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Blind's Bib: An Invention of Wearable Aid Prototype specific to Potholes and Uneven Surface Detection

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ABSTRACT

In recent times, the population of Blind people has been increasing by around 250 million in the world, and an attempt to improve the quality of their lives. However, despite the promising research outcomes, the existing wearable aids for blind or visually impaired people have numerous weaknesses in terms of weight, feature limitations, and cost. In this manuscript, a novel invention of lightweight design of wearable aid for visually impaired and blind people. The proposed design of a wearable aid will help them to walk and detect the environment around them with ease and make them independent in their life. The proposed system uses the fusion of sensor and vision-based technologies. It includes Google Vision API services, Lidar Technology, Arduino Nano, and Raspberry Pi 4. Based on the appearance of this prototype, this invention is named Blind's Bib. This assures the proposed aid is designed with lightweight, easy to use, and with a minimum number of instructions for operation. All the necessary security and frequently needed features are included in this system. Experimental results are demonstrated with blindfolded subjects and visually impaired participants.

Keywords: VL53L1X Time-of-flight Distance Sensor, Raspberry pi, Arduino Nano, Google Vision API, Object Detection, Pi camera, Text to speech conversion.

I. INTRODUCTION

Wearable assistive devices are playing a vital role in improving the quality of life [1] for visually impaired elderly individuals and blind people. Research and inventions in this field have focused on developing wearable assistive devices to aid the blind and visually impaired. The state-of-the-art advancements in this area aim to present the latest approaches for assisting and designing wearable assistive devices or systems.

Blind people face various challenges, from navigating their homes (indoors) to moving freely outdoors. However, with technological advancements, many software programs now assist blind individuals by integrating with electronic gadgets like mobile phones and computers. Advanced systems leveraging deep learning and AI help blind people navigate and perform daily activities with greater ease and comfort.

For example, [2] a low-cost, portable, and easy-to-use writing aid designed for blind and visually impaired individuals. This aid is based on Morse code communication and utilizes intelligent hardware with electronic components, including a bill of materials (BOM), to create a lightweight and affordable writing tool. In [3], different activities and applications related to the mobility of blind and low-vision individuals are explored.

The proposed framework aims to enhance their quality of life and reduce the associated socioeconomic costs. In [4], a user-centric approach is proposed to assist visually impaired people with indoor navigation.

The paper is organized as follows: Section II reviews related works, Section III describes the prototype design, and Section IV presents the results and observations. The concluding remarks are provided in Section V.

II. RELATED WORKS

A comparative survey on different portable and wearable devices specifically designed for blind people aims to inform researchers and users about the efficiency and performance of each device by considering both qualitative and quantitative parameters [1]. This survey focuses on various categories of visual substitution systems, including electronic travel aids, electronic orientation aids, and position locator devices. By comparing the different products available for blind people, this study helps analyze and understand the impact of technology in assisting visually impaired individuals.

[2] proposes a solution using a walking stick integrated with an Infrared Sensor to detect staircases and a pair of ultrasonic sensors to detect obstacles in front of the blind person. As an indication method, speech warning messages and vibrating motors are used when an obstacle is detected. The stick uses a microcontroller 18F46K80 embedded system and ISD1932 flash memory, along with vibrating motors. The advantages of this smart stick include flexibility in walking at a normal speed, obstacle detection within a range of 4 meters, low cost, low power

consumption, and quick response time, which helps protect users from danger.

However, the main drawback of this design is the use of Ultrasonic sensors, which have a lower reading frequency compared to Lidar and Time-of-Flight sensors. This limitation might reduce the stick's efficiency in detecting moving obstacles. Another disadvantage is that users must manually point the stick in a specific direction to detect obstacles, which may not be efficient, especially if obstacles vary in height and shape. Additionally, holding the stick for extended periods can be tiring.

In [3], the author presents an intelligent guide stick for blind people. This stick includes an ultrasound displacement sensor, two DC motors, and a microcontroller. However, it weighs 4 kg, which is heavy for most users, and its dimensions are 85 cm in height and 24 cm in width, making it cumbersome to handle.

[4] proposes a methodology for guiding blind people indoors using a walking stick and radio frequency signals with different carrier frequencies. Each path to a destination is associated with a specific frequency, and deviations from the path produce tactile vibrations. However, this approach is limited because the paths may not always remain constant.

[5] introduces a system using ultrasonic sensors and water sensors to detect obstacles and water content, respectively. It employs both voice-based warnings and vibration alerts. Notably, all the authors in [2, 3, 4, 5] used vibrations for obstacle warnings as they are more reliable than voice alerts, especially in noisy environments.

[6] proposes a remote guidance system for blind individuals, where video data from a camera carried by the user is transmitted to a remote assistant who provides navigation instructions. However, this method is inefficient because it relies on human assistance and may pose safety risks if guidance is misinterpreted.

[7] describes a voice-based guidance system using Ultrasonic and IR sensors along with an APR sound system to alert users about obstacles. This system is versatile as it can be used both indoors and outdoors, with or without a guiding stick.

[8] employs a GSM-GPS module to pinpoint the user's location and provide directional guidance. It uses Ultrasonic sensors for obstacle detection and vibrating motors for alerts. Accelerometer sensors are also used. This approach is similar to the methods in [2, 3, 4, 5]. The primary focus of this study is on guiding directions using GPS modules.

[9] and [10] demonstrate effective ways to measure distances between objects using Ultrasonic and IR sensors. [10] also proposes a method for detecting potholes using Lidar sensors. The system uses GPS to record the coordinates of detected potholes and sends the information to the relevant authorities.

[11] presents an indoor navigation assistive system based on vision and mobile technologies to help blind and visually impaired individuals travel independently indoors.

[12] introduces a user feedback-based indoor navigation system utilizing wearable haptic technology. This system includes visually impaired users in all stages of development. It builds on previous ideas and can also be used as an outdoor travel aid.

III. DESIGN OF THE BLIND'S BIB

The proposed design is a wearable assistive system for the visually impaired, enabling them to walk independently with minimal assistance [14]. In brief, the design of assistive devices is presented here. It utilizes VL53L1X Time-of-Flight Lidar Sensors, Raspberry Pi 4, Pi Camera, Arduino Nano, and Google Vision API services for enhanced navigation and obstacle detection.

The VL53L1X Lidar sensor is based on Time-of-Flight technology, which measures the distance to a target by emitting rapid laser pulses—up to 120,000 pulses per second—at a surface. The sensor calculates the distance by measuring the time taken for a wave pulse to reflect off an obstacle and return to the sensor. These sensors are strategically placed on the system at specific positions. When an object is detected within a certain threshold distance at a particular position, a vibration motor at that position activates to alert the user. The number of motors vibrating at different positions allows the user to judge the height and width of the obstacle effectively.

To assist the user in identifying the names of obstacles and objects in their surroundings, the system incorporates a Pi Camera that captures images of the environment. These images are then processed using Google Cloud Vision services via the Vision API on Raspberry Pi 4. Google's hybrid convolutional neural networks are utilized to detect objects within the images. The results are returned as a JSON response to the Raspberry Pi, which is then converted into speech using the eSpeak library in Python. This feature allows the visually impaired user to hear the names of objects around them.

In addition to obstacle detection, the VL53L1X sensor is also employed for detecting potholes and other uneven ground surfaces. To enhance safety and monitoring, the system includes a GPS module that allows caretakers to trace the location of the user in case of emergencies.

The specific design of the pothole indication components is illustrated in Figure 1. This innovative approach ensures a comprehensive navigation aid for the visually impaired, promoting independence and safety.

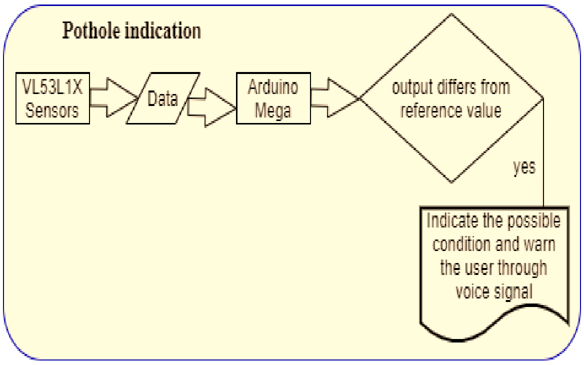

Fig. 1. Block Diagram of Pothole indication design

A VL53L1X sensor is positioned at the user's abdomen level to detect ground surface variations. It emits light pulses that hit the ground and reflect back to the sensor. The sensor calculates the time taken for the pulses to return, determining the distance to the ground. This distance data is sent to the Arduino Mega, which analyzes the information. Based on the measurements, the Arduino Mega will either activate or deactivate the pothole indication system, alerting the user to uneven ground surfaces for safer navigation.

Algorithm 1: Pothole detection
Condition →True
Counter → 0
Initial Value → Distance (Value read from the sensor)
Sleep for 2 seconds
While Condition is True:
    Reading Value → Distance (Value read from the Sensor)
    If Absolute (Initial Value - Reading Value) is less than 10 cm //Readings are consistent
        If counter == 6 // To make sure that values are consistent for some time
            Condition → False
        Else
            Counter = Counter + 1
    Else
        Initial Value → Reading Value
        Counter → 0

According to algorithm 1, the sensor requires a few seconds to establish an initial reference value. This reference value is used as a baseline to detect uneven surfaces. As mentioned in [10], the detection is achieved by comparing the difference between the reference value and the subsequent readings obtained from the sensor. This approach allows the system to accurately identify changes in the ground surface, ensuring reliable detection of potholes or other irregularities.

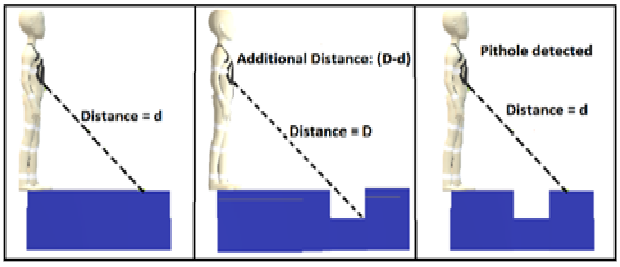

Fig. 2. Potholes detection

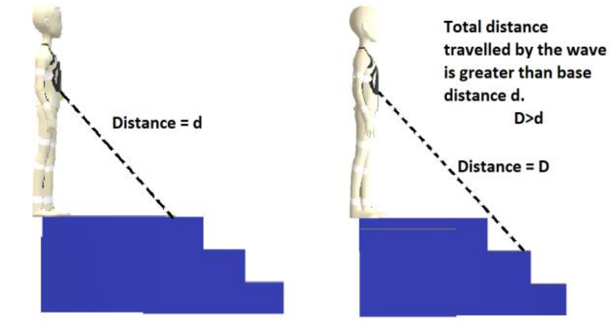

Fig. 3. Slope and downward steps detection

Figure 2&3 The system detects potholes, and steps, and measures distances using a VL53L1X sensor configured based on the user's height. This configuration establishes a constant reference value, 'd,' which represents the distance from the user's abdomen to the ground at a specific angle, forming a hypotenuse from the abdomen to a point on the ground. This reference value remains unchanged until manually reset by the user.

When the user approaches a pothole or slope, the hypotenuse length measured by the sensor will either increase or become out of range. If the sensor detects that the calculated distance is greater than 'd' or is out of range, the system concludes that there is an uneven surface ahead. The user is then alerted to ensure safe navigation.

IV. RESULTS AND DISCUSSION

After designing and implementing the technologies specified, favorable results were observed and noted. The distance encountered at various obstacles such as potholes, dining table, and steps are considered as three different cases and shown as time series plots in figure 4.

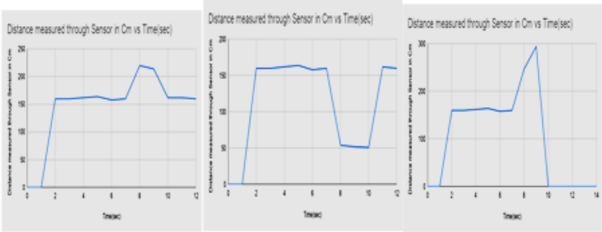

Fig. 4. Time series plots of distance observation (a) Pothole (b) a dining table (c) downward steps

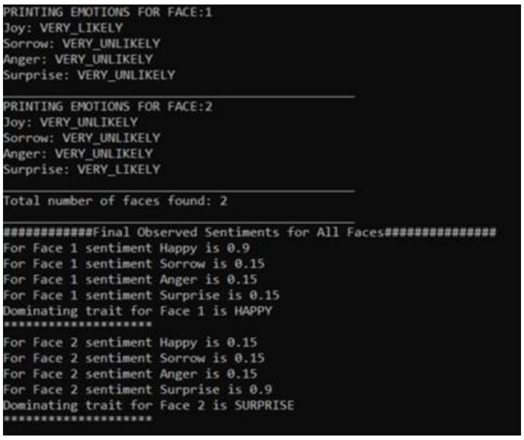

Fig. 5. Vision API Response

Figure 5 shows the experimental result from the Vision API services, with a response time of about 3 seconds. Using Google's cloud-based Vision API provided faster object detection compared to local processing with custom Convolutional Neural Nets, which took nearly 15 seconds due to high GPU demands.

IV. CONCLUSION

The novel invention blinds bib design aims to address the needs of visually impaired people with the fusion of sensor and vision technologies. The currently available aid design and technology are two barriers for blind and elderly people. Hence these technological inventions are not properly reached by them. This can be overcome in our invention with light weight, easy to use, and with the minimum number of instructions for operation. All the necessary security and frequently needed features are included in this system. Experimental results are demonstrated with blindfolded subjects and visually impaired participants.

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REFERENCES

[1] X. Chen, A. Shrivastava, and A. Gupta. Neil, "Extracting visual knowledge from web data", In ICCV, 2013. 1 , DOI: 10.1109/ICCV.2013.178

[2] Dimitrios, D., Nikolaos G, Bourbakis.: Wearable Obstacle Avoidance Electronic Travel Aids for Blind. IEEE Transactions on systems, man and cybernetics 40(1), 25 - 35 (2010).

[3] Nada, Ayat., Mashali, Samia., Fakhr, Mahmoud., Seddik, F, Ahmed.: Effective Fast Response Smart Stick for Blind People. In: Second International Conference on Advances in Bio-Informatics and Environmental Engineering (2015).

[4] Sung, Jae, Kang,.Young, Ho, Kim., In, Hyuk, Moon, F.: Development of an Intelligent Guide-Stick for The Blind. IEEE International Conference on Robotics & Automation (2001).

[5] S, Chaurasia., K, V, N, Kavitha.: an electronic walking stick for blinds. International Conference on Information Communication and Embedded Systems, pp. 1–5. Chennai (2014).

[6] Mohd, Helmy, Wahab., Amirul, A, Talib., Herdawatie, A, Kadir., A, Noraziah., Roslina, M, Sidek.: Smart Cane: Assistive Cane for Visually-Impaired People, International Journal of Computer Science Issues. 8(4).(2011).

[7] M, Bujacz., P, Baranski., M, Moranski., P, Strumillo., A, Materka.: Remote mobility and navigation aid for the visually disabled. In Proc. 7th Intl Conf. on Disability, Virtual Reality and Assoc. Technologies with Art ArtAbilitation, in PM Sharkey, P. Lop.

[8] Arjun, Sharma., Rahul, Patidar., Shubham, Mandovara., Ishwar, Rathod.: Blind Audio Guidance System. National conference on Machine Intelligence Research and Advancement, INDIA.

[9] Abdel, Ilah, Nour, Alshbatat.: Automated Mobility and Orientation System for Blind or Partially Sighted People. International Journal on Smart Sensing and Intelligent System. 6(2), 568-582. (2013)

[10] Tarek, Mohammad.: Using Ultrasonic and Infrared Sensors for Distance Measurement. World Academy of Science Engineering and Technology. (2009).

[11] Benet, Gilabert., Ginés, Blanes., Francisco, Simo., Jose, Perez, Pepita.: Using Infrared sensors for distance measurement in mobile robots. Robotics and Autonomous Systems. 40, 255-266 (2002).

[12] Li, Bing.: Vision-based Mobile Indoor Assistive Navigation Aid for Blind People. IEEE transactions on mobile computing, 18(3), 702-714. (2019).

[13] Barontini, F., Catalano, MG., Pallottino, L., Leporini, B., Bianchi, M.: Integrating Wearable Haptics and Obstacle Avoidance for the Visually Impaired in Indoor Navigation: A User-Centered Approach. IEEE Trans Haptics. 14(1), 109-122. (2021).

[14] Bala, M.M., Vasundhara, D.N., Haritha, A. *et al.* Design, development and performance analysis of cognitive assisting aid with multi sensor fused navigation for visually impaired people. *J Big Data* **10**, 21 (2023). https://doi.org/10.1186/s40537-023-00689-5