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DEVELOPMENT OF AN ADVANCED BLIND STICK FOR ENHANCED MOBILITY AND SAFETY OF VISUALLY IMPAIRED AND ELDERLY INDIVIDUALS USING IOT

Amit Kumar Singh[a]*, Madhumitha M[b], Abinaya B[b], Chandrikavathi C[b], Yuvaraji R[b], Marieswaran M[c]

[a]Department of Biomedical Engineering, Vignan's Foundation for Science, Technology & Research, Vadlamudi, Guntur. Andhra Pradesh, India
[b]Department of Biomedical Engineering, VSB Engineering College, Karur, India
[c]Department of Biomedical Engineering, National Institute of Technology Raipur, India

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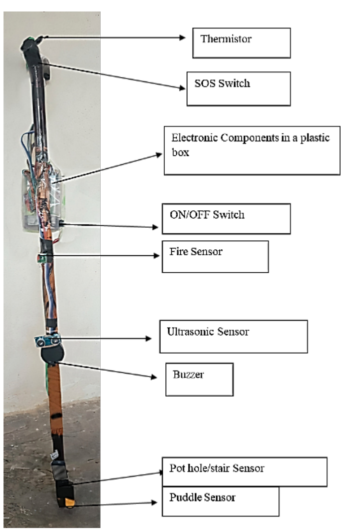
*Corresponding author
draks_bme@vignan.ac.in

Graphical abstract



Abstract

With the growing challenges faced by visually impaired and elderly individuals, particularly regarding mobility and safety, the development of advanced assistive technologies has become crucial. This paper presents the design and implementation of an Advanced Blind Stick (ABS) leveraging Internet of Things (IoT) technology. The ABS integrates multiple sensors, including ultrasonic sensors for obstacle detection, infrared sensors for fire and pothole/stair detection, a moisture sensor for puddle detection, a GPS module for real-time location tracking, and a thermistor for temperature monitoring. An Arduino microcontroller processes sensor data, providing real-time feedback via a smartphone application. The system also includes an emergency save our soul (SOS) button, allowing users to alert caregivers or emergency services during critical situations. The developed ABS enhances mobility and safety by incorporating advanced features absent in previous models. It uniquely detects puddle, monitors both ambient and user temperature, and retains essential functionalities such as potholes/stair detection, IoT integration, caregiver reporting, SOS, and fire detection. This comprehensive assistive device ensures real-time assistance, improved usability, and greater independence for users. Tested with visually impaired and elderly participants, the ABS demonstrated significant improvements in mobility, safety, and confidence. Its lightweight, cost-effective design makes it particularly beneficial for resource-constrained settings, offering an invaluable tool to enhance the independence and well-being of visually impaired and elderly individuals.

Keywords: Blind Stick, IoT, obstacle detection, elderly assistance, assistive technology

1.0 INTRODUCTION

With the evolution of human society, the world is facing many challenges related to ageing and blindness. Ageing, the universal transition from youth to old age, is a complicated phenomenon that involves biological, psychological, and social changes. While ageing is a natural part of human life, it is sometimes veiled in mystery, eliciting both intrigue and anxiety. The term "blind" has several meanings. In its most literal definition, it refers to the whole or partial loss of eyesight. Beyond the physical, "blind" can be used figuratively to denote a lack of awareness, comprehension, or judgment. Blindness can result from a variety of causes. Blindness is grouped into several categories based on the kind of visual loss. According to the World Health Organization's 2022 report, 2.2 billion individuals suffer from near or distant visual impairments [1]. Around 32% of blind persons were between the ages of 45 and 59, whereas 58% were older than 60 [2].

Elderly people, especially if they are blind, face many problems, some of them are:

(1) Increased risk of falls and accidents: Blindness can increase the risk of falls and accidents, especially in elderly people with other health conditions that affect their balance and coordination.

(2) Difficulty with daily activities: Blindness can make it hard for elderly people to perform daily activities such as cooking, cleaning, and personal hygiene.

(3) Difficulty with mobility: Blindness can make it challenging for elderly people to move around and navigate their environment, especially if they have limited mobility or use a wheelchair.

(4) Social isolation: Blindness can lead to social isolation, which can be particularly difficult for elderly people who may already be dealing with other age-related challenges such as mobility issues, chronic illnesses, and cognitive decline.

(5) Depression and anxiety: Blindness can lead to depression and anxiety, especially if the person was not blind earlier in life. Mastering new technologies can present a significant hurdle for older adults, who may also be dealing with age-related cognitive decline.

(6) Lack of access to information: Vision loss in older adults can significantly hinder their ability to acquire information and engage with their surroundings. This social disconnect can lead to feelings of isolation and exclusion. Blindness can make it challenging for elderly people to move around and navigate their environment.

A traditional white cane helps provide basic mobility and independence; it is limited in its capabilities. With the advancement in technology, different researchers have developed smart blind stick (BS) that has different features and uses different sensors to help blind/aged people in a real-time situation. Natarajan et al. have developed a BS that aids blind people in navigation and obstacle detection (OD) using IoT. The BS incorporates ultrasonic sensors, Global Positioning System (GPS), Global System for Mobile Communications (GSM), and a vibration motor to provide real-time feedback [3]. Jeevitha et al. designed a BS for blind people using IoT technologies for navigation and OD. The BS uses ultrasonic sensors, GPS, and a microcontroller to provide haptic feedback to the user. Jeevitha et. al. also highlights the benefits of IoT-enabled devices for improving the lives of visually impaired individuals [4]. Ghosal et al. have developed an IoT-based smart stick for blind individuals to detect obstacles and provide guidance. The BS employs ultrasonic sensors, a microcontroller, and a vibration motor for haptic feedback. This research further emphasizes the potential of IoT technologies in assistive devices for blind people [5]. Rahman et al. designed an IoT-based smart stick for visually impaired people to detect obstacles and warn the user. The stick uses ultrasonic sensors, a microcontroller, and a vibration motor to provide real-time feedback. The paper offers an affordable and effective solution for OD in assistive devices [6]. Tamboli et al. developed a smart stick that leverages IoT technologies to assist blind people in navigation. The BS has ultrasonic sensors, GPS, GSM, and a microcontroller for OD and location tracking. This research highlights the use of IoT to improve the independence and mobility of visually impaired individuals [7]. Romadhon et al. designed a smart stick for blind people that incorporates Arduino, ultrasonic sensors, and Android devices. The stick uses an Arduino microcontroller board, ultrasonic sensors, and an Android app for navigation support. The paper demonstrates a practical and cost-effective solution for guiding visually impaired people using widely available technologies [8]. Singh et al. described an advanced smart cane equipped with obstacle detection, fire alarms, puddle detection using water sensors, an emergency SOS button, GPS for location tracking, and IoT integration for real-time data transmission [9].

Numerous recent papers are centered on creating a smart stick for the visually impaired using Internet of Things (IoT) technology. Their primary goal was to enhance navigation and obstacle detection for users. The methodologies use ultrasonic sensors, microcontrollers, and various feedback mechanisms. While some papers introduce novel features like voice control or Android integration, the overall goal remains the same: to improve the lives of visually impaired individuals by leveraging the advancements in IoT technologies, as many use an ultrasonic sensor to detect obstacles. However, the ultrasonic waves are dependent on ambient temperature [10] and hence when the temperature changes, the distance of the obstacle cannot be detected correctly. Also, as we see during the COVID-19 pandemic, humans suffer from fever. So, monitoring the temperature of the user's body would be a good feature to be incorporated into the proposed blind stick. So, in this work, we incorporated the existing features like OD, fire detection, water detection, GPS-based navigation, emergency SOS button, and IoT integration and also included some additional features like pothole detection, stair detection, buzzer, temperature monitoring of the user and the ambient, and real-time monitoring of the blind person using the smart mobile app to improve the performance of the existing BS.

2.0 METHODOLOGY

The block diagram for the electronic components used in the advanced blind stick (ABS) is shown in Figure 1. The 5 V battery provides the power for all the electronic components used in the stick.

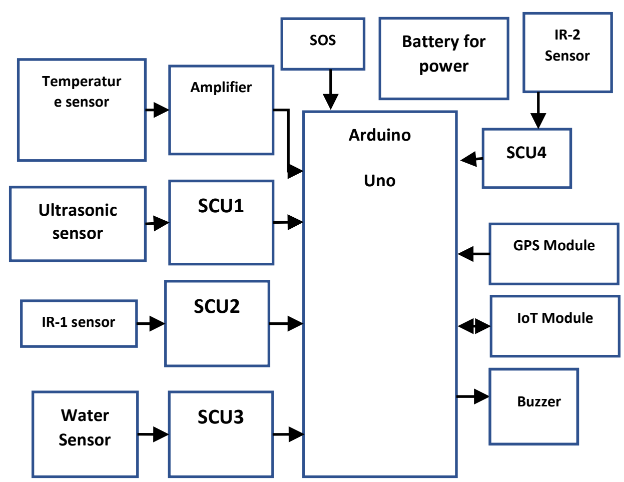


Figure 1 Block diagram of the circuit used to make the ABS

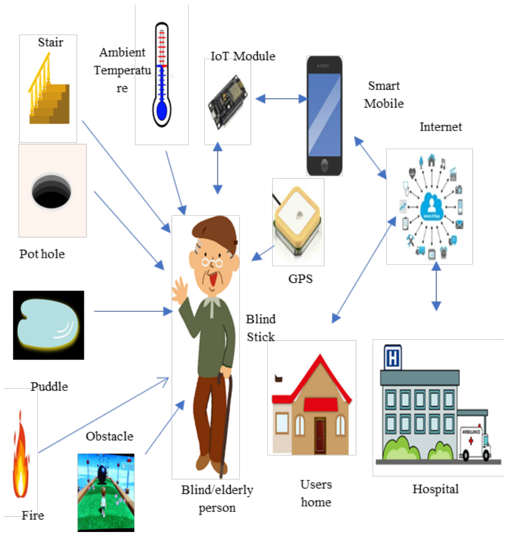


Figure 2 The block diagram of the procedure for the developed ABS

The system uses an Arduino Uno Atmega 328 board to manage and control the stick's data communication. It also has an emergency save our soul (SOS) button, an ultrasonic sensor module HC- SR04, for OD, an infra-red (IR) sensor for fire detection (REES52 IR sensor module), an IR sensor for pothole/stair detection (Infrared based obstacle detecting sensor module), a thermistor NTC- 103K for temperature sensing, GPS Neo-6m GPS module was used for the user's live location, an IoT Module - ESP8266 to transfer real-time data (using Serial Peripheral Interface protocol), and a piezoelectric based buzzer for the user's emergency it has an SOS button. There are two IR sensor modules; one is an infrared (IR) sensor (E18-D80NK) for pothole/stair detection with a range of 3-80 cm, while the fire sensor module uses the 760 to 1100 nm light emitting diode (LED) with a range of 80 cm was used for fire detection. All the electronic components were procured from MACFOS private limited company [11]. All the sensors have their signal conditioning circuit to be interfaced with the Arduino board controller analog to digital convertor (ADC). The ADC built-in microcontroller converts the analogue voltages (coming from different sensors) into the corresponding sensor readings. The buzzer was used to alarm the user for any emergencies. This innovative walking aid aims to empower users with visual impairments and age-related mobility limitations by detecting and alerting them to obstacles, fire hazards, puddles, and elevation changes, promoting independent navigation. The system also monitors the user and the ambient temperature to know the user's health along with providing the ambient temperature compensation of the ultrasonic sensor. Regarding pothole/stair detection, only one IR sensor is used to detect both functions to reduce the cost along with the size and weight of the developed ABS. The user can use it for both functions by changing the angle of the stick while walking.

Figure 2 shows the block diagram of the procedure for the developed ABS. The user of the developed ABS first activates the ABS with the help of a power-on button. The ABS will detect different environmental factors like obstacles, fire hazard identification, potholes/stairs presence, and moisture detection (puddles). When any of the above environmental parameters are detected, the user is alarmed via the IoT module to his smart mobile. The GPS coordinates are also recorded whenever the ABS is working. All the data is combined and shared with the user's smart mobile via the IoT module. The ambient temperature is also recorded for the environment temperature identification. All the recorded data was also sent to the caregiver/hospital via the Internet and in case of the SOS button pressed or any other emergency the help can be provided to the blind person by getting the GPS location of the user. For user awareness, the device also provides aural feedback through vibrations or voice prompts on the user's smart mobile.

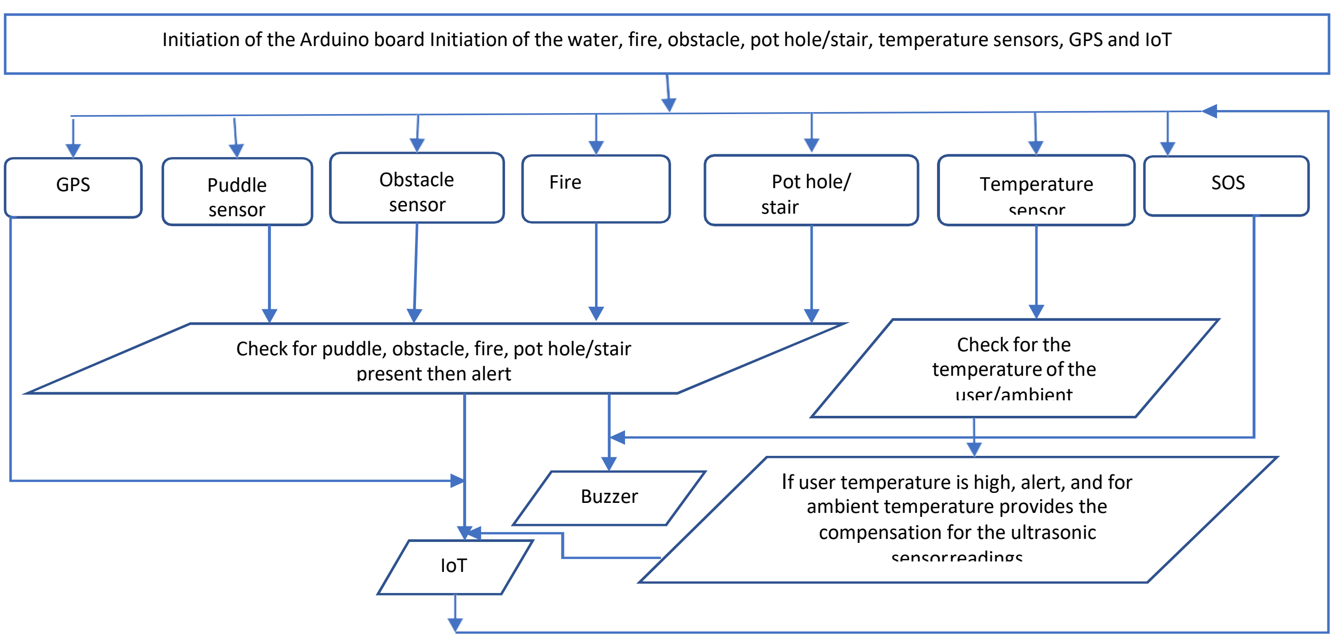


Figure 3 The flowchart for the program of the ABS

The software for the Arduino board was created in the Arduino IDE in C. Figure 3 shows the flowchart for the C program. The microcontroller was initialized first, followed by all of the sensors, GPS, and IoT modules [12]. The water sensor detects puddles, the ultrasonic sensor detects obstacles, the IR-1 sensor detects fire, and the IR-2 sensor detects potholes or stairs. For any of the above sensor readings in the specified range of the system, the microcontroller sends alerts to the user by using the buzzer of different alarms. The system also reads the GPS data and records. The system also reads the temperature sensor readings; for the first minute, it reads the user's temperature, and if the readings of the user's temperature are abnormal, it alerts the user via a buzzer. Then afterwards, the same sensor reads the ambient temperature to compensate for the ultrasonic sensor distance reading. The system also alerts the user via IoT module if the user presses the SOS button during unprecedented emergencies the user can face if far from home. The microcontroller culminates the process by transmitting all sensor data to the IoT platform. This data then triggers updates within the user's smartphone application, enabling real-time monitoring. The system functions in a continuous loop, consistently evaluating environmental parameters.

Figure 4 The snapshot of the developed app taken from the user's smartmobile

The ThingSpeak Smart mobile app was used for displaying the data in the smart mobile. The software is easy, and the user may install it on their smartphone via the Google Play Store. To use the program, the user must provide their user name and password. Finally, the entered data is presented in the app. Figure 4 depicts an app snapshot captured on a smart mobile. The user interface presents sensor readings alongside corresponding GPS coordinates. After receiving the data the user can terminate the application. The system facilitates real-time data updates within the companion smartphone app every 10 seconds using the user's internet. Additionally, in emergency scenarios, user data is transmitted to the designated caregiver's or emergency services' smartphone application. The app and the software used in the development of the ABS are open access and thus further helping in reducing the development cost of the ABS.

3.0 RESULTS AND DISCUSSION

The project commenced with the development of the core electronic circuitry for the walking aid. The subsequent development stage involved assembling all electronic components onto a commercially acquired wooden walking aid. Maintaining a sequential order from bottom to top. Subsequently, all components were rigorously tested to ensure real-time processing of sensor data. Then we calibrate all the sensors used in the ABS. For example, we have used a mercury-based thermometer to calibrate the thermistor-based temperature sensor. The Equation of the slope for the temperature sensor is shown in Equation (1) [13].

$$Slope = \frac{T2 * T1}{T2 - T1} \ln \frac{R1}{R2} \quad (1)$$

Where T1 and T2 are two different temperatures, and the R1 and R2 are the corresponding resistances of the thermistor at different temperatures. The fire detection range may be adjusted using a potentiometer on the IR-1 sensor. The obstacle detection sensor has a maximum range of approximately 80 cm. During testing, it was evaluated for objects as small as 5 cm, similar to the size of a matchstick flame. Likewise, the IR-2 sensor used detects the pothole/stair and for calibration purposes, a potentiometer is given to adjust its range within 3 to 80 cm. A potentiometer in its SCU (signal conditioning unit) does the puddle sensor calibration. The ultrasonic sensor components were arranged as follows: puddle detection sensor, uneven surface detection sensor (combining pothole and stair detection), obstacle detection sensor, fire detection sensor, Arduino microcontroller unit, GPS module, integrated IoT module, audible alert (buzzer), 5-volt battery, power activation switch, emergency SOS button, and temperature sensor.

All the sensors except the temperature sensor, used in the system were readymade calibrated, and we used Equation (2) to provide the temperature compensation coming from the temperature sensor [14] for correcting the OD. The t is the flight time of theultrasonic pulse in seconds. T data comes from the ambient temperature sensor and the unit is in Celsius.

$$\text{Temperature compensated OD} = 0.5 * (331.45 + 0.6067 * T) * t \quad (2)$$

During testing, the sensor's functionality was evaluated for an obstacle range of up to 2 meters, demonstrating its potential to assist visually impaired individuals with age-related limitations. The system's GPS functionality underwent rigorous outdoor testing to ensure accurate real-time location reporting. Similarly, the integrated IoT module was evaluated for its ability to transmit sensor data from the microcontroller in real-time. However, data transmission requires internet connectivity for the IoT module. Additionally, the emergency SOS button was thoroughly tested to verify real-time user data upload for care giver/medical personnel access.

Low-vision and elderly populations tested the smart stick indoors and outdoors. According to them, there is improvement in balance, mobility, confidence, and safety due to the SOS button and real-time caregiver monitoring. In addition, the user felt more confident going outside, knowing the SOS button could summon help in emergencies from the caregiver/hospital monitoring the user.

Figure 5(a) shows the user using the developed ABS. Figure 5(b) showcases the assembled device with its various components designed to assist users with visual impairments and age-related limitations. The ABS incorporates essential functionalities including GPS location tracking, emergency SOS alerts, fire hazard detection, puddle identification, obstacle detection, uneven surface recognition (encompassing stairs and potholes), temperature monitoring, and an integrated IoT module.

The field trials were done during the College Fest in 2023. For the field trials, first, we get consent from the user and then familiarize the ABS to the user with the walking aid's operation. The ABS was distributed to twenty elderly users to test under various real-time scenarios. The distributed ABS was tested in specific locations on the college campus for all the parameters.

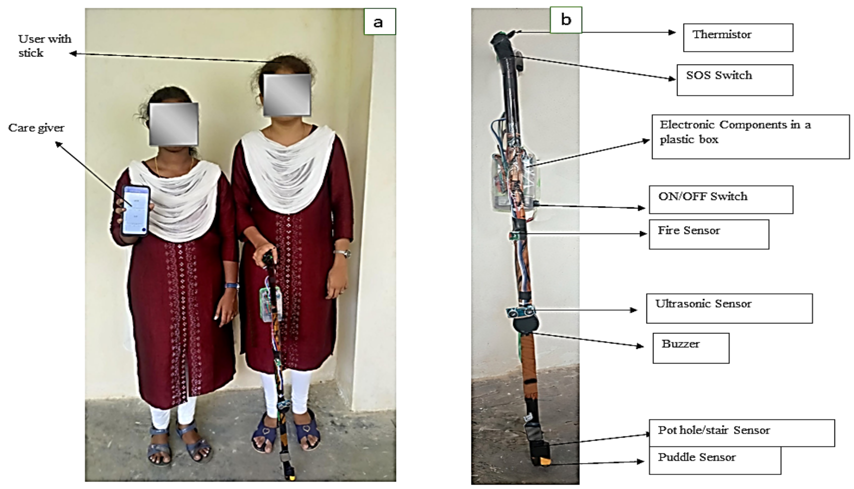


Figure 5 (a) The photo of the students using the developed smart stick (one is the user and one is the care giver) (b) The photo of the developed smart stick

It took around 10 minutes per user to check the usage of the stick after user learning the guidelines for using the ABS. After distribution we got the participants to interact with the device while all pertinent data was captured through the Things-speak app. The app automatically saved the data on the user's mobile device in an Excel format, and the received data is shown in Table 1. Table 1 shows the 20 user's GPS locations latitude, longitude, presence of any fire, puddle, temperature compensated obstacle distance, SOS button status, ambient temperature (oC), pothole/Stair presence, date and time in the real-time status of the ABS user.

The developed ABS was first tested in the controlled environment and system response times were also computed as well. The obstacle and fire detection ranges for the system were tested for 30 to 200 cm and 10 to 80 cm, respectively, and its reaction time was 600 ms. The reaction times for the temperature sensor, pothole/stair detection, and SOS button were 100 ms, 600 ms, and 600 ms, respectively. The puddle sensor reaction time was 500 ms, whereas the GPS response time was around 10 seconds. The system's projected overall reaction time is one to two seconds, and data is refreshed every ten seconds. The gross weight of the developed stick is around 600 gm. The designed smart stick had a power consumption of about 600mW and the total hardware component cost was about $60 for the ABS. On the other hand, if the gadget was manufactured in large quantities, the price may go down and end customers could afford it more easily.

Table 1 Data stored by the app in an Excel sheet for the caregiver of 20 different users.

S No	GPS Location (Latitude: Longitude)	Fire	Puddle	Obst-acle	Temperature-compensated Distance (m)	SOS	Temperature (°C)	Pot Hole/ Stair	Date	Time
1	10.83000: 78.69000	Yes	No	Yes	1.19	No	37.2	No	04.04.2023	10.00 am
2	10.96000: 77.95000	No	No	Yes	1.20	No	35.0	No	05.04.2023	10.30 am
3	10.607030: 78.417900	No	No	Yes	1.16	No	37.0	No	06.04.2023	10.00 am
4	10.367312: 77.980293	No	No	Yes	1.10	No	34.0	No	07.04.2023	11.00 am
5	10.163710: 77.759651	Yes	Yes	Yes	0.75	Yes	32.0	Yes	08.04.2023	10.00 am
6	10.224758: 77.746635	No	No	Yes	0.93	No	33.0	No	09.04.2023	11.00 am
7	10.379663 : 78.820847	No	No	No	NA	No	30.0	No	10.04.2023	5.00 pm
8	10.804973: 78.6870296	No	Yes	Yes	1.18	Yes	37.0	Yes	11.04.2023	5.30 pm
9	10.6011992: 78.6804986	No	No	Yes	1.20	No	38.0	No	12.04.2023	5.00 pm
10	10.2732753:77.5116082	No	Yes	Yes	1.19	No	34.0	No	13.04.2023	10.00 am
11	10.959610: 78.447021	Yes	No	No	1.10	No	35.0	No	14.04.2023	11.00 am
12	10.933600: 78.420998	No	No	No	1.50	No	32.0	No	15.04.2023	12.00 am
13	10.7473305: 78.5164222	No	No	No	1.90	No	34.0	No	16.04.2023	10.30 am
14	10.822226: 78.6834046	No	No	No	2.00	No	36.0	No	17.04.2023	4.00 pm
15	10.8155: 78.69651	Yes	Yes	Yes	1.80	Yes	33.0	Yes	18.04.2023	4.30 pm
16	10.224758: 77.746635	No	No	No	0.90	No	31.0	No	19.04.2023	10.00 am
17	10.804973:78.6870296	No	No	No	1.20	No	30.0	No	20.04.2023	11.30 am
18	10.367312: 77.980293	No	Yes	Yes	1.90	Yes	32.0	Yes	21.04.2023	5.00 pm
19	10.163710 : 77.759651	No	No	No	2.00	No	33.0	No	22.04.2023	5.30 pm
20	10.96000: 77.95000	No	Yes	Yes	1.00	No	37.0	No	23.04.2023	10.00 am

Table 2 Feature based comparison of different blind sticks developed by different researchers and the developed ABS:

S.No	Features	Research [16]	Research [15]	Research [9]	Developed ABS
1	Combined used by elderly/blind	×	×	√	√
2	Pothole	×	×	×	√
3	Stair	√	×	×	√
4	IoT	√	×	√	√
5	Caregiver reports in real-time.	√	×	√	√
6	SoS facility	√	×	√	√
7	Fire	×	√	√	√
8	Ambient temperature monitoring	×	×	×	√
9	User temperature monitoring	×	×	×	√

The comparison of different blind sticks developed by various researchers and the newly developed ABS is shown in Table 2. Table 2 highlights significant advancements in assistive technology for the visually impaired and elderly persons. Previous models, such as those proposed by Anwar [15] and Kunta et al. [16], primarily focused on visually impaired individuals. However, Singh et al. [9] introduced a model aimed at both the elderly and visually impaired. The developed ABS further enhances this dual usability, ensuring comprehensive support for both groups. While Anwar [15], Kunta et al. [16], and Singh et al. [9] did not include pothole detection, which is crucial for safe outdoor navigation, the developed ABS addresses this gap, preventing accidents caused by uneven surfaces. Similarly, stair detection was incorporated only in Singh et al. [9], while the developed ABS ensures safer movement by detecting stairs and alerting users accordingly.

IoT-based solutions were explored by Anwar [15] and Singh et al. [9] but were absent in Kunta et al. [16]. The developed ABS integrates IoT technology, enabling real-time monitoring, location tracking, and smart alerts, improving caregiver connectivity. While Singh et al. [9] and Anwar [15] included real-time caregiver reporting, Kunta et al. [16] lacked this functionality. The developed ABS provides continuous updates to caregivers, enhancing user safety and emergency response. Additionally, an SOS alert system was incorporated by Anwar [15] and Singh et al. [9], whereas Kunta et al. [16] had not tested this feature. The developed ABS ensures immediate emergency notifications via a dedicated SOS button, improving response time in critical situations.

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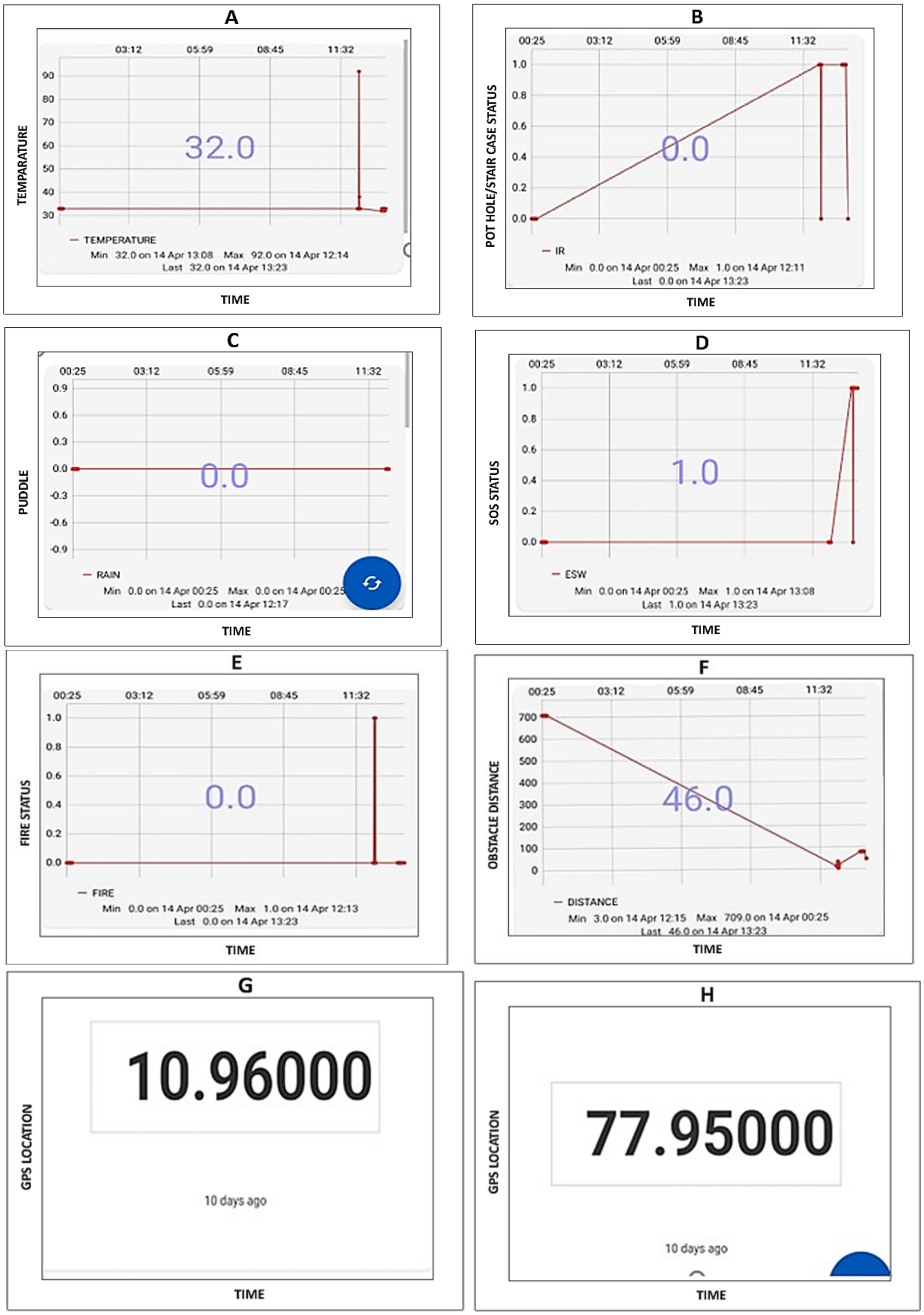

Figure 6 Thingspeak app snapshot of the data for all the parameters tested by the user for the ABS in real time (a) The snapshot of the app showing the ambient temperature (b) IR sensor status for the pot hole/stair (c) Puddle status (d) SOS status (e) Fire status (f) Temperature compensated OD. Figure (G) and (H) shows the GPS co-ordinates of the ABS tested.

ABS ensures immediate emergency notifications via a dedicated button, improving response time in critical situations. Fire detection was included in Kunta et al. [16] and Singh et al. [9] but absent in Anwar [15]. The developed ABS incorporates fire detection, adding an extra layer of safety. Previous studies did not address ambient temperature monitoring, which is a key feature for user comfort and safety. The developed ABS introduces this capability, helping users avoid extreme weather conditions. Furthermore, no earlier models monitored user body temperature. The developed ABS integrates this feature, allowing real-time health monitoring and early detection of health issues. A glimpse of the caregiver's smartphone's data for various sensor statuses and

SOS with GPS is displayed in Figure 6 (shown for the test result of one ABS tested on the different user).

4.0 CONCLUSION

The comparison of the developed ABS with the three different blind sticks has been shown in Table 2. It concludes that the developed ABS outperforms previous blind stick models [9][15][16] by integrating several advanced features, making it a comprehensive assistive device for both the visually impaired and the elderly. Unlike earlier models, it uniquely detects potholes and monitors both ambient and user temperature, addressing key limitations of prior designs. Additionally, it retains essential functionalities such as obstacle detection, puddle, stair detection, IoT integration, caregiver reporting in real time, SOS facility, and fire detection, ensuring enhanced safety, real-time assistance, and broader usability.

The ABS effectively detects obstacles and enables visually impaired and elderly individuals to navigate both indoors and outdoors independently, reducing their reliance on caregivers. Alerts are sent via buzzers and audio alarms on the user's smartphone, promoting seamless navigation. Equipped with GPS tracking, an SOS button for emergencies, and a dedicated caregiver-hospital app, the ABS enhances real-time monitoring and emergency response.

Designed to be lightweight, portable, and affordable, the ABS is particularly beneficial for developing and resource-constrained regions. Improving mobility, not only minimizes accident risks but also boosts job prospects and self-reliance among visually impaired individuals. However, field experiments revealed certain challenges, emphasizing the importance of effective user training to maximize the device's benefits. The continued dependence of users on caregivers highlights the need for further technological advancements. This research paves the way for future improvements, potentially integrating artificial intelligence and additional sensors to develop even more sophisticated smart walking aids that can be used by both the elderly and blind persons.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

References

[1] WHO.year? Blindness and vision impairment. https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment. Retrieved 22 April 2023.

[2] Kaphle, D. Gyawali, R. Kandel, H. Reading, A. Msosa, JM. 2016. Vision Impairment and Ocular Morbidity in a Refugee Population in Malawi. *Optometry and vision science.* 93(2):188–93. DOI: http://dx.doi.org/10.1097/OPX.0000000000000775

[3] Natarajan, V. Yogeshwaran, M. Canessane, A. 2022. IoT based Smart Stick with Automated Obstacle Detector for Blind People. *Proceedings of 6th International Conference on Trends in Electronics and Informatics* (ICOEI). 536–40. DOI: http://dx.doi.org/10.1109/ICOEI53556.2022.9777174

[4] Jeevitha, S. Kavitha, P. Keerthana, C. 2022. Smart Blind Stick Using IoT. *International Journal of Advanced Research in Science, Communication and Technology.* 2(1):535–8. DOI: http://dx.doi.org/10.48175/ijarsct-3598

[5] Ghosal, A. Majumdar, A. Dhar, P. Kundu, A. Mondal, A. Biswas, A. 2020. Smart Stick for Blind using IoT. *International Journal of Innovative Research in Technology.* 7(5):12–4.

[6] Rahman, M. Islam, R. Rashid, 2018. MH. IoT based Blind Person's Stick. *International Journal of Computer Applications.* 182:19–21. DOI: http://dx.doi.org/10.5120/ijca2018917824

[7] Tamboli, AR. Suryawanshi, AN. Bohra, AD. Pal, DD. Kapadnis, JY. 2017. IoT Based Smart Stick for Blind People. *International Journal of Advance Research and Innovative Ideas in Education.* 3(2):4949–52.

[8] Romadhon, A. S. & Husein, A. K. 2020. Smart stick for the blind using Arduino. *Journal of Physics: Conference Series,* 1569(3), 032088.DOI: https://doi.org/10.1088/1742-6596/1569/3/032088

[9] Singh, AK. Rajarajeshwari, P. Rathika, R. Shobiya, B. Keerthi, P. Marieswaran, M. Common Smart Stick for Blind and Elderly People to Detect Environmental Factors and Free Navigation. *2024. 2nd International Conference on Biomedical Engineering Science and Technology.* 388–400.

[10] Wang, Y., Zou, F. and Cegla, F. (2017). Acoustic waveguides: An attractive alternative for accurate and robust contact thermometry. *Sensors and Actuators A: Physical*, 270: 1–10. DOI: http://dx.doi.org/10.1016/j.sna.2017.12.049

[11] Robu. India's Robotics, DIY, Engineering Online Store. https://robu.in/. Retrieved 25 April 2023.

[12] Apu, A. Nayan, AA. Ferdaous, J. Kibria, M. IoT-Based Smart Blind Stick. 2022. *Lecture Notes on Data Engineering and Communications Technologies.* 447–60.

[13] AspenCore. Thermistors and NTC Thermistors. https://www.electronics-tutorials.ws/io/thermistors.html. Retrieved 25 April 2023.

[14] Abdullah, RH. 2015. Design and Implementation of Ultrasonic Based Distance Measurement Embedded System with Temperature Compensation. measurement embedded system with temperature compensation. *International Journal of Emerging Science and Engineering,*3(8): 30–7.

[15] Anwar, A., 2017. A Smart Stick for Assisting Blind People. *IOSR Journal of Computer Engineering,* 19: 86–90. DOI: https://doi.org/10.9790/0661-1903028690

[16] Kunta, V., Tuniki, C., Sairam, U., 2020. Multi-Functional Blind Stick for Visually Impaired People, in: *2020 5th International Conference on Communication and Electronics Systems (ICCES).* 895–899. https://doi.org/10.1109/ICCES48766.2020.9137870.