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Smart Shoes: Wearable Navigation Assistant for Visually Impaired People

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Abstract: *Vision is one of the powerful sense in all of the senses. Visually challenged people face many problems in terms of obstacles in their mobility in the case of outdoor as well as indoor. For their daily activities, they are always reliant on others. Visually impaired people meet many accidents, they often fall off and they may get lost in some unknown areas due to failure in adapting and identifying the surrounding environment. "Smart Shoes" are designed to provide a better solution for the visually impaired to move safely and independently. It is built using "Internet of Things" technology and the shoes are embedded with various sensors, microcontrollers, buzzer, speaker and vibration motor. The shoe alerts the wearer whenever he or she walks in front of an obstacle. Also, it detects the wet floor and water bodies and gives alert about it. To increase the security and safety of the visually impaired, whenever the person falls down an alert message is sent to the parent's or caretaker's telegram bot. Smart shoes are designed to provide a safe and comfortable companion in their daily life activities. As a result, a complete adaptive equipment is being advanced to improve the standard and comfort of life of the visually impaired.*

Keywords: Smart Shoes, visually impaired, obstacle detection and Internet of Things (IoT)

I. INTRODUCTION

Loss of sight is a lack of visual insight caused by physiological disorder or neurological disorder. Total blindness is the complete absence of sense of sight, whereas partial blindness is the absence of incorporation in the growth of the optic nerve or visual centre of the eye. If a person enters an unfamiliar location, to get to the destination one must first seek guidance from others. But if the person is visually impaired, he must rely entirely on others to get to the destination. In general, we find that a white cane is a visually impaired person's best friend. However, this cane is not always useful. A visually impaired person may get confused in an unfamiliar environment. As a result, their mobility is limited and they have to rely on others. No matter how many tools are evolved, the factor which helps a person to movement is his or her own personal skills.

The term blindness is defined as the total absence in the sense of sight and it is medical filed it is known as "No Light Perception" (NLP). The term blindness is used to determine the persons inability in sight of seeing and loss vision. The people who are having only less ability to see and having no more ability to distinguish between light and dark and to determine the direction of light.

People who are suffering from visual disability which prevents them to travel independently. As a result, blind person must use variety of equipment's and technologies as an aid to their movement. The blind people use to make use guide dogs, who are specially qualified to assist the visually impaired for movements by crossing the obstacles and alerting him or her to change the path. Still, the above method has some constraints like dog's inability to understand the complex directions, and only the children aged five and above are suitable to use it. The cost for guided dogs is very high, and many blind and visually impaired people face difficulty to look after another living being. To improve the movement of the visually impaired, white cane along with a red tip has been used, it is an international indicator for blind. The white cane is an easy and efficient mechanical equipment that uses simple tactile-force feedback to identify obstacles on the footing area, irregular surfaces, gaps, and stairs. The equipment is small and convenient, but it has its own limitations due to its volume, and it cannot detect driving obstacles or obstacles that are not located on the floor. Many techniques which depend on processing signals and sensor technology have recently been evolved to improve the navigation of the

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visually impaired. These devices, known as electronic travel aids (ETA), allow the visually impaired to navigate independently in the surrounding without caring about the changes in the environment.

However, all existing system have their own limitation like the distance and the area they cover, speed and accuracy of the devices. To address the limitations which are mentioned above, this prototype provides a simple, reliant, and comfortable navigational assistant for the visually impaired. Shoes are the most common thing that men or women wear, having wearable technology built into them makes the visually impaired person to achieve his/her task easier. The work is unique because it employs a vision system of ultrasonic sensors and IR sensor which combines the signals to identify the obstacles. Along with that, the user need not to carry a white cane or any other tool along with them. The system detects the obstacles and provide safety while walking. It is ideal for real-time applications. The work is unique in this it incorporates multiple functions into a single system, including detection of obstacles, wet floors, fall detection and also sends the notification to the parents/ caretaker in the event of a fall.

II. RELATED WORK

Jitendra Singh et al. [1] (2017) present a shoe that includes an ultrasonic sensor, a microcontroller, and a wireless headphone. The goal is to create an electronic kit that will assist blind people in navigating an obstacle-free path. If an obstacle is encountered, an indication will be relayed by a single ultrasonic sensor placed inside the shoe. This unit would process the instructions via the microcontroller and generate a sound in wireless headphones. A 9V dc battery is also installed in the shoe which provides power to the circuit.

The integration of various working modules such as obstacle detection, pedometer, electricity generation, health tracking and fall detection into a single system is done by *Rutuja Anil Shinde et al.* [2] (2019). Smart shoes incorporate the concept of gait analysis. The proposed system's smartness includes features such as generating electricity while movement, detecting obstacles, pedometer and tracking the user's location. The Arduino Uno micro controlling board is used to control all the connected components.

The blind shoe based on ultrasonic sensor with a “Light Dependent Resistor” (LDR) has been proposed in the paper by *Shyamal Mandal and Adarsh B. Chandra* [3] (2020). An ultrasonic sensor is used to assist in detection of obstacles on the path and alerting the blind person about the presence of an obstacle near him. The LDRs are added to inform the person, weather he is in dark area and the one will be notified of the danger.

The proposed system consists of combination of three ultrasonic sensor systems and an infrared sensor (IR) to detect an obstacle using an Arduino microcontroller. The proposed idea uses IR sensing technology to determine a location's depth. In addition to this, piezoelectric sensors as self-power generating tool, where the pressure applied while walking is transferred into electric energy. The paper is presented by *B. Uma Maheshwari et al.* [4] (2020).

Manali Tayadeand et al. [5] (2021) proposed using ultrasonic sensors and a buzzer to alert the end-user of impending obstacles. Sending data via Wi-Fi module, such as footstep count and calories burned, and storing it on the cloud and displaying it to users via the mobile application. This also encourages them to participate in fitness activities and live a healthy lifestyle.

A review of all papers is conducted by *Pradeepa R et al.* [6] (2021) and proposes a solution for blind people's problems using smart shoes. Smart shoes will assist a blind person in moving around independently by using an ultrasonic sensor to detect obstacles. This work discusses various smart shoes for blind technology that make use of the Internet of Things.

A work which develops a smart shoe that can detect and warn blind people of upcoming obstacles in their path, as well as provide information about the exact distance and direction of the obstacle from the user is done by *Divya V Chandran et al.* [7] (2020). The shoe is connected to the user via an Android application, which provides audio output through speakers or headphones. The shoe has ultrasonic sensors that detect obstacles in the path and a step counter that counts the number of steps to the point.

A system that consists of ultrasonic sensors coupled to a servo motor for sensing obstacles in the surrounding environment and covering the greatest possible area with the motor. These are linked to buzzers, which provide information to the user about the nearest object within the range of the location. The goal is to make the user self-sufficient and to protect him or her from potentially fatal obstacles. The system praposed by *Teja Chava et al.* [8] (2021) for visually impaired people consists of smart shoes and a pair of smart glasses.

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Roy Abi Zeid Daou et al. [9] (2020) proposed a system which has four important functionalities: obstacle detection, patient fall detection, wet floor detection, and along with that a android application has been developed. The alerting system is divided into two modules: embedded alarm within the shoes (vibratory circuit and audible sound file) and android application which gives the notification. All the modules are integrated with the hardware components, software components, protocols for communication and required tools for communication among them.

Proposed system consists of a microcontroller, sensor which is ultrasonic sensor, a smart phone for the GPS Module, a vibration motor, and a Zigbee unit. These are intended to provide human detection, object detection, and real-time assistance which was introduced by *Kumara B A et al.* [10]. This ETA (Electronic Travel Aid) is attached to the shoes. When an object comes near the shoes or a person approach, the person gets alerts by vibratory circuit and speakers or through the head phones with a voice command, with the help of a custom phone application. The main criterion here is power supply. The shoes are equipped with a self-power generation unit, so there is no need for a power backup.

III. WORKING PRINCIPLE

The following are some of the important sections of the proposed model:

- Sensors
- Controlling unit
- Output section
- Power supply

Sensors- The proposed system includes ultrasonic sensors, IR sensor, water sensor and fall detection (MPU6050) sensor. The ultrasonic sensors and IR Sensor detects the obstacle present within 50cm. The water sensor detects the slippery floor and water bodies outdoor. The fall detection sensor detects if the person has fallen down.

Power supply- A DC power supply of 9V is used in Smart shoes for supplying power to the sensors and circuits.

Controlling unit- Arduino Uno, Arduino Nano and Node MCU are the controlling units used in this work. Arduino boards are used in this system as they are inexpensive, assembly of the boards are easy and can run on various operating systems. Node MCU is used to build communication with the telegram bot.

Output section- It consist of buzzer, speaker and vibration motor as the output devices in the work. Telegram bot has been created to notify the parent/caretaker about the fall of the visually impaired person.

There are three main modules in this model:

- Object detection
- Water detection
- Fall detection

3.1 Object Detection

As shown in the Fig. 3, three ultrasonic sensors, one IR sensor, one buzzer, one vibrator motor, one speaker and power supply are linked together using an Arduino Uno. In Fig.1, the ultrasonic sensor operates on the principle that it consists of two parts: a transmitter and a receiver. At regular intervals, the ultrasonic sensor sends out sound waves. These travel through the air medium at the speed of sound. If the wave strike on an object, the pulses are reflected back to the receiver as echoes.

An Arduino Uno is typically used to communicate with the ultrasonic sensors. To measuring the distance between the object and the sensor, trigger signals are sent by Arduino to the ultrasonic sensor, which has a duty cycle of 10 microseconds for the sensor in use. When triggered, the ultrasonic sensor produces 8 acoustic wave bursts and the timer starts. The timer stops, when the reflected signal is received. The sensors produce a high pulse with the exact duration as the time difference between the transmitted and received ultrasonic bursts. Arduino converts the time signal into the distance measurement.

To improve system efficiency, three ultrasonic sensors are deployed. If the object is in different directions, the use of a single ultrasonic sensor does not reflect the pulse. As a result, combining three ultrasonic sensors with the Arduino yields the best results. The three sensors operate in a linear fashion but not simultaneously. The first ultrasonic sensor will look for any objects, and if none are found, the second ultrasonic sensor will take over, and so on. The assigned distance is 50cm, so if an object is detected within this range, the buzzer will begin buzzing, vibrator motor vibrates.

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In Fig. 2, An Infrared sensor (IR) is a sensor that emits infrared light to detect objects around it. They operate on the fundamental principle of light reflection. The IR light is emitted by the IR transmitter, and when it hits a surface and bounces back, the photodiode detects the IR Light, letting sensors know there is an object in front of them. Whenever an object appears in front of the sensor, a corresponding voice command is played through the speakers.

Fig. 1: Ultrasonic sensor

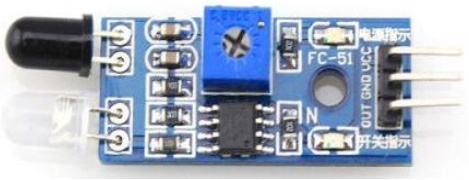

Fig. 2: IR sensor

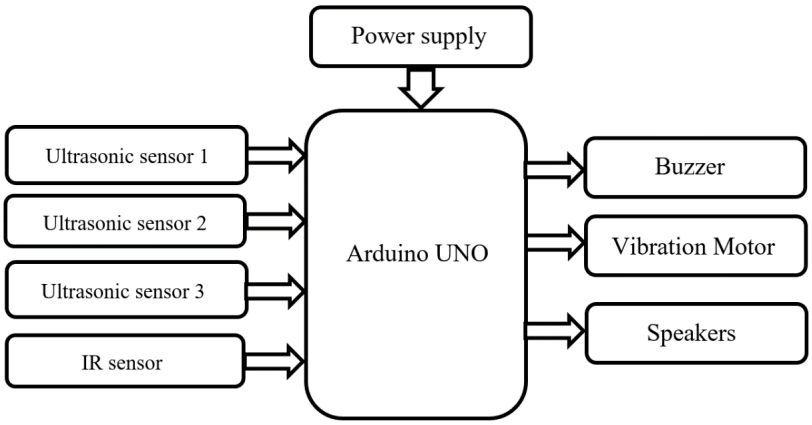

Fig. 3: Obstacle detection block diagram

3.2 Water Detection

As in Fig. 4, presence of water can be detected using the water sensor. Sensor consists of a sequence of ten exposed copper traces, where five of the traces are power traces, while the other five are sense traces. These traces are placed in parallel so that every two power traces have a sense trace in between them. These traces are not connected until they are underwater and until they are united by water. The traces serve as variable resistance, with resistance that fluctuates with water level.

As shown in Fig. 5 whenever the water is detected by the water sensor, the analogy data from the sensor is translated into digital data with the help of Arduino nano microcontroller. The alert is given to the visually impaired with the help of speakers. A preinstalled audio message will be played through the speakers.

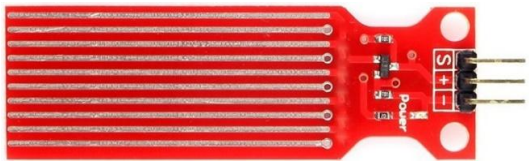

Fig. 4: Water sensor

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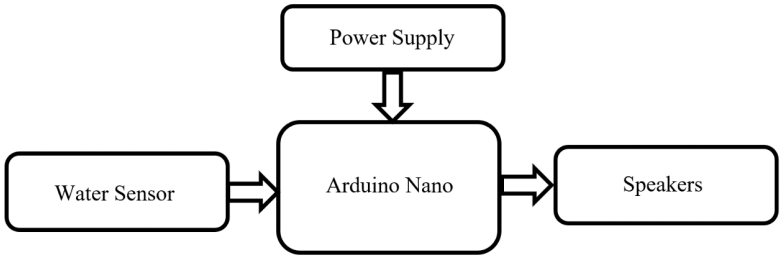

Fig. 5: Water detection block diagram

3.3 Fall Detection

As shown in the Fig. 6, MPU6050 sensor is used to detect the fall. A combination of an accelerometer and gyroscope are included within MPU6050 sensor module. The accelerometer provides information about the angular parameters such as the X, Y, and Z-axis data, while the gyroscope determines the orientation. The comparison between the acceleration magnitude and the threshold value is done to detect a fall. When a fall is detected by the model an alert message is sent to the concerned person with the help of Node MCU microcontroller. The Node MCU ESP8266 is used as a microcontroller and Wi-Fi module in this project to connect with the Telegram bot as shown in Fig. 7.

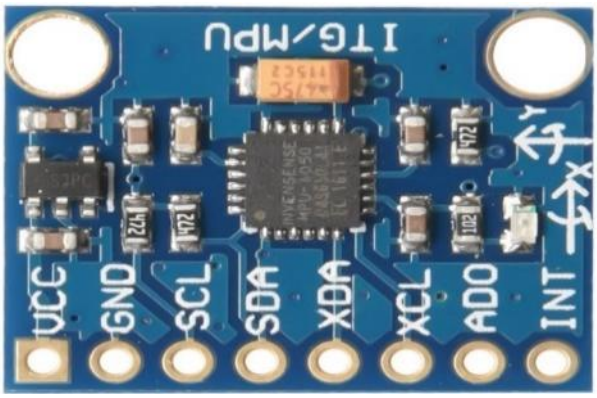

Fig. 6: MPU6050 sensor

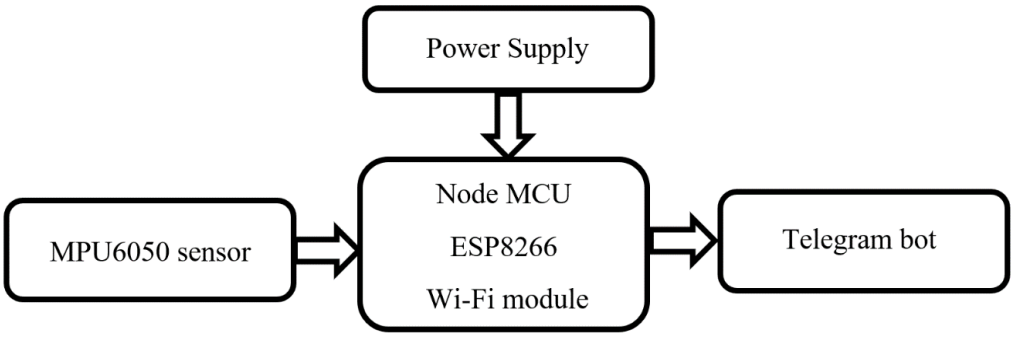

Fig. 7: Fall detection block diagram

IV. RESULTS

As shown in the Fig. 8, all the sensors are placed inside the shoes. One ultrasonic sensor and the IR sensor is place at the front and corresponding two ultrasonic sensors are placed at right side and the back side of the shoes. Speakers, vibrators and buzzers are also placed within the shoes. The proposed model gets power supply by the 9V battery.

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Fig. 8: Overall implemented system in the shoes

Fig. 9: Fall message in Telegram bot

The MPU6050 sensor is placed in another shoe for fall detection and the controlling unit is Node MCU. Node MCU is an open-source Lua-based firmware and development board which is mainly designed for Internet of Things (IoT) applications. It comprises firmware based on the ESP8266 Wi-Fi SoC from Espressif Systems, as well as hardware based on the ESP-12 module. Whenever fall has been detected, an alert message is sent to the Telegram Bot of the corresponding parent or caretaker through the internet as shown in the Fig. 9. The shoes should be connected to the internet always. The speed of the message sent to the parent or caretaker is depended on the internet speed.

V. CONCLUSION

The proposed work is a solution which is based on embedded system that combines hardware and software to provide a technical aid. This technology is used for blind and people with visual impairment for obstacle detection, slippery floors and detects the fall of the person and send an alert message to the concerned person. Finally, it was able to create a low-cost, standalone, and electrically safe smart shoes for people with visual impairment and for blind which give assistant in the event of falls and prevents unwanted collisions. Furthermore, testing this prototype on a larger population to identify all system issues in order to improve performance in future versions is of great interest.

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