An Intelligent Haptic-Audio Guidance System for Enhancing Mobility of Disabled Users

Dr. S. Rama Devi
Assistant professor,
Dept of Electronics and Communication Engineering
Andhra University College of Engineering for Women

B. Meghana, B. Vindya, G. Bhavani Devi
Final Year, B. Tech,
Dept of Electronics and Communication Engineering
Andhra University College of Engineering for Women

ABSTRACT

Visually impaired individuals face significant challenges in navigating unfamiliar environments due to their inability to detect nearby obstacles. To address this issue, we propose a Smart Stick, an affordable and effective assistive mobility device aimed at enhancing the independence and safety of blind users. The device utilizes ultrasonic sensors to continuously monitor the path ahead, and upon detecting obstacles, it activates a vibration motor to provide haptic feedback, allowing the user to take appropriate precautions. In addition to aiding navigation, the Smart Stick is equipped with an SOS emergency button a crucial feature for speech-impaired users. When pressed, it triggers a speaker feedback as an "Emergency help" audio message, allowing users to signal distress and seek help in critical situations. The core of the system is an Arduino Uno microcontroller that processes sensor data and coordinates the vibration and audio outputs in real time. The device is lightweight, power-efficient, and ergonomically designed for user comfort and long-term battery usage. By integrating tactile and auditory feedback along with an emergency communication feature, the Smart Stick significantly improves mobility, safety, and quality of life for users with visual, hearing and speech impairments.

Keywords: Arduino Uno, Ultrasonic Sensors, Vibration Motor, Assistive Device, Obstacle Detection, Mobility Aid, Visually Impaired, Smart Stick.

INTRODUCTION

For visually impaired people, it is a daily struggle to travel around safely and independently. Identifying objects, sensing obstacles, and spotting hazards such as staircases and manholes call for vigilance at all times, which proves to be a challenge without the aid of someone. Without assistance, visually impaired people mostly depend on caregivers or guiding canes to travel around, which does not allow them to be independent [1]. To solve this problem, we suggest a Smart Stick, an easy-to-use and trustworthy aid device that promotes mobility and safety. The Smart Stick [2] is a device that enables visually impaired people to move confidently minimizing their reliance on others and reducing the risks of daily movement.

The Smart Stick is constructed from an Arduino Uno and ultrasonic sensors to sense obstacles in real time [3]. The ultrasonic sensors constantly scan the environment and detect objects in the user's way, giving immediate feedback. One of the most important aspects of the Smart Stick is its dual alert system, which provides users with warnings in a manner that is convenient for them. The first type of alert is voice guidance, where a built-in speaker gives clear voice warnings when an object is detected. This assists blind users in knowing what is happening around them without touching them [4].

The second alert mode is vibration feedback, which is important for both deaf and blind users. There is a vibration motor built into the stick that generates certain vibration patterns to send alerts about nearby objects. This allows deaf-blind users to feel alerts through touch, making it possible for them to move safely [5].

To enhance the safety and usability of the Smart Stick further, an SOS button is incorporated into the device. In emergency situations, the user can use this button to send an alert, informing people around them that they need help. This is particularly helpful in scenarios where the user can be lost, hurt, or in trouble, offering an easy method of calling for help. Furthermore, the stick is made lightweight and user-friendly so it can be easily held and carried around for long periods. It is also powered with low power consumption, so the battery lasts longer and the device can run constantly throughout the day [6].

Through the use of affordable and efficient technology, the Smart Stick provides a practical solution for visually impaired users. It enables them to move around freely, confidently, and safely without requiring constant external support. This tool not only increases their capacity to move around the world but also encourages more independence and self-reliance. As technology advances, there is the potential to make further adjustments to incorporate more smart features, making the Smart Stick even smarter and more Efficient.

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HARDWARE COMPONENTS:

1.ULTRASONIC SENSOR:

FIGURE 1. Ultrasonic sensor module HC-SR04

Ultrasonic sensors are the core of the Smart Stick, which allows blind people to walk safely. The sensors assist in detecting obstacles, staircases, and open areas such as manholes, keeping the user away from possible hazards while walking.
How Do Ultrasonic Sensors Work?
Imagine ultrasonic sensors as a bat's echolocation system. Like bats, which emit sound waves and hear the echo to determine their environment, ultrasonic sensors work in a similar way.
Here's the process:
There is a transmitter in the sensor that emits high-frequency sound waves (which are inaudible to humans).
The waves propagate in the air until they reach an object and rebound.
A sensor receiver detects the reflected waves and times how long it takes for them to come back.
Based on this time, the system determines the distance to the object.
This powerful yet easy technology enables the Smart Stick to "see" around it and alert the user in real-time.
How Does the Smart Stick Utilize These Sensors?
Smart Stick ultrasonic sensors are used for several things:
1.Detecting Obstacles:
If there's an object in the way (like a wall, pole, or person), the sensor detects it and sends a warning. The stick then vibrates and plays a voice alert, so the user knows something is ahead.
2.Staircase Recognition:
It is difficult for an individual who cannot see staircases to walk up or down them. The sensor detects the direction of a staircase as up or down and informs the user accordingly.
3.Manhole & Open Space Detection:
When the sensor cannot find a surface near within a predefined range (such as more than 45 cm), it takes this to mean that there must be an open gap – maybe a manhole or open pit. Under these circumstances, an alarm for emergency notification is initiated to inform the user.
Why we Use Ultrasonic Sensors?
1. No Fuss with Darkness or Sunlight: Contrary to cameras or human eyesight, ultrasonic sensors are not affected by lack of light or even very strong sunlight.
2. No Physical Contact Required: The user doesn't need to touch anything to sense an obstacle – the sensor does it all.
3. Fast Response Time: The system senses objects in real-time, so the user is alerted before they reach proximity to danger.
Energy Efficient & Cost-Effective: These sensors consume very little power, so they are convenient for everyday use without needing constant recharging.

Final Thoughts
Ultrasonic sensors are what make the Smart Stick so beneficial for the visually impaired. By assisting in the detection of obstacles, staircases, and open spaces, they enable users to navigate safely and independently. With rapid warnings and minimal design, this technology can have a great impact on an individual's day-to-day life.

2.ARDUINO UNO MICROCONTROLLER

FIGURE 2: Arduino Uno (ATmega328 Microcontroller)

The Arduino Uno is a popular, budget-friendly, and easy-to-use open-source microcontroller board that's great for all kinds of electronic projects. It's highly versatile — you can connect it with other Arduino boards, Arduino shields, or even a Raspberry Pi. It can control various output devices like LEDs, motors, servos, and relays, making it suitable for hobbyists, students, and professionals alike.
At the heart of the Arduino Uno is the ATmega328 microcontroller. The board connects to a computer through a USB cable, and you can program it using the Arduino IDE (Integrated Development Environment). It comes with 32KB of flash memory for storing programs, 2KB of SRAM, and 1KB of EEPROM for additional storage.
The board runs at a working voltage of 5V, meaning both the microcontroller and its components operate at 5 volts. However, it can handle a supply voltage between 6V and 20V, though the recommended input range is between 7V and 12V for stable performance.

Key Features:
Input Voltage Range: 7V to 12V (Recommended)
14 Digital Input/Output Pins (6 of them support PWM)
6 Analog Input Pins
32KB Flash Memory
16 MHz Clock Speed

FIGURE 3: ARDUINO UNO PIN DIAGRAM

IN THIS PAPER WE PROPOSED AN ASSISTIVE DEVICE FOR BLIND, DEAF, AND DUMB INDIVIDUALS, WE USE AN ARDUINO AS THE CENTRAL PROCESSING UNIT. THE ARDUINO MICROCONTROLLER IS RESPONSIBLE FOR OBSTACLE DETECTION READS DATA FROM THE FRONT ULTRASONIC SENSOR .IF AN OBSTACLE IS DETECTED, IT GIVES AN ALERT THROUGH THE SPEAKER TO SAY "FRONT WARNING " AND ACTIVATES THE VIBRATOR (ONE BEAT).STAIRCASE AND MANHOLE DETECTION ,READS DATA FROM THE DOWNWARD-FACING ULTRASONIC SENSOR .IF A STAIRCASE OR MANHOLE IS DETECTED, IT TRIGGERS THE VIBRATOR (TWO BEATS) AND, FOR BLIND INDIVIDUALS, PLAYS A WARNING SOUND THROUGH THE BUZZER/SPEAKER. SOS BUTTON FUNCTIONALITY. WHEN PRESSED, THE ARDUINO COMMANDS THE SPEAKER TO SAY "EMERGENCY HELP". ACTIVATES THE VIBRATOR BASED ON DETECTED OBSTACLES. CONTROLS THE BUZZER AND SPEAKER TO PROVIDE AUDITORY ALERTS. REAL-TIME DECISION-MAKING , THE ARDUINO CONTINUOUSLY MONITORS SENSOR INPUTS AND MAKES DECISIONS INSTANTLY TO ASSIST THE USER.

3.VIBRATION MOTOR

FIGURE 4: Vibration Motor Coin Type Micro Disc

A coin-type vibration motor is a compact, flat-shaped actuator designed to generate vibrations for haptic feedback applications. These motors are commonly used in electronic devices such as mobile phones, smartwatches, and assistive devices for visually or hearing-impaired individuals.

Working Principle

The motor operates using an eccentric rotating mass (ERM) mechanism, where an off-centre weight attached to the motor shaft rotates at high speed. This motion generates vibrations, providing tactile feedback to the user. Coin-type vibration motors are typically driven by DC power and controlled through pulse-width modulation (PWM) to vary the intensity of the vibration.

Applications in Assistive Devices

In devices designed for blind, deaf, or mute individuals, coin-type vibration motors play a crucial role in alerting users to environmental changes. For instance:

- Obstacle Detection: The motor vibrates when an ultrasonic sensor detects nearby objects.
- Manhole & Staircase Detection: Different vibration patterns can indicate whether a detected surface is a staircase or a manhole.
- Navigation Assistance: Vibrations can guide users toward a safe path by providing directional feedback.

Advantages

- Compact & Lightweight: Ideal for wearable and portable applications.
- Low Power Consumption: Efficient for battery-powered devices.
- Silent Operation: Provides discreet alerts without sound.

By integrating coin-type vibration motors into assistive technology, users can receive non-visual, non-auditory feedback, enhancing accessibility and safety in everyday navigation.

4.SPEAKER

FIGURE 5: Small Mini Speaker

Features:
Power Rating: 0.5 Watts
Impedance: 7ohm
Diameter: 65 mm
Width: 6.5 cm
Subwoofer Diameter: 2.5 inches
Sound Channel Configuration: 2.1 Channel
Channel Type: Stereo

small mini speaker with a power rating of 0.5 watts and an impedance of 8 ohms is a compact and efficient audio component used in various electronic applications. It is commonly found in devices that require clear but low-power sound output, such as assistive technologies, alarms, voice-based systems, and embedded projects. Due to its small size, it is ideal for space-constrained designs while still delivering adequate sound for voice prompts, notifications, and alerts. These speakers are often used with microcontrollers and may need an amplifier for better sound quality, especially when powered by low-voltage circuits. Their lightweight and durable construction makes them a popular choice for portable and battery-operated devices, ensuring reliable performance in everyday applications.

5.PUSH BUTTON MODULE

FIGURE 6: Push Button Module

The push button module is a compact and highly responsive switch used for detecting user input. It features a 3-pin interface with a straightforward design, ensuring stable and reliable performance. Due to its lightweight structure and easy integration, it is widely used in DIY projects, embedded systems, and automation applications.

Specifications and Features:

- Operating Voltage: 5V DC
- Contact Resistance: ≤50 MΩ
- Operating Temperature Range: -25°C to 105°C
- Lifespan: ~100,000 cycles
- Compact and Lightweight
- Easy to Install and Use
- Stable and Durable Performance

Other additional hardware components are mentioned below Bread board, battery power supply, jumper cables, transistor for amplification of speaker.

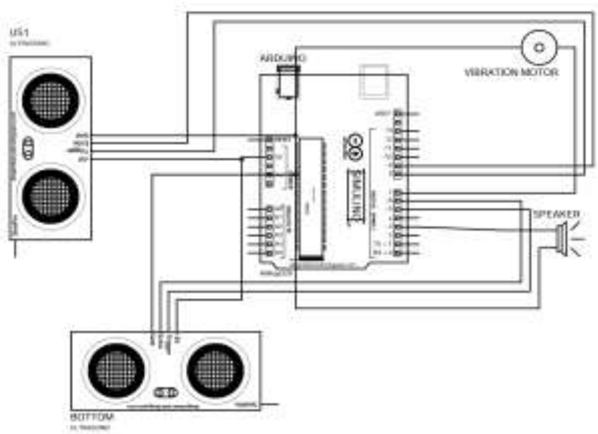

FIGURE 7: Schematic diagram

Our project centres on creating an assistive device for blind, deaf, and mute people. The device has two ultrasonic sensors, which have different functions. one sensor detects obstacles in front of the user to ensure safe navigation, while the other detects staircases and open manholes. When it senses an obstacle, staircase, or manhole, the device gives feedback through multiple alert means.

Arduino pins used	Connected device pin
D3	Speaker pin
D4	Vibration motor pin
D5	Trigger pin of Bottom sensor
D6	Echo pin of Bottom sensor
D7	SOS button pin
D8	Trigger pin of Front sensor
D9	Echo pin of Front sensor
D13	Buzzer pin
5V	Common +5v to all devices
GND	Common Ground (-) to all devices

Table 1: Arduino connections with pins

A vibration motor is employed for alerts to hearing and speech-disabled people, and a speaker and buzzer produce auditory warnings for visually disabled users. This multi-sensory method provides accessibility and increased user safety.

Staircase identification

In order to identify the staircase, here in this paper we have designed a technique on the basis of threshold value. The design of the recognition system is shown in the figure 5. From this technique we can identify the down staircase and the up staircase. In order to do this, we use the downward ultrasonic sensor that creates the sound waves from its transmitter and receives the echo when the transmitted signal rebounds off the surface. Now the distance travelled by the signal is calculated by the internal code, processed by the microcontroller using the sensor from the formula,

Distance=(Speed*time)/2

First, we divide the value of distance by 2 since it is a sum of receiver and transmitter signal distances. Next from the distance, we estimate up and down the staircase using the threshold values.

Estimation of threshold:

Since users do not necessarily keep the stick at a constant height, we provide a threshold distance for staircase detection that considers differences in user handling. If the measured distance goes beyond this predetermined limit, the system labels the surface as a staircase; otherwise, as plain ground. When a staircase is detected, the device notifies the user using vibrations, allowing them to proceed safely.

Identification of Manhole:

In order to differentiate manholes from other surfaces, we have set a threshold distance. When the ultrasonic sensor receives a reflected signal with a depth of more than 45 cm and fails to detect a parallel surface in the same range—like the steps of a staircase—the system classifies the area detected as a manhole. On detection, the corresponding alert mechanism is activated, allowing the user to take precautions. By incorporating these features, our assistive device can aid in improving mobility and independence for the handicapped, minimizing the hazards encountered when navigating daily routines.

Front Obstacle Detection:

In order to help the users sense the objects in front, our device uses an ultrasonic sensor that sweeps the surroundings constantly by rotating the stick in the direction the user wants to move. The system approximates the distance to the object based on the time taken for the signal to bounce back.

When the measured distance is less than 75 cm, the device detects it as an obstacle and warns the user immediately. When it comes to blind individuals, a buzzer and speaker give an audio warning, while when it comes to deaf and mute individuals, a vibration motor is utilized to send feedback. This assists users in responding within time and avoiding accidents, rendering travel easy and safe.

Status	Threshold value(cm)
Down staircase	Greater than 45
UP staircase	Less than 25
Obstacle	Less than 75
Manhole	Greater than 50

Table 2: Threshold values

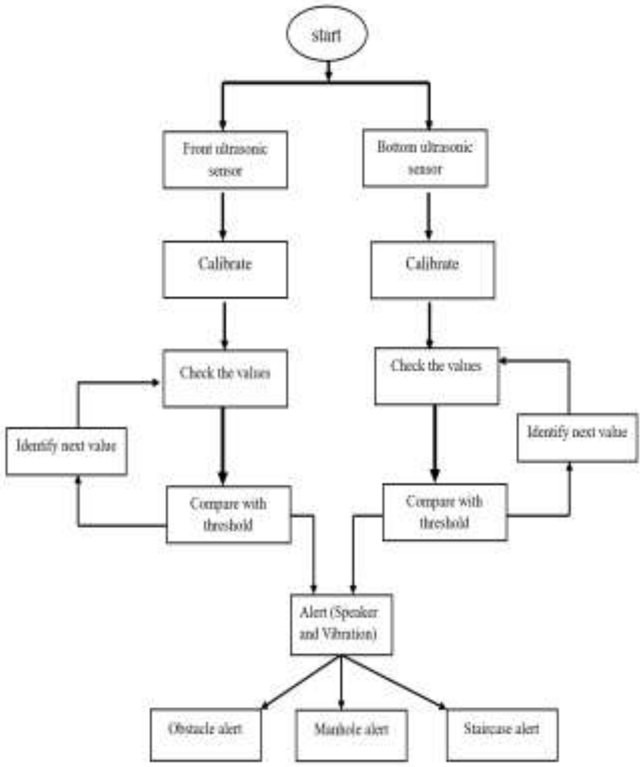

FIGURE 8: Flowchart

RESULTS AND DISCUSSION

The assistive device successfully integrates ultrasonic sensors, a vibrator motor, and an speaker(audio) output system to help blind, deaf, and dumb individuals. The system was tested under various real-world conditions to evaluate its effectiveness.

Obstacle Detection: The front ultrasonic sensor accurately detects obstacles and triggers the speaker to announce "Front Warning", while the vibrator provides a single beat for tactile feedback.

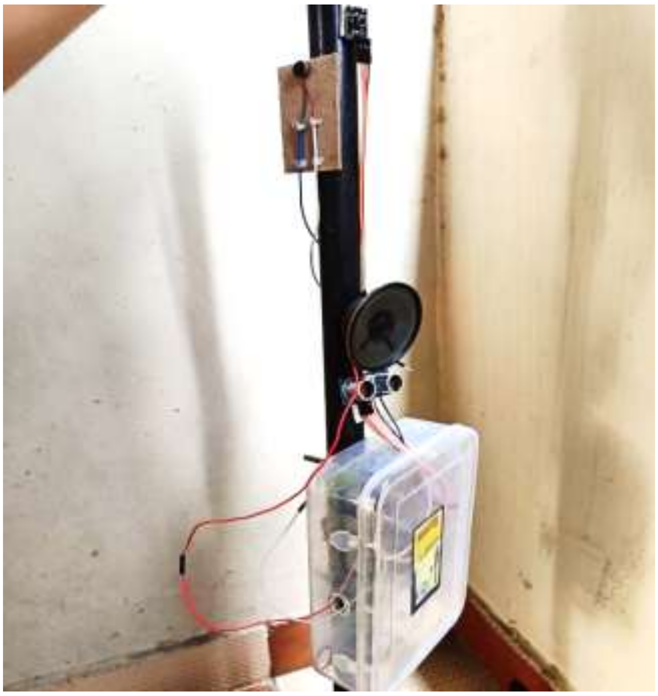

FIGURE 9: Front obstacle detection

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SERIAL MONITOR OUTPUT :

FIGURE 10: Front and bottom distance readings(in cm) and SOS activation.

FIGURE 11: Manhole detection

FIGURE 12: Staircase detection

Tactile and Audio Feedback: The combination of vibration and voice alerts ensures accessibility for all three disabled groups. Reliability and Performance: Testing demonstrated consistent accuracy in detecting obstacles and staircases, making it a practical solution for enhancing mobility.

The results indicate that the device significantly improves safety and awareness for visually and hearing-impaired individuals. Future enhancements could include AI-based object recognition for advanced guidance

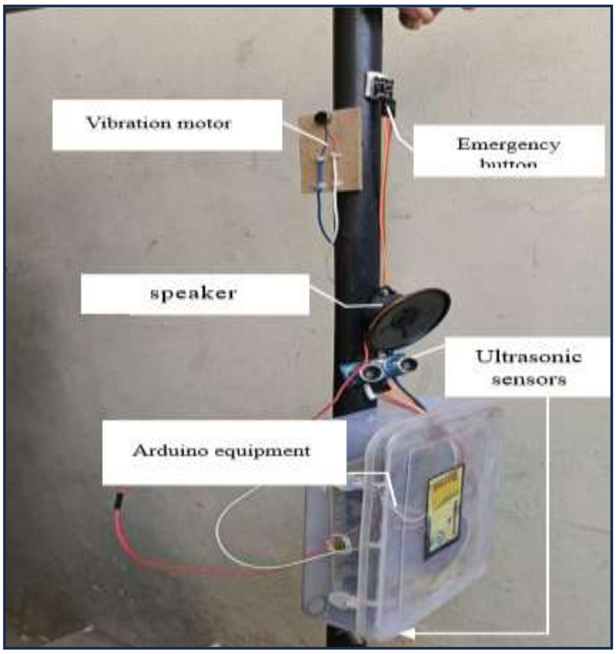

FIGURE 13: Proposed device with complete equipment

Conclusion:

Our assistive device is a step towards creating a more inclusive world for individuals who are blind, mute, and deaf. By combining ultrasonic sensors with smart detection techniques, it ensures real-time identification of obstacles, staircases, and open manholes, allowing users to navigate safely. The device provides immediate alerts through vibrations, buzzers, and speakers, enabling quick responses to potential dangers. Additionally, the SOS button serves as an essential safety feature, allowing users to call for help when needed.

Beyond functionality, this device is designed to be cost-effective, reliable, and easy to use, ensuring that assistive technology remains accessible to a larger population. By enhancing mobility and personal security, it empowers differently-abled individuals to move with greater confidence and independence. Our goal is not just to provide assistance but to offer a sense of freedom and control over one's surroundings. With continuous advancements, this device has the potential to become a vital companion in the daily lives of those with sensory impairments.

GPS Integration for Navigation Assistance: Incorporating GPS technology would be a major step forward in helping users navigate unfamiliar environments. By integrating GPS with voice or haptic feedback, the device could guide users through streets, buildings, and public spaces. Advanced features such as real-time route planning, landmark recognition, and emergency location sharing could further enhance independence. Additionally, AI-driven navigation assistance could provide alternative routes based on obstacles detected in real time, ensuring a seamless and safe experience.

By focusing on these advancements, the assistive device can evolve into a more intelligent and versatile tool, making life even more accessible and empowering for individuals with visual, speech, and hearing impairments.

Future Scope

Advanced Sensing Technology: While ultrasonic sensors provide reliable obstacle detection, upgrading to LiDAR technology can significantly improve accuracy and range. Unlike ultrasonic sensors, which may struggle with certain surfaces or complex environments, LiDAR uses laser-based detection to map surroundings in greater detail. This would allow for better differentiation between objects, more precise.

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