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An Integrated IoT Smart Cane for the Blind and Visually Impaired Individuals

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Abstract The advancement of Internet of Things (IoT) technologies has paved the way for innovative solutions in various domains, including assisting visually impaired and blind (VIB) individuals. Smart canes with IoT capabilities enhance safety by providing real-time information about the user's surroundings, enabling them to avoid obstacles and potential hazards. This scientific article develops an intelligent cane for visually impaired and blind (VIB) people integrated with an IoT system. This smart device promotes independence and confidence for VIB individuals. The smart cane was designed using SolidWorks 3D modelling software. It detects water, obstacles, and fire. The IoT smart cane employs ultrasonic sensors to help VIB users go up and down the stairs and detect obstacles. The system is controlled via the Arduino module. The cane automatically notifies VIB users when it detects hazards. The family tracks the individual through the fixed MCU Node that sends the navigation to the family smartphone on the Blynk application. The system is calibrated versus different objects, and the blind location is sent to the family successfully through the Blynk mobile Application.

Keywords: IoT; smart cane; obstacle detection; Arduino visually impaired; Blynk mobile application.

1 Introduction

Globally, Blindness is a common disability. In 2023, According to the World Health Organization (WHO), 2.2 billion people worldwide have a vision impairment [1] Also, In at least 1 billion of these, vision impairment could have been prevented or is yet to be addressed by correcting their cataracts through surgery [2]. They cannot practice everyday life easily and need assistance to avoid their difficulties. Consequently, Smart canes aid them in practising everyday life.

Several numbers of research published previously to develop an intelligent cane system. N. Dey et al. [3] improved a smart walking stick controlled by a microcontroller to detect obstacles and wet areas. A. I. Apu. et al. [4] enhanced an Obstacle-sensing walking stick advanced with IR sensors. I. Mohamed et al. [5] improved a navigation cane consisting of ultrasonic sensors and a camera by Raspberry Pi; this device works by calculating the distance between the user and objects using the sensors, and consequently, it collects the data from the camera. The developed system analyses the collected data using Artificial Intelligence. A. Sfiiyan et al, [6] designed a fast-response smart cane equipped with infrared, ultrasonic and moisture sensors and controlled it with an 18F46K80 microcontroller. R. K. Megalingam [7] supported his smart cane with heat, obstacle detection, and Bluetooth modules; An Arduino module operated the system. The ultrasonic sensor calculated the distance and buzzed the user in case of danger.

The Internet of Things (IoT) has made significant strides in medical devices, offering innovative solutions to enhance patient care, monitoring, and overall healthcare efficiency. IoT-enabled medical devices allow continuous remote monitoring of patient's vital signs, chronic conditions, and post-surgical recovery to assist early detection of any anomalies and reduce the need for

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frequent hospital visits [8]. Implants equipped with IoT technology can provide real-time data about their status and the surrounding tissue conditions; this is particularly beneficial in monitoring the healing progress of bone fractures and post-surgical implants [9]. IoT devices can help patients manage their medications by sending reminders to take pills, providing dosage instructions, and even tracking medication adherence [10]. Furthermore, wearable devices equipped with IoT technology can monitor physical activity, heart rate, sleep patterns, and more, providing insights into a patient's overall health and well-being [11]. IoT-enabled medical equipment, such as infusion pumps and ventilators, can provide real-time data on usage, performance, and potential malfunctions, enhancing patient safety [12]. IoT devices play a crucial role in telemedicine by facilitating remote consultations and diagnostics through video conferencing, data sharing, and real-time monitoring [13]. IoT techniques in medical devices involve a combination of hardware, software, networking, and data analytics [14] strategies to enable seamless communication, data collection, and analysis. The IoT medical devices use wireless communication protocols (e.g., Bluetooth, Wi-Fi, NFC, Zigbee) to transmit data from sensors to central servers, healthcare providers, or mobile applications. This enables remote monitoring and data sharing without the need for physical connections. Cloud Computing improves data storage by providing scalability, accessibility, and computational power for data analysis and storage. IoT medical devices often leverage cloud-based platforms to store and process the vast data generated [15]. These techniques collectively contribute to the successful implementation of IoT in medical devices, leading to improved patient care, efficient healthcare processes, and better medical outcomes [16].

This article represents an integrated IoT smart cane for VIB individuals. The implemented system detects obstacles within 180 degrees. The developed IOT smart cane is supported by a water sensor for detecting mud and an infrared sensor to detect a flame, The sensors collect real-time data and send it to the Arduino microcontroller for processing. After processing, the microcontroller invokes a speech warning message through an earphone as audio feedback. The IoT smart cane allows the family to track the blind through a Blynk mobile application.

The paper's plan is outlined in the following manner: The first section in this paper is the Introduction, the second section is the methodology, and this section represents the sensors employed in the cane, then the IoT Platform's development technique. The third section contains the results, while the last section discusses the results.

2 Martial and Methods

The Visually impaired suffer during everyday life, and they need an assistive tool to avoid the difficulties that they encounter daily. Biomedical engineers aid blind people by developing assistant tools to allow them to live easily. This section demonstrates the proposed IoT-based smart cane for reducing the blindness risk. The intelligent cane collects data from ultrasonic sensors, flame and wet detection sensors. The family tracks the visually impaired through a Blynk mobile Application.

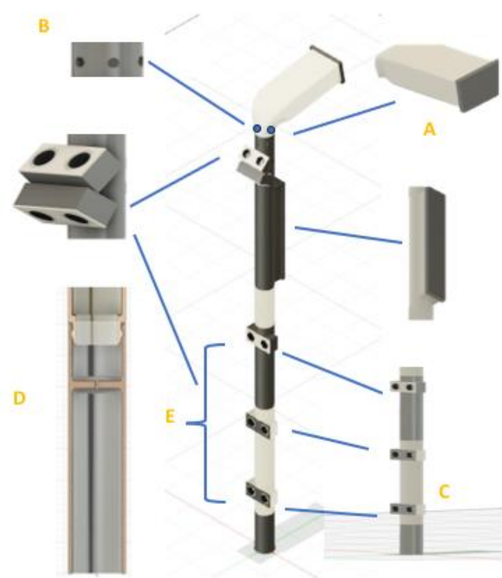


Fig. 1. The 3D Design of the Smart Stick illustrates A) the Hand grip that contains the control unit, B) the Emergency LEDs linked with a helping button, C) the battery case, D) the Water sensor, E) the Ultrasonic sensors distribution on the cane.

Fig. 1 illustrates the 3D design of the implemented cane as a pre-manufacturing step using SolidWorks 3D modelling software. The developed IoT smart cane assists the blinds through advances: 1. Emergency LEDs connected with a helping button, 2. Ultrasonic sensors for obstacles and stairs detection, 3. A slot rechargeable battery is fixed in the middle of the cane inside the battery case. A water detection sensor to detect mud. All the cane components are described in detail as follows.

2.1 sensors

Lightness: This smart cane uses two lighting systems: 1. Emergency LEDs connected with an assisting button to turn on the LEDs manually, 2. Light Dependent Resistor (LDR) detects darkness and allows the LEDs to switch on automatically. Fig 1B shows the place of 3D design for the LEDs.

Water Pits Detection: A water detection sensor is a resistor (1MΩ) that detects mud and water level. It is connected to the lower part of the cane. Arduino reads the output signal directly and notifies the user by a recorded message.

Flaming detection: The developed cane supports flame and radiation detection by detecting near-infrared radiation from 760 to 1100 nm. It is used as a flame detector. The detection range is up to 50 cm with a 60-degree angle.

Stairs and Obstacle Detection: This IOT cane detects the obstacles in front of the VIB user and gives a message to notify him in case of hurdle detection in the set range. Five ultrasound sensors are distributed over the cane to detect obstacles and help the Visually Impaired go upstairs and downstairs; two ultrasonic sensors are fixed with an angle of 45 degrees to detect high obstacles, as shown in Fig. 2(A).

Up the stairs: Three ultrasonic sensors are accomplished together to complete this task and are distributed over the cane, as shown in Fig.2(B). According to standards, one stair height is 30 cm. The code is adjusted to give a "Go UP" message if the three sensors calculated the distances as the following,

If the height 1 is less than 30 and more than 35

And the height 1 is equal to height 2

And the (height 3 –height 2) = (height 2 –height 1)

Go up.

Down the stairs: An ultrasound sensor is fixed in the lower with an angle of - 30 degrees to direct the visually Impaired down the stairs as shown in Fig. 2 (C). The code is adjusted to give "Go down" message in case of the distance staircase is on average 15-20 cm; according to the following pseudo-code,

If (*height* 4 is more than (R+15 cm) and less than (R +20 cm))

go down.

Alarm System and Audio Feedback: The intelligent cane includes a buzzer for asking for assistance. The sensor feedback is sent to the user as an MP3 audio message. Also, an audio notification notifies the family member through the mobile notification.

Emergency Button: When the emergency button is pressed, LEDs, the buzzer ring & notification with "I need help", the family member will receive a message & the user's location.

2.2 Microcontroller

Arduino is an open-source platform for building and programming electronics. For developing the IOT smart cane, Arduino Uno, a microcontroller board based on the ATmega328P, is employed to complete this task. It has 14 digital input/output pins (six of them can be used as PWM outputs, six for the analogue inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button. The feedback from the sensors is sent to the user as MP3 audio files to ease the interface between the cane and the visually impaired. Fig.3. shows a block diagram representing the input sensors and their connection with the IoT platform that connects the stick with the family mobile in case of danger. Fig. 4 shows a schematic diagram for all the sensors connected to the Arduino and the connection with Node MCU. Figure 5 shows the flowchart of the system.

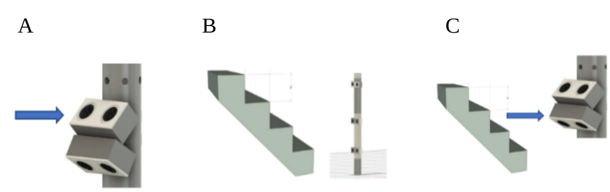


Fig. 2. 3D design of the ultrasound sensors distributed over the cane: A) Obstacles detection, B) Upstairs sensors, C) Downstairs detection.

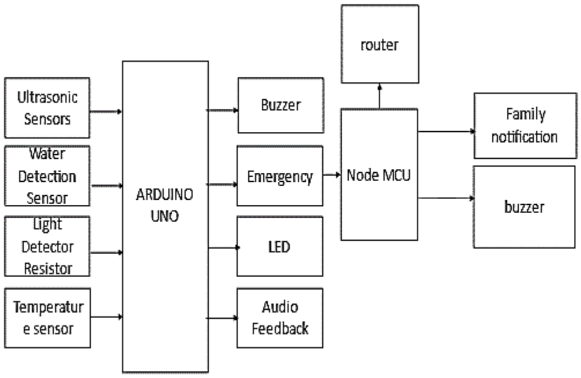


Fig. 3. Block diagram of Integrated IoT Smart Cane.

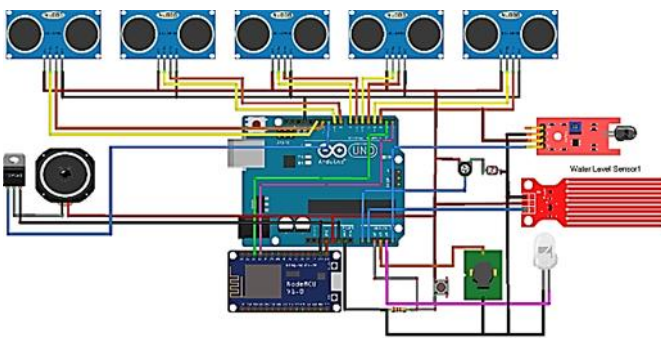


Fig.4. Schematic diagram for the connected sensors to the Arduino.

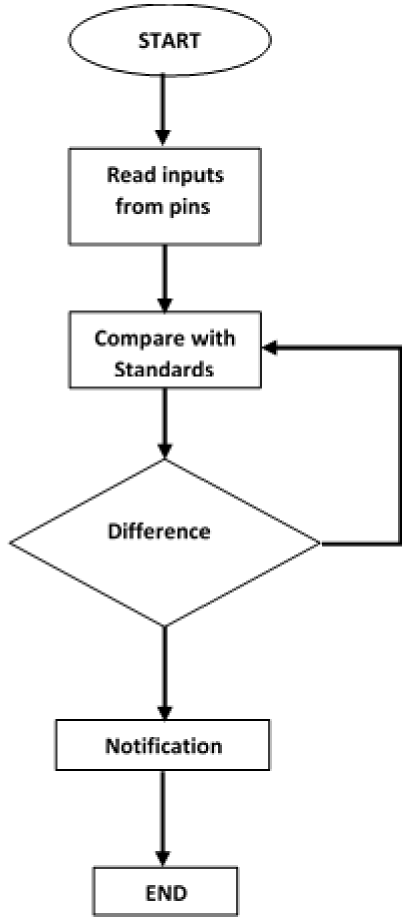


Fig.5. Flow diagram of the System

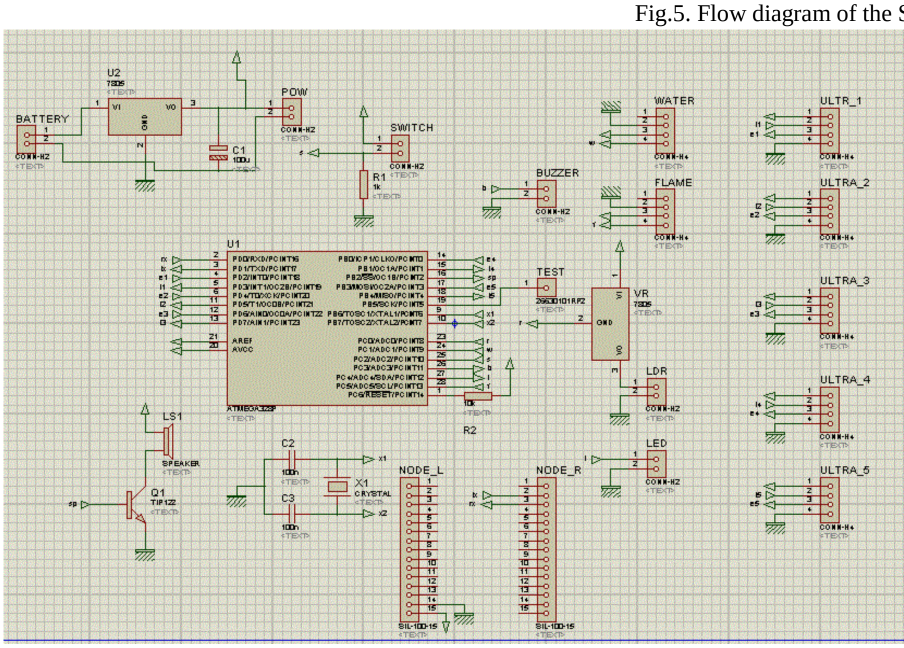


Fig. 6. Proteus diagram shows all components in the smart cane.

<u>2.4 System implementation</u>

Firstly, A Proteus design was the pre-step to carry out a

Printed circuit board (PCB). It is used as a pre-process to build electronic circuit boards to get their life phase in a physical form. Proteus is a software suite for simulating and designing electronic circuits and microcontroller-based systems. It's commonly utilized in electronics, embedded systems, and IoT device development. Proteus PCB Design module facilitates the design of printed circuit boards (PCBs) for electronic circuits.

It provides tools for schematic capture, component placement, routing, and generating manufacturing files. The module translates electronic circuit designs into physical PCB layouts. Also, it is considered a Microcontroller Simulation for a wide range of microcontrollers, allowing the designing and simulation of microcontroller-based systems. It is employed to carry out the PCB; It is used as a preprocess to build the electronic circuit boards to get its life phase in a physical form.

Fig. 6 displays the Proteus diagram of the control circuit that contains all the selected sensors and the components. **Fig. 7** shows different designs of the control circuit as bottom Cupper, upper Silk, 3D PCB Design, and 3D PCB design with components as represented in **Fig. 7** (A), (B), (C), (D), (E), respectively. **Fig. 8** represents the different stages of the implementing the control circuit. PCB Printing, PCB Chemical Etching, PCB Drilling, and the stage of the Components placement are shown respectively in Fig. 6 (A), (B), (C), (D).

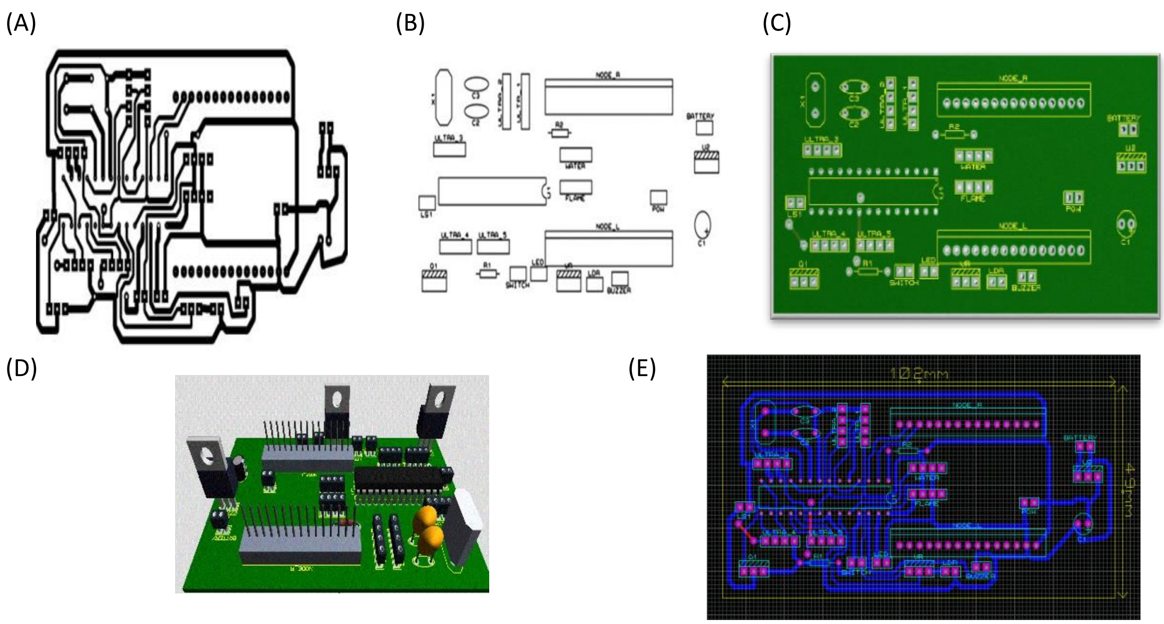
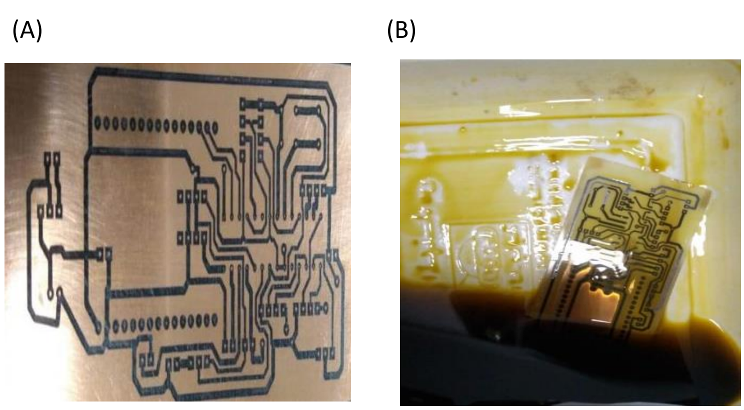


Fig. 7. A) Bottom Cupper, B) Upper Silk, C) 3D PCB Design, D) 3D PCB Design with components.



(C) (D)

Fig. 8. Circuits performing A) PCB Printing B) PCB Chemical Etching C) PCB Drilling D) Components Placement.

2.4 Developed Blynk IoT Platform

It is employed to visualise the collected data from the hardware remotely, the IoT system consists of principal components: 1. Blynk App creates interfaces using different widgets, 2. Blynk Server is a connection point between the hardware and the host (phone cell); Blynk Cloud runs the private Blynk server locally. This open-source IoT system remotes thousands of devices, 3. Blynk Libraries control sending or receiving information to the server and the process of the in/out commands for all the employed hardware platforms. In the proposed IOT cane, a mobile application is installed on the family mobiles to track the blind and to receive notifications from the cane. The internet is connected through the built ESP8266 Wifi-chip, with the open-source Arduino-based NodeMCU board. It transfers data through TCP/IP protocol stack, the NodeMCU-based ESP8266 works as a standalone application host; it can delegate the Wi-Fi networking tasks to another application processor.

Fig.9. Real snapshot of the intelligent cane.

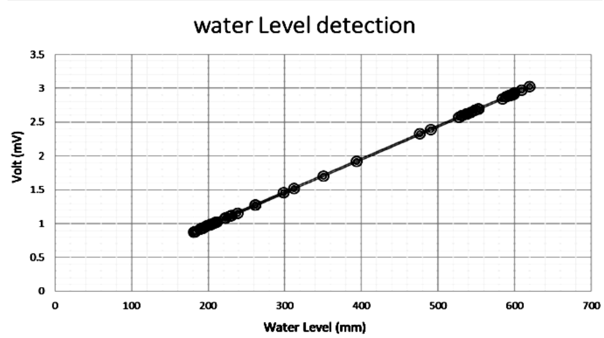


Fig.10. The measurements of the water level versus the voltage.

3 Results

A developed IoT smart cane (**Fig. 9**) proposed several assistive tools such as wet places, obstacles, and flame detection. Also, it instructs the blinds during up and down stairs. The collected data from the sensors are illustrated. **Fig.10** shows the water level measurements against the voltage value. The ultrasonic sensors are calibrated against several obstacles, such as wood, glass, and wall (concrete). **Fig.11** depicts the measured volts(mv) against the selected objects (mm). A water detection sensor is employed to notify the user in the case of wet detection. The cane based on IoT supported a Blynk mobile application installed in the family's mobile to send notifications to track blinds, as shown in **Fig 12.**

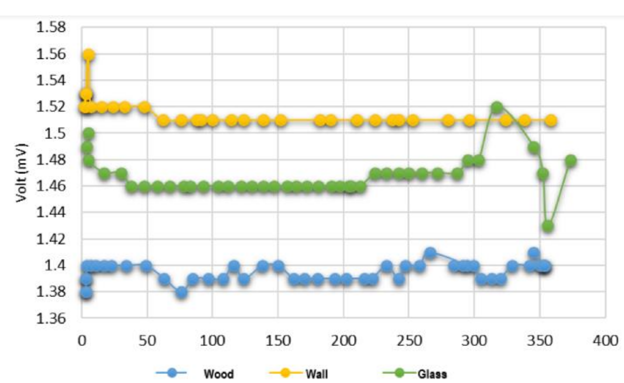


Fig.11. The measurements of the different obstacles (wood- wall – glass) versus the voltage.

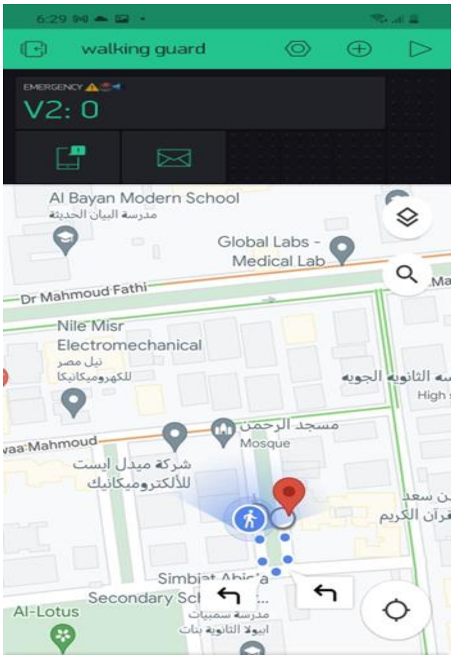


Fig.12. Screenshot for the Blynk application to track the blinds.

4 Discussion

This research article suggests a blind navigation assistance system works using different sensors and is connected by the IOT. The objectives of the developed system are to recognise the obstacles, Water Pits, and fires besides helping in the up and down stairs. The obstacle's type is classified by examining the voltage distribution at different angles, the ultrasound sensors are distributed on the cane by different angles to determine low and high obstacles. The lowest ultrasound sensors aid the user up and down the stairs. The tracked system pointing angle of the ground scanning period was about - 30 degrees to direct the VIB individuals down the stairs. The water level calculations are estimated at various water levels. The family can track the user through the mobile application.

Ultrasound sensors versus different objects are calibrated. When the system's performance is calibrated in real life, the Arduino measurements detected a difference in the calibrated values among the various objects, the highest voltage measurements were for wood, while the lower voltage measurements were for the wall. The results showed that the obstacles can be classified accurately. When the system is applied in a natural environment, the estimated distance error is insignificant compared to an average walking step. The water level measurements are assessed at various water levels. The measurements of the water level detector were linear, and voltage reads were directly proportional to the water level. Blynk mobile application is installed in the family's mobile, and the notifications are sent to track the visually impaired. The development IoT stick supports sending messages to family members and tracking the blind by showing navigation places on the Blynk mobile application.

By comparing our proposed Integrated IoT Smart Cane with the previously implemented system, we found a limitation of other systems. Dang Q, [17] improved a virtual blind cane based on laser light to measure distances although the laser light harms the eyes. A. Rai[18] developed a smart blind walking to detect obstacles only. T. Sharma[19] suggested a cane to detect obstacles and mud only. Using different image processing techniques, P. N. Karthikeyan [20] improved smart glasses for VIB individuals based on image analysis.

Our proposed system is advantageous because it detects obstacles, Water Pits, and fires. Furthermore, it helps the VIB individuals the up and down stairs. The family can navigate the user through the mobile application. On the other hand, the proposed system is simple, cost-effective, and accurate.

5 Conclusion

This applied article proposes a navigation assistance smart cane for VIB individuals that supports obstacle detection, flame, and water level detection controlled by Arduino. The Blynk Cloud runs successfully locally to the private Blynk server and sends the stick's information to the family members through the IoT platform. Supported the cane with Artificial Intelligence will help blind people with more details about the surrounding environments.

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