falling or getting lost. In addition, such canes do not have an emergency alert system which slows in obtaining assistance in emergency situations. These dangers can be spotted in the reality of accidents whose consequence is the accidental falling of a blind man into an open manhole that his cane could not detect [4], and a person of old age who knocked himself when he crossed a dark road [5]. Certain older adults whose health condition did not allow them to report about the stroke or falls because of the lack of the alert capabilities [6]. Slipping trips on wet surfaces are also frequent, as in the case of one man breaking his hip outside a supermarket [7], a woman slipping on a wet office floor [8].

To tackle these problems, this project aims at the development of a Smart Cane that has several smart features. These are the adjustability of the light-emitting diode system put in place, which is operated by a button, the presence of an emergency warning signal that transmits real-time position data to the pre-registered contacts and the reliable blocking detection that uses ToF sensors and vibration feedback. The cane also has got water detection by way of a water level sensor that rings the user when the gadget detects the presence of water within a height of 1-4 cm off the ground. All the elements such as ToF sensors, GPS module, emergency button, microcontroller, rechargeable battery and vibration motor are composed and thoroughly selected to make them usable, precise and cheap.

Advanced Assistive Technology has gained much significance about assisting in the mobility and security of blind people as well as elderly adults. The constancy in research and development into the functionalization and efficacy of these technologies is very relevant in solving the predicaments facing these users. Table 1 makes a comparison of the Smart Cane systems that have been developed and how they differ with the proposed project. Smart canes that are used by people with blindness have undergone massive developments recently. This simple but efficient cane developed by Dey et al. [9] comprises ultrasonic sensor and PIC microcontroller to identify the impediments in the range of 5 to 35 cm before it represented enhanced navigation. In the same manner, Gbenga [10] singled out the Smart Stick as a viable and inexpensive platform upon which more could be built, and it could sense objects that were up to three meters away.

More advanced designs incorporate IoT and GPS functionality, as seen in [11], enabling real-time location sharing with family members and better obstacle awareness through buzzers, vibrations, and LED lights. Other systems, like in [12] and [13], integrate IR cameras, ToF sensors, water detection, and health monitoring features to enhance user safety and well-being. Mobile app integration and intelligent algorithms [14] provide audio alerts and detailed obstacle information, while [15] and [16] further improve safety with health sensors, GSM alerts, and vibrotactile feedback. Overall, these innovations demonstrate a shift from basic mobility aids to multifunctional smart devices that enhance independence, safety, and communication for visually impaired users.

Table 1 *Table of Comparison*

Ref/Year	Title	Advantages	Disadvantages	Compared to my proposed
My Project "Smart Cane"	Smart Cane : A Safety & Mobility Enhancement Tool for The Elderly & Visually Impaired	Combines lighting, emergency alert, obstacle and water detection; simple design	No audio or GPS-based tracking; limited automation	Balanced and practical for visually impaired users where ideal for basic smart assistance
[9] 2018	Ultrasonic Sensor Based Smart Blind Stick.	Obstacle detection with buzzer; low cost	Short range (5–35 cm); lacks emergency and water alert	My project has broader safety coverage including flood and emergency features
[10] 2017	Smart walking stick for visually impaired people using ultrasonic sensors and Arduino	Energy-efficient, low-cost design	No emergencies, water, or lighting system	My project has better real-world adaptability
[11] 2022	SCBIoT: Smart Cane for Blinds using IoT.	Combines GPS, obstacle detection, and LED light	Depending on Wi-Fi hotspot; more battery consumption	Similar but my project is simpler and includes water detection
[12] 2019	Smart Electronic Stick for Visually Impaired	Uses IR camera, Google API, emergency system	1m range only; app-dependent	My project is more hardware-reliable and doesn't rely on API/cloud
[13] 2024	Smart Blind Stick	Health monitoring, water and obstacle detection, GPS alert	Complex integration; higher cost	My project is more accessible and user-friendly, though less medical-focused
[14] 2018	Smart Blind Stick Using Arduino	Voice feedback, wearable, sonar-based	App-reliant; no lighting or water detection	My project covers more physical hazards; theirs offers hands-free interaction
[15] 2021	GPS and GSM enabled Smart Blind Stick.	Health and location alerts; vibration for obstacles	GSM required; complex setup	My project provides similar functions in a simpler offline form
[16] 2018	Smart Blind stick for Visually Impaired People.	Real-time tactile feedback using sonar sensors	Lacks audio, water, and emergency features	Similar navigation system but my project is more feature-complete

2. Methodology

2.1 Project Development

Overall, a block diagram is an overview of the entire system such that the connection between input, output and microcontroller can be explained. The project on the smart cane has 4 circuits which are categorized as system 1, system 2 and system 3 and system 4. The block diagram of the system 1 Smart Canes is displayed in Fig. 1 with LED light and switch button. While Fig. 2 will show the combined block diagram of System 2 (Emergency Alert System), System 3 (Obstacle Detection System) and System 4 (Water Detection System). The following single diagram demonstrates the collaboration of the three mechanisms that secure the efficiency of the project in general. Fig. 3 indicates the flow chart of the system 1, system 2, system 3 and system 4 that represents the work principle of Smart Cane project.

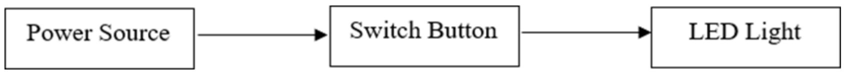


Fig. 1 *Block diagram of system 1 Smart Canes for LED light with Switch Button.*

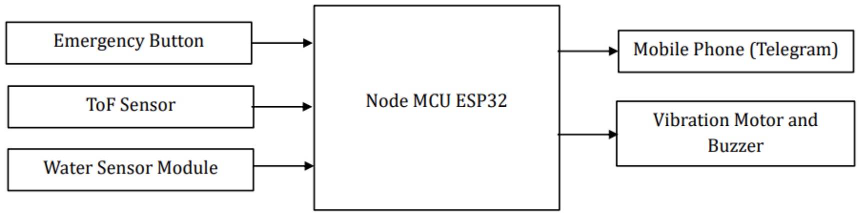


Fig. 2 *Block diagram of system 2 (emergency alert system), system 3 (obstacle detection system) and system 4 (water detection system).*

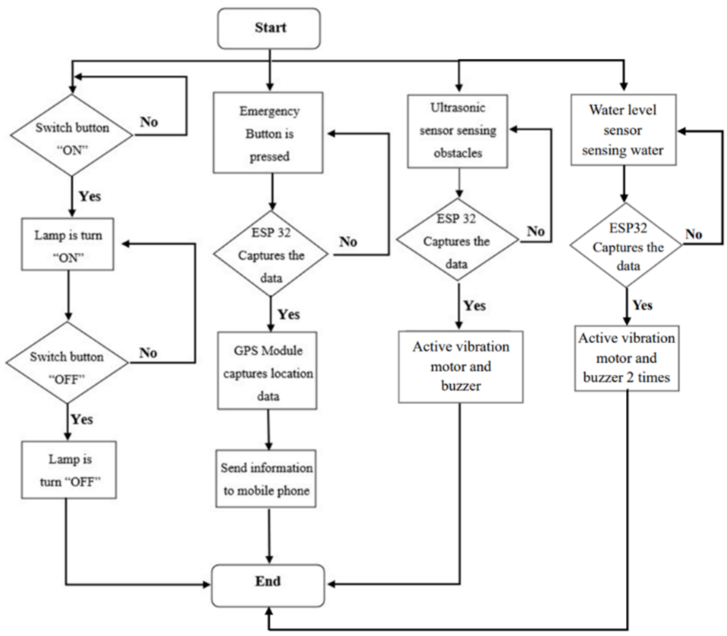


Fig. 3 *The flow chart that explains all the work principles for the Smart Cane project.*

2.2 Schematic Diagram

Fig. 4 is the circuit diagram of System 1 which aims at the feature of LED lighting system that has a rocker switch and operates on Li-ion battery. In the meantime, Fig. 5 exhibits the circuit diagrams of System 2, an emergency alert, sending the location updates to caregivers through push button and GPS module, circuit diagrams of System 3, adding obstacle detection system with the use of ToF Sensor to trigger a vibration motor and a buzzer to give its user the tangible feedback, and System 4, a water detection system, sensing the presence of water.

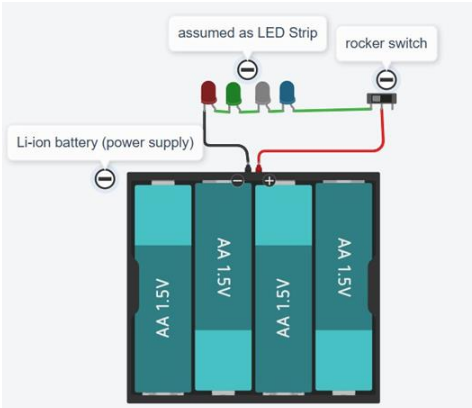


Fig. 4 *Electrical Design of the LED Lighting System (System 1)*

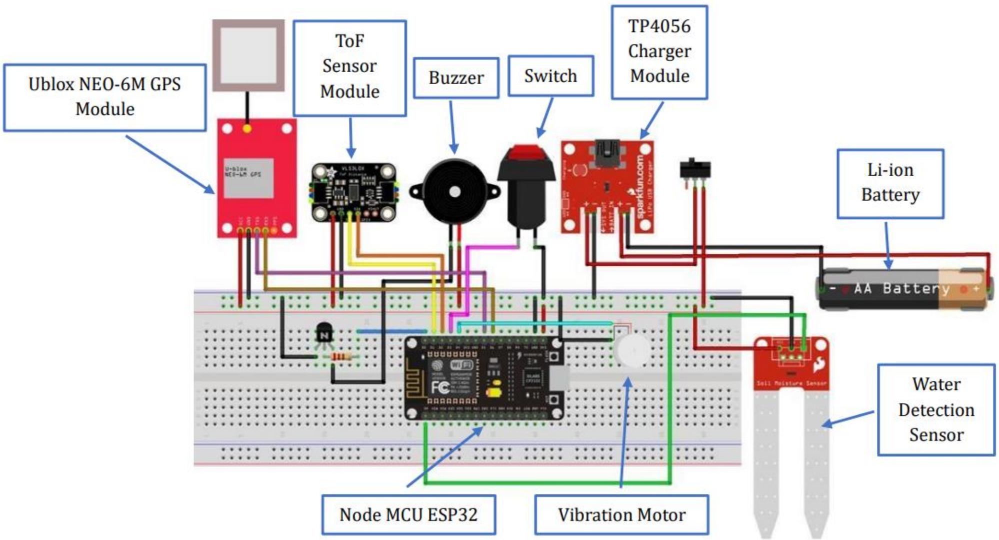


Fig. 5 *Electrical Design of System 2, System 3 and System 4*

3. Result and Discussion

3.1 System 1 (Lighting System) Analysis

The Lighting System, which is called System 1, concentrates on the measurement of the brightness level of a LED strip through the application of a light meter that can be found in the play store or apple store as shown in Fig. 6. Table 2, showing the light intensity (in lux) at different distances to the LED strip, contains results that help to identify the most successful effective range of illumination of the Smart Cane in the case of low-light conditions while Table 3 shows the result of lux for each distance. It is important to measure the maximum, minimum and average values of lux to determine the extent to which the light can guarantee visibility to the user during various conditions of walking. The maximum value denotes the brightest state and is normally nearest to the source of light whereas the minimum value aids determining the farthest reachable distance where the visibility might be inadequate. An average lux acts as a linear to determine performance of the overall light display based on the range of operation by the user.

Fig. 6 *Light Meter Application*

Table 2 *Figures of Testing*

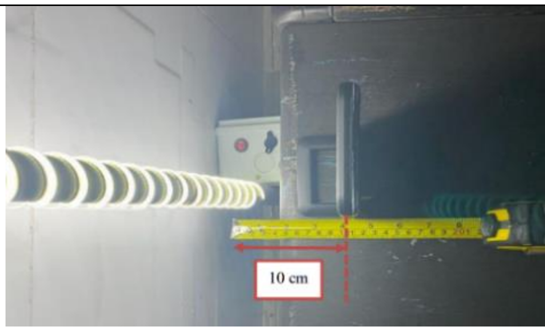
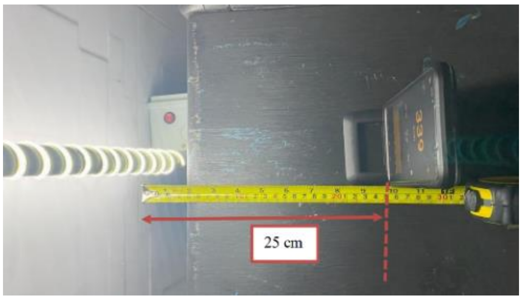
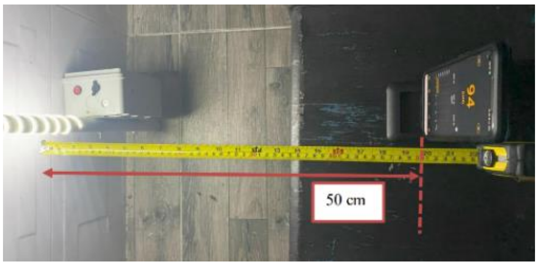
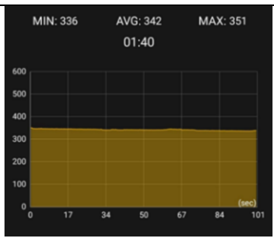
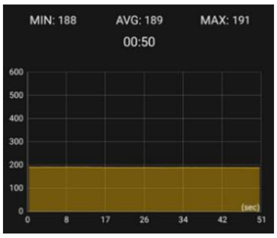
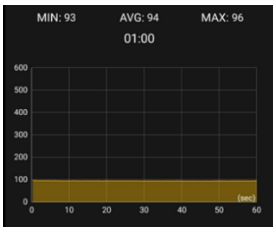
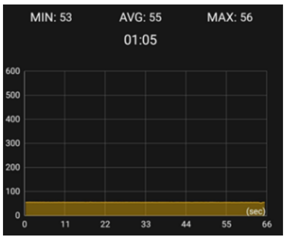
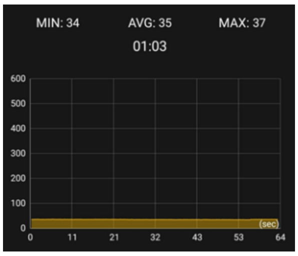
Distance from LED Strip (cm)	Figures of Testing
10	
25	
50	
75	
100	

Table 3 Results *of each distance*

Distance from LED Strip (cm)	Figures of Testing	Minimum, Average and Maximum Reading	Observation
10		Min : 336 Avg : 342 Max : 351	Light intensity is very high at this close range, providing strong and reliable illumination for sensor detection.
25		Min : 188 Avg : 189 Max : 191	Light remains sufficiently bright, showing a moderate drop in intensity but still within an effective detection range.
50		Min : 53 Avg : 55 Max : 56	Noticeable decrease in brightness; illumination is still detectable but begins approaching lower light thresholds.
75		Min : 53 Avg : 55 Max : 56	Light intensity is significantly reduced, suitable only for high-sensitivity sensors or systems calibrated for low lux.
100		Min : 34 Avg : 35 Max : 37	Illumination is weak at this distance, nearing the lower limit of effective detection, indicating the need for enhanced sensing or ambient light support

3.2 System 2 (Emergency Alert System) Analysis

Emergency Alert System (System 2) comes into play after pressing a button on the handle of the cane in case of emergency. After activation it rings a buzzer and forwards the GPS position of the user through Telegram to a designated contact. This makes it possible to instantly notify and track and it is particularly valuable when operating under the danger of visually impaired users. Pushing the button will transmit an order to the Telegram bot as indicated in Fig. 7 and the communication received should be within approximately one minute of the GPS link. The location accuracy can be seen in Fig. 8 and its margin is between 3 and 4 meters. Experiments carried out in a slightly different place than the house rented by the user have proven that the system determines real-time reliable location. Its quick and stable nature is very important to provide timely help in case of any crisis.

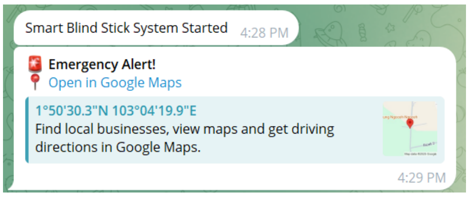


Fig. 7 *Showed the System is activated and send the locations of user*.

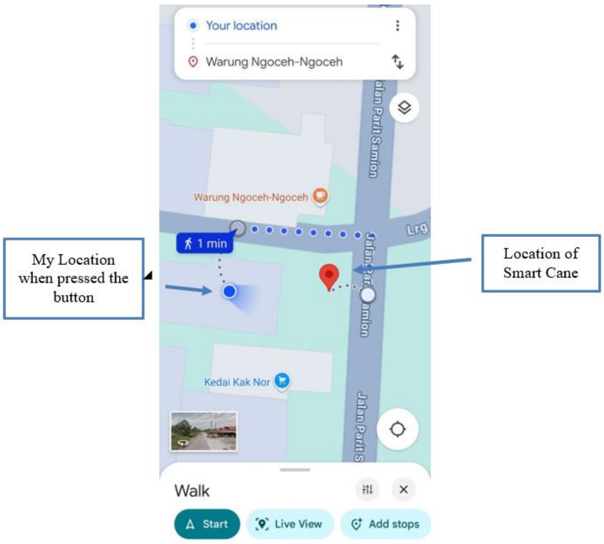


Fig. 8 *GPS Location by Google Maps*

3.3 System 3 (Emergency Alert System) Analysis

Under System 3 (Obstacle Detection), a test was carried out to analyze the performance of ToF Sensor in obstacle detection based on different distances and how it is likely to perform on different surface material. At distances of 5 cm to 25 cm the sensor has been tested with different materials typical to use wood, cloth and plastic. The findings are summarized in Table 4, identifying the responsiveness of the sensor and the error rate upon identifying objects with new textures and vary in density. Test objects were selected among the mirror, wall, and chair cushion so that they could model different surfaces in real-life that have various textures and reflectivity rates. The mirror challenges the capability of the ToF sensor when it comes to the handling of heavily reflective surfaces, which are commonly known to influence sensor accuracy. The wall is a solid surface normally used at homes, and it acts as a reliable reference on the detection of constants with respect to obstacles. In the meantime, the chair cushion is depicted as soft and absorbent surfaces with an irregular texture, which put the sensor capacity to obey the low-reflectivity objects under a challenge. Collectively, these objects allow to evaluate the performance of sensors in typical indoor or outdoor conditions.

Table 4 *Obstacle Detection Test on Mirror, Wall and Chair Cushion*

Distance	Sensor Status	Vibration Status	Buzzer Status
5	Active	Active	Active
10	Active	Active	Active
15	Active	Active	Active
20	Active	Active	Active
25	Active	Active	Active

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(a) *Mirror* **(b)** *Wall* **(c)** *Chair Cushion*

Fig. 9 Obstacle Detection Testing Based on Surface Type and Distance (System 3)

3.4 System 4 (Water Detection System) Analysis

System 4 is analysis was carried out by testing the sensor water detection to different depth of water to see when the buzzer and the vibration motor is activated as in Fig. 10 below. The circuit was dipped in the water to varying depths which were shallow and deep as a way of analyzing its sensitivity and responsiveness. The results showed that the buzzer and vibration motor worked every time there was water detected at any depth and this showed the efficacy of the system in alerting the user about the occurrence of water. This ascertains the effectiveness of the water detection feature in delivering the warnings in due time taking into account the different levels of water. While Table 5 below shows the result of testing.

Table 5 *Buzzer and Vibration Motor Activation at Various Water Depths*

Distance	Sensor Status	Vibration Status	Buzzer Status
1	Active	Active - Vibrate 2 times	Active – Beeps 2 times
2	Active	Active - Vibrate 2 times	Active – Beeps 2 times
3	Active	Active - Vibrate 2 times	Active – Beeps 2 times
4	Active	Active - Vibrate 2 times	Active – Beeps 2 times

(a) *1 cm* **(b)** *2 cm* **(c)** *3 cm* **(d)** *4 cm*

Fig. 10 *Figure testing with different water depth*

3.5 Vibration Analysis for System 3 and System 4

In this test, I applied a mobile application as shown in Fig. 11, namely Vibration Meter, to measure the vibration of Systems 3 and 4. The phone was fastened to the handle of the smart cane as shown in Fig. 12, and the application feature presented a graph of the vibrations, and the highest number measured. The vibration of the motor in the System 3 is once in the presence of an obstacle, whereas in System 4, the vibration of the motor is twice after getting some water. Results of the vibrations can be demonstrated in Fig. 13.

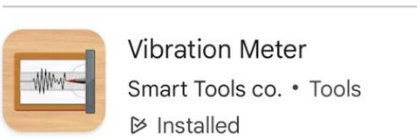
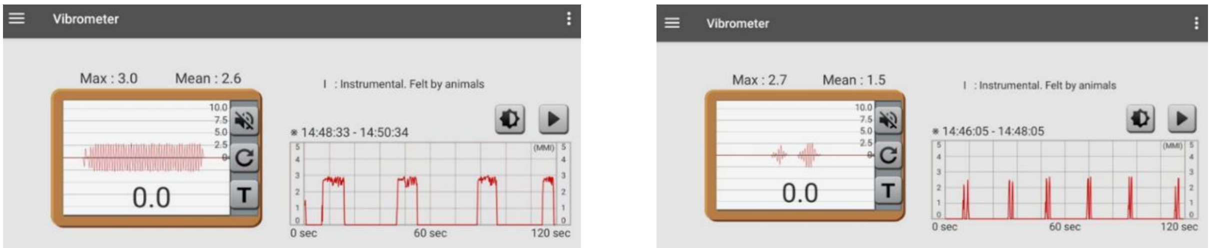


Fig. 11 *Vibration Meter Apps*

Fig. 12 *Mobile Phone Placement on Cane Handle for Vibration Measurement*



(a) *System 3* **(b)** *System 4*

Fig. 13 *Result Vibration*

The result of the vibration test of System 3 and System 4 is indicated in Fig. 13 (a) and (b) respectively. System 3 was performed four times and there was one vibration peak produced on each trial by an obstacle detection, whereas System 4 was performed six times and there was two peaks on each trial, which corresponds to provide water detection. The duration of vibration was relative to the time that the object or water stayed in acquaintance with the sensor. System 3 produced a maximum MMI value of 3.0 with a mean of 2.6 and system 4 a maximum MMI of 2.7 with a mean of 1.5, thus all values were in a comfortable range where the vibration can be felt but not to an intensity that makes the vibration overwhelming. These patterns of vibration conform to the systems being responsive, reliable and well-integrated since they offer timely and user-friendly feedback within the context of being used in real assistive situations.

4. Conclusion

To sum up, the Smart Cane has indeed been able to meet its objective of developing a usable assistive instrument among the old and visually impaired demographic by inculcating within it important attributes, namely, LED light system, obstacle, and water detection systems, and emergency alerting mechanisms using NodeMCU ESP32 with the objective of wireless communication. The project has proven the application of IoT and embedded systems as well as developing the knowledge of sensitizing, circuit implementation, and user design. Based on these limitations, the prototype offers a solid basis in the future. Advanced sensors such as LiDAR, power recharge and solar charging, real time GPS tracking with cloud-based software platform, voice responses and better mechanical design with light-weight materials and ergonomic designs should be added to future versions to enhance their performance and ease of use. Another way to make the cane more effective and personal is to consider an adaptive learning approach that would integrate AI and make the transformation even more significant as an efficient and easy-to-use mobility tool.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The author attests to having sole responsibility for the following: planning and designing the study, data, collection, analysis and interpretation of the outcomes, and paper writing.

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