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Smart Assistive Stick: Merging Technology and Accessibility

Audrija Banerjee[1], Arkadeep Bhowal[2], Rupam Pal[3], Subhadeep Bera[4], Arpita Santra[5]

[1,2,3,4]Department of Electronics and Communication Engineering, Narula Institute of Technology , Nilgunj Road, Agarpara, Kolkata-700109 {Corresponding author's email: rupampal2082003@gmail.com}

[5] Assistant Professor, Department of Electronics and Communication Engineering, Narula Institute of Technology , Nilgunj Road, Agarpara, Kolkata-700109 {Corresponding author's email: arpita.santra@nit.ac.in}

Abstract:

The Smart ***Blind Stick*** is an intelligent assistive device designed to support visually impaired individuals in navigating their surroundings safely and independently. Unlike traditional walking sticks, this system integrates advanced technologies such as ultrasonic sensors to detect obstacles within a specified range and height. Upon detecting an obstacle, the stick provides immediate feedback to the user through vibration or audio alerts, enabling timely response and safer movement.

In addition to obstacle detection, the device can incorporate features like a GPS module for location tracking, a moisture sensor to detect puddle, and an emergency alert system to notify for upcoming obstacles. Designed to be lightweight, portable, and energy-efficient, the Smart Blind Stick aims to improve the quality of life for visually impaired users by enhancing mobility, reducing the risk of accidents, and offering additional safety functionalities.

This project presents a low-cost, practical, and user-friendly solution that leverages simple yet effective technology to address the daily challenges faced by visually impaired individuals.

Keywords: assistive technology; obstacle detection; ultrasonic sensor; smart cane; GPS tracking; fall detection; embedded system

Introduction

The ***Smart Blind Stick*** [1] is a technologically advanced mobility aid designed to assist visually impaired users in safely navigating their surroundings. By incorporating sensors such as ultrasonic modules, the stick can detect obstacles in the user's path and provide timely feedback[2] through audio alerts. This enables the user to avoid potential hazards before physical contact occurs.

In addition to obstacle detection, the smart stick can be equipped with supplementary features like a GPS module for real-time location tracking, an emergency alert system[3], and puddle detection. These enhancements not only improve the user's mobility but also contribute to their overall safety and independence.

The primary objective of this project is to develop a cost-effective, portable, and reliable device that can significantly improve the quality of life for visually impaired individuals[4]. By leveraging simple, affordable components and intuitive feedback systems, the *Smart Blind Stick* offers a practical solution to a critical daily challenge faced by millions around the world.

PROPOSED MODEL

The proposed system is a Smart Blind Stick designed to enhance the mobility and safety of visually impaired individuals by integrating multiple sensors[5] and communication technologies into a compact, user-friendly device.

HARDWARE INTERFACE:

1. Obstacle Detection

- Three ultrasonic sensors are mounted at different heights on the stick:
  - **Lower Sensor** to detect ground-level obstacles (e.g., curbs, steps).
  - **Middle Sensor** to detect mid-level obstacles (e.g., furniture, walls).
  - **Upper Sensor** to detect head-level obstacles (e.g., tree branches, signboards).
- These sensors continuously scan the environment and measure the distance to nearby obstacles.

2. Puddle Detection

- A **moisture sensor** is attached near the tip of the stick to detect puddles or wet surfaces.

- On detecting water, the system alerts the user immediately to prevent slipping accidents.

3. User Feedback Mechanism

- Based on sensor inputs, the system triggers **buzzers**:
  - Different buzzers or vibration patterns indicate the type and proximity of detected obstacles.
  - A specific alert pattern is used if puddles are detected.

4. Accident and Fall Detection

- A **gyroscope sensor** monitors the stick's orientation and detects sudden changes or impacts.
- In case of a suspected fall or accident, the system automatically initiates an emergency protocol.

5. Emergency Alert and Location Sharing

- Upon detecting an accident:
- The system sends an **email alert** to the user's guardian or emergency contact.
- A **GPS module** retrieves the real-time location and attaches it to the alert message.
- This ensures that immediate assistance can be provided to the user.

6. Overall System Integration

- All sensors and modules are controlled by a microcontroller (e.g., Arduino, ESP32).
- The device is powered by a rechargeable battery, ensuring portability and continuous operation.
- The design ensures the stick remains lightweight, ergonomic, and easy to use.

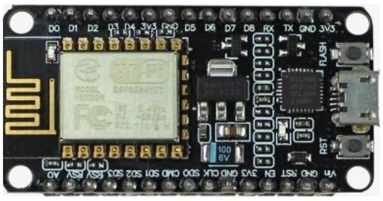
SOFTWARE INTERFACE:

- **ArduinoIDE** – The Arduino Software (IDE) makes it easy to write code and upload it to the board offline.

COMPONENTS REQUIRED

NodeMCU ESP8266 – It refers to a low-cost open-source IoT (Internet of Things) development platform based on the ESP8266 Wi-Fi module.

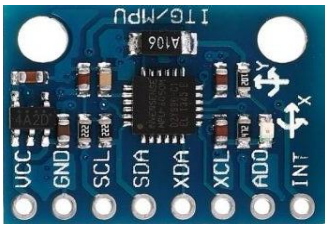
- NodeMCU: Stands for "Node MicroController Unit". It's a development board and a firmware based on the Lua scripting language.
- ESP8266: A popular Wi-Fi SoC (System on Chip) developed by Espressif Systems, offering Wi-Fi capability and modest processing power.
- Development Board: The NodeMCU board includes the ESP8266 chip (typically ESP-12E or ESP-12F module), a USB-to-serial converter (like CP2102 or CH340G), voltage regulators, and easy-to-use pins (GPIOs) for connection with sensors, actuators, etc.



Gyroscope - MPU6050 – It is a very popular, low-cost **6-axis** (3-axis gyroscope + 3-axis accelerometer) MEMS (Micro-Electro-Mechanical Systems) sensor module. It's commonly used in electronics projects with boards like the **NodeMCU ESP8266**.

MPU6050 Basics

- Accelerometer: Measures acceleration in 3 axes (X, Y, Z).
- Gyroscope: Measures angular velocity (rotation) in 3 axes.
- Communication: Uses I2C (Inter-Integrated Circuit) protocol to communicate with microcontrollers (like ESP8266, Arduino, Raspberry Pi).
- Built-in Processor: It has a Digital Motion Processor (DMP) that can do complex calculations like sensor fusion (combining gyro and accel data) internally.
- Voltage: 3.3V–5V tolerant (but safer to use 3.3V with ESP8266).



GPS MODULE - GY - GPS6MV2 - It is a small GPS module based on the **NEO-6M** chip that provides real-time location data like latitude, longitude, and speed. It communicates using UART (serial) and works easily with microcontrollers like the **NodeMCU ESP8266**, making it ideal for GPS tracking and navigation projects.

- Core Chip: NEO-6M GPS receiver by u-blox (a Swiss company specialized in positioning and wireless communication).
- Main Purpose: It receives signals from GPS satellites to determine its geographic location (latitude, longitude, altitude, speed, time, etc.).
- Update Rate: 1Hz default (1 location update per second), but can be increased up to 5Hz.
- Antenna: Comes with a small ceramic patch antenna. Some versions have a socket for an external active antenna (via U.FL connector).
- Communication Protocol: UART Serial (TX and RX pins).

Ultrasonic Sensor HC-SR04 - The **HC-SR04** is a low-cost ultrasonic distance sensor that measures the distance to an object by sending out sound waves and measuring the time it takes for the echo to return. It's widely used with microcontrollers like the **NodeMCU ESP8266** for obstacle detection, distance measurement, and robotics projects.

- VCC: Power supply (5V or 3.3V, but 5V is preferred).
- GND: Ground.
- Trig (Trigger): Sends a pulse to trigger the ultrasonic burst.
- Echo: Receives the reflected pulse and measures the time delay.

ESP32 c3 Super Mini – It is a compact development board based on the ESP32-C3 chip by Espressif. This chip is part of the ESP32 family but uses a RISC-V architecture, making it an energy-efficient, cost-effective, and powerful option for a variety of projects. The ESP32-C3 features both Wi-Fi and Bluetooth 5.0 (BLE) capabilities, making it suitable for IoT and wireless applications.

Moisture Sensor – It is used to measure the soil moisture content, making it very useful for automated irrigation systems and plant monitoring projects. These sensors typically consist of two parts: a probe that gets inserted into the soil, and a circuit that detects the resistance (or capacitive changes) in the soil, which correlates to its moisture level.

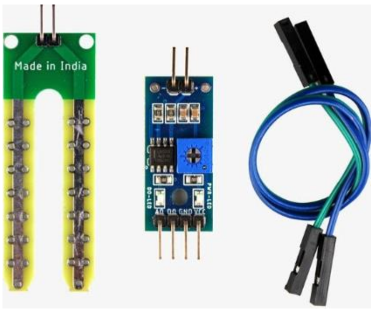
Common Moisture Sensor: YL-69 / FC-28

This is a resistive type sensor commonly used in hobby projects. It includes two parts:

- Sensor Probe: The part that you insert into the soil.
- Control Board: The part that interfaces with your microcontroller (like ESP32 or Arduino).

Pinout for YL-69/FC-28 Moisture Sensor:

- VCC: Power supply (typically 5V or 3.3V).
- GND: Ground.
- A0: Analog output pin (gives a variable voltage based on moisture level).
- D0: Digital output pin (high/low signal indicating if moisture is below a threshold).



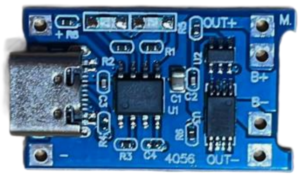
Buzzer – It A **buzzer** is a small electronic component that produces sound when voltage is applied. It's used for alarms, notifications, or simple sound signals in electronic projects.

There are **two main types**:

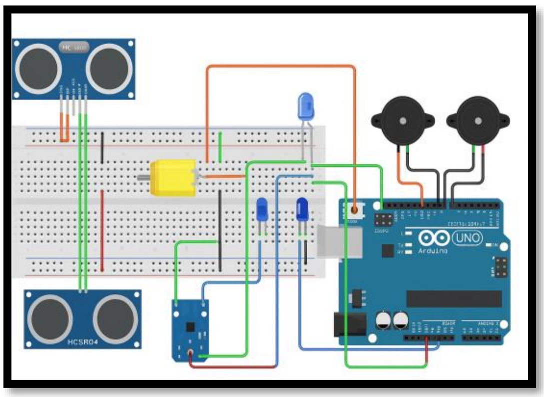
- **Active Buzzer**:
  - Has a built-in oscillator.
  - It sounds as soon as you apply voltage (easy to use).
  - Only needs **HIGH** or **LOW** signals.

- **Passive Buzzer**:
  - No internal oscillator.
  - You must send it a tone (like using tone() function in Arduino).
  - You can play different pitches and notes.

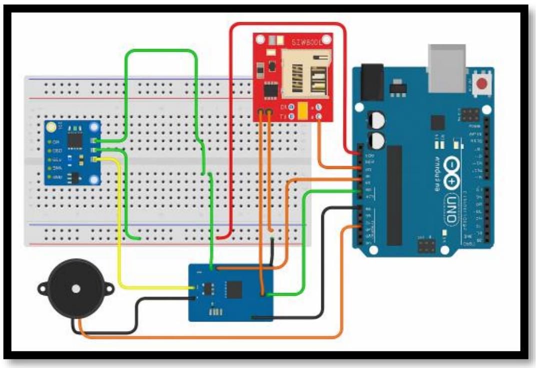
Charging Module TP4056 – It is a small, cheap lithium-ion (Li-Ion) / lithium-polymer (Li-Po) battery charging module. It's mainly used to safely charge single-cell 3.7V batteries (like 18650 cells) from a 5V power source (USB or another 5V input). It has overcharge, over-discharge, and short-circuit protection (in some versions with protection ICs like DW01A).



CIRCUIT DIAGRAM

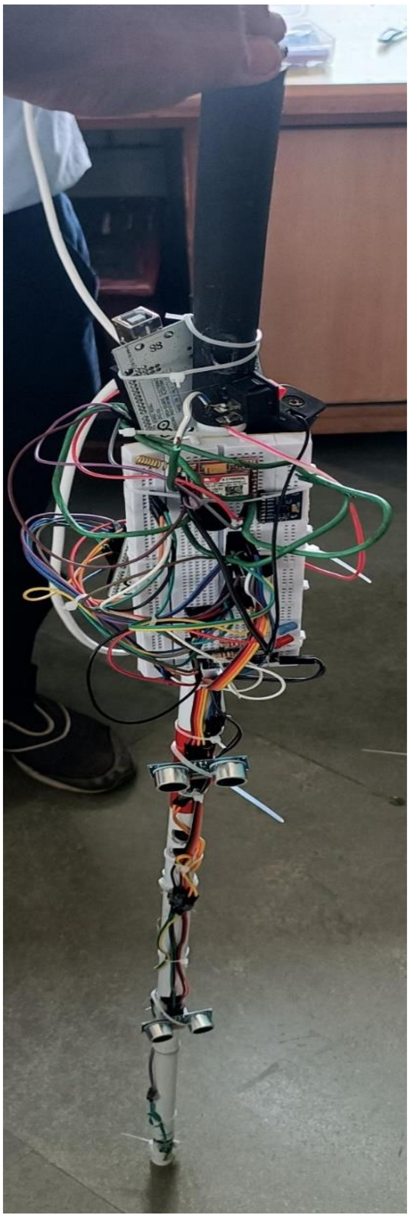


OBSTACLE DETECTION



EMERGENCY ALERT SENDING

PHYSICAL CIRCUIT DIAGRAM



Methodology

The Smart Blind Stick is designed by systematically integrating hardware components with embedded software programming to enhance the mobility and safety of visually impaired users. The methodology is divided into hardware development, software development, and system integration as described below:

1. Hardware Setup

- The heart of the system is the ESP32-C3 Super Mini microcontroller, which collects sensor data and controls outputs.
- Three HC-SR04 Ultrasonic Sensors are mounted at different heights on the stick to detect obstacles at ground, waist, and head levels.
- An MPU6050 Gyroscope Sensor is installed to detect sudden orientation changes, indicating a fall or accident.
- A Moisture Sensor is fixed at the lower part of the stick to detect puddles or wet surfaces on the path.
- A GY-GPS6MV2 GPS Module is used to fetch the real-time location of the user.
- A Buzzer is connected to alert the user immediately when an obstacle, puddle, or accident is detected.
- A TP4056 Charging Module is added to manage safe charging of the rechargeable battery powering the stick.

2. Software Development

- Arduino IDE is used for coding, compiling, and uploading the program to the ESP32-C3.
- Sensor libraries like Wire.h (for MPU6050), NewPing.h (for Ultrasonic Sensors), and TinyGPS++ (for GPS Module) are used.
- The program logic includes:
  - Measuring distance from each ultrasonic sensor.
  - Detecting water presence from the moisture sensor.
  - Monitoring acceleration and orientation using the gyroscope.
  - Triggering the buzzer based on sensor inputs.
  - Sending an automatic email (using Wi-Fi capabilities of ESP32-C3) with location details when a fall is detected.

3. Working Process

- The stick continuously scans the environment through the three ultrasonic sensors.
- When an obstacle is detected at a specific height, a buzzer sound alerts the user accordingly.
- If a puddle is detected, a different buzzer pattern alerts the user.
- The gyroscope constantly monitors for unusual tilts or free falls.
- Upon detecting a fall, the ESP32-C3 fetches the user's location via the GPS module and sends an emergency email to the guardian.
- All components are powered by a rechargeable battery managed by the TP4056 module, ensuring efficient energy use.

4. System Integration and Testing

- After assembling the hardware and uploading the program, the system is tested:
  - For obstacle detection accuracy at different heights.
  - For reliable puddle detection.
  - For proper fall detection and automatic emergency notification.
  - For GPS location accuracy during emergency alerts.

APPLICATIONS

The Smart Blind Stick, with its integrated sensors and communication system, can be applied in multiple real-life scenarios to assist visually impaired individuals and enhance their safety. The key applications include:

1. Mobility Assistance for the Visually Impaired

- Helps users detect obstacles at ground, mid, and head levels to safely navigate different environments (streets, homes, public spaces).
- Provides real-time feedback through buzzers, improving confidence while moving independently.

2. Puddle and Wet Surface Detection

- Alerts users about puddles, wet floors, or slippery surfaces, preventing accidents such as slipping or falling.
- Very useful in rainy weather or in areas prone to water spills.

3. Accident and Fall Detection

- Detects sudden falls or unusual movements and immediately triggers an emergency alert.
- Enhances user safety by ensuring rapid response from guardians or caregivers after an accident.

4. Emergency Communication and Location Tracking

- Sends automatic email alerts along with the user's real-time GPS location to guardians in case of accidents.
- Useful in ensuring timely help, especially if the user is alone and unable to call for assistance.

5. Navigation Aid in Unknown Environments

- Helps users confidently move through unfamiliar places by detecting unexpected obstacles or hazards that a traditional cane might miss.

6. Use in Elderly Care

- Apart from visually impaired individuals, the smart stick can also be adapted for elderly people who are at risk of falling, offering an additional layer of safety through fall detection and emergency communication.

FUTURE SCOPES

While the Smart Blind Stick developed in this project offers significant benefits, there is potential for further enhancement to make the device even more effective and user-friendly. Some future improvements could include:

❖ Integration of Voice Assistance
- Adding a voice module to provide spoken alerts instead of or along with buzzer sounds, making notifications clearer and more descriptive (e.g., "Obstacle ahead at head level").

❖ Use of LiDAR Sensors
- Replacing or supplementing ultrasonic sensors with LiDAR technology could provide more accurate distance measurements and better object detection, especially in complex environments.

❖ Mobile Application Connectivity
- Developing a mobile app that connects via Bluetooth or Wi-Fi to the stick, allowing guardians to track real-time location, monitor the user's status, and receive notifications through a mobile platform.

❖ Obstacle Classification
- Enhancing the system with machine learning techniques to classify the types of obstacles (like walls, vehicles, stairs) and adjust feedback accordingly.

❖ Solar Charging Integration
- Incorporating a small solar panel for eco-friendly, extended battery life, especially useful for outdoor usage.

❖ Vibration Motor Feedback
- Adding a vibration motor along with or instead of buzzers for silent, tactile feedback, useful in noisy environments where buzzer sounds might not be easily heard.

❖ Improved Internet Connectivity
- Integrating GSM modules for SMS alerts where Wi-Fi is not available, making emergency notifications more reliable anywhere.

❖ Waterproof and Rugged Design
- Enhancing the durability of the stick by making it waterproof and shock-resistant for better outdoor usability.

Conclusion

The Smart Blind Stick developed in this project successfully addresses the major challenges faced by visually impaired individuals in their daily navigation. By integrating three ultrasonic sensors at different levels, the stick effectively detects obstacles at ground, waist, and head heights, providing timely alerts through a buzzer system. The addition of a moisture sensor enhances safety by identifying puddles and wet surfaces, preventing slip-related accidents.

Moreover, the integration of the gyroscope sensor allows the system to detect falls or accidents, triggering an automatic emergency alert that sends an email with the user's real-time GPS location to their guardian. Using the ESP32-C3 Super Mini and Arduino IDE, the device remains lightweight, compact, energy-efficient, and reliable.

Overall, the Smart Blind Stick offers a low-cost, smart, and user-friendly solution that significantly enhances the independence, mobility, and personal safety of visually impaired users. It proves that the thoughtful application of simple sensors and communication technology can greatly improve the quality of life for people with visual impairments.

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