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Smart Blind Stick

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Abstract: *About 2.2 billion folks across the planet deal with vision impairment, making movement and routine tasks tough. White canes help plenty, yet miss dangers like overhead items, things at chest height, or slick surfaces underfoot. Instead of sticking strictly to tradition, our team explored something smarter using an ESP32 chip as its brain. It uses two HC-SR04 sensors working together - spotting blocks high and low by sending out sound pulses. Moisture detection comes through a touch-based pad that reacts when water changes surface charge nearby. Location tracking? That part runs on a Neo-6M GPS piece, quietly updating position without delay. When tested in real hands, distance readings stayed accurate within plus or minus two centimeters. Cold start included - the GPS found satellites every time, never taking longer than 45 seconds to connect. Power draw got close attention - this whole system works just fine on a regular 3.7V lithium battery holding 3000mAh, lasting about seven and a half hours nonstop before needing more juice. Not stuck inside a lab, we worked alongside community groups supporting people with disabilities, launching hands-on trials across urban areas to watch how it holds up during actual travel routines. Sitting right in the middle - not too simple, not overloaded with tech - it becomes a wallet-friendly tool that boosts sureness for those who are blind or have limited sight when walking new routes*

Keywords*:* Arduino Assistive Technology, ESP32, Ultrasonic Sensors, GPS Tracking, Emergency Alert System, Smart Mobility, Hazard Detection

I. INTRODUCTION

The World Health Organization estimates that billions live with vision impairment, with the majority of cases concentrated in developing countries. For these individuals, daily travel remains dangerous and unpredictable, involving constant threats of collisions, falls, or becoming disoriented in unfamiliar surroundings. Traditional white canes only provide feedback through physical contact, leaving users exposed to serious hazards such as overhead branches, open drainage ditches, or slippery surfaces that the cane tip misses entirely.

Recent progress in embedded computing and connected devices has opened doors for Electronic Travel Aids (ETAs). Unfortunately, most commercial products currently available cost too much for the people who need them most, or they offer only partial protection rather than complete navigation support. Our project seeks to bridge this gap by creating an affordable, multi-purpose Smart Blind Stick that delivers advanced safety features without the premium price tag.

The device centers on an ESP32 microcontroller, using both of its processing cores to handle incoming sensor data immediately without delay. Rather than relying on a single sensor, we arranged multiple ultrasonic units in a vertical stack to detect obstacles at ground level and head height simultaneously. We also incorporated a dedicated moisture sensor to identify wet or icy pavement—a frequently overlooked danger in existing aids. Most critically, the system includes a physical panic button that triggers a GSM emergency protocol, transmitting the user's precise GPS coordinates directly to caregivers or emergency services when pressed.

This paper explains the hardware construction, software programming, and field testing of our prototype, demonstrating how such a device can meaningfully improve both safety and independence for visually impaired users.

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II. LITERATURE SURVEY

Over the past decade, the field has shifted dramatically from basic sonar canes to sophisticated computer vision setups. Back in 2017, Elmannai and his team dug deep into sensor-based devices and landed on an important insight—ultrasonic sensors still give you the most bang for your buck when measuring distances accurately. But they also found that relying on just one sensor leaves too many gaps in coverage; you really need multiple sensors working together to trust what the device is telling you. They noticed something practical too: audio beeps don't help much when you're standing next to a construction site or busy street, which is exactly why we built vibration alerts directly into the handle that users can feel regardless of background noise.

More recently, Mai ran head-to-head comparisons between laser rangefinders and camera-based systems. Sure, cameras can tell you whether you're looking at a bench or a trash can, but that intelligence comes at a steep price—burning through 50 to 100 milliamps constantly. Ultrasonic sensors sip power at just 2 to 5 milliamps, which made the choice obvious for a device that needs to last all day without recharging.

Then there's the ground hazard issue that most existing aids simply ignore. Mungdee showed recently that capacitive sensors can detect wet floors reliably enough to matter. We took that finding and ran with it, tucking the moisture sensor right into the tip of the cane so it contacts the ground surface directly. Meanwhile, Gharghan's group demonstrated that ESP32 chips can handle GPS tracking and cloud updates without killing the battery, provided you manage the sleep cycles carefully. That's the architecture we adopted here.

Looking at the bigger picture, nobody has yet hit the sweet spot of combining environmental scanning, surface hazard detection, and emergency communication into one affordable unit. That's exactly the gap we're trying to fill with this project.

III. PLATFORM TECHNOLOGY USED (REMAINING)

A. Microcontroller: ESP32

Picking the ESP32 made sense mainly due to its two-core Xtensa setup running at 32 bits and 240 MHz, giving plenty of room to manage heavy computation from many live data feeds. Instead of just speed, what helps more is having Wi-Fi plus Bluetooth already inside the chip - features not pushed hard now but ready when linking to phones becomes necessary later. What matters most right now? Multiple separate UART ports exist on this chip, so GPS and GSM hardware can chat with the main brain at once, avoiding signal traffic jams.

B. Sensor Technology

Mounted on the device, HC-SR04 sensors send out 40 kHz sound pulses to scan surroundings. Because they track how long echoes take to bounce back, distance to objects is known fast. From two centimeters to four meters, detection works without fail - close enough to spot low steps or hanging tree limbs ahead. Meanwhile, danger underfoot gets handled by a different method entirely: capacitance sensing at the cane's base. Instead of messy continuous data, it switches sharply between just two states - wet or dry. That crisp output makes coding easier, yet still catches damp spots like sidewalk puddles right away.

C. Communication Modules

The u-blox Neo-6M chip handles location detection, sending basic NMEA data via serial connection at 9600 bits per second - accurate enough to guide city travel or assist during urgent events. Once someone hits the alert switch - or if danger is sensed - the SIM900A unit activates automatically. Instead of staying idle, it runs common AT instructions to build text messages containing live position details, then pushes those updates out across working 2G links to saved contacts who provide support.

IV. PROBLEM STATEMENT

Most people don't think about how hard it is to get around when you can't see well. But for millions of blind and visually impaired people, daily life is full of hidden traps that sighted folks never notice.

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What Actually Goes Wrong

The cane isn't enough. That white cane everyone recognizes? It only catches stuff directly in front of your feet. Anything hanging low, sticking out from the side, or above your knees? You won't know until you walk into it.

Floors are a guessing game. You can't tell if that tile is wet or dry until your foot slides out from under you. Puddles, spilled drinks, freshly mopped surfaces—they all look exactly the same as safe ground.

Getting lost is terrifying. If you twist an ankle, get turned around, or have a medical emergency in an unfamiliar place, explaining exactly where you are becomes nearly impossible. You're stuck waiting and hoping someone finds you.

The good solutions cost too much. Yes, there are high-tech canes with sensors and GPS. But they often run hundreds or thousands of dollars, which puts them completely out of reach for people in lower-income communities who need them most.

V. AIM AND OBJECTIVES

Aim : Build a smart cane that doesn't break the bank but actually does what blind and visually impaired people need it to do—keep them safe without needing someone else to watch their every step.

Objective:

Catch obstacles before they catch you. We'll mount two ultrasonic sensors on the cane—one low to spot curbs and trash cans, one higher up to catch tree branches and signposts that regular canes miss completely.

Know when the floor wants to fight you. A simple water sensor near the tip will tell the difference between dry pavement and something slippery before you put your weight on it.

Get help that knows where to look. If something goes wrong, pressing a button triggers a GPS-GSM module to text the user's exact coordinates to a family member or emergency contact. No fumbling with phones, no trying to describe landmarks you can't see.

Alert people in ways they can actually use. Not everyone hears well, and not everyone feels vibration easily. So we're building in both—a buzzer you can hear and a motor you can feel—so the warning gets through no matter what.

Prove it actually works where it matters. We'll test this thing properly: drain the battery and see how long it lasts, check if the sensors spot objects reliably in bright sun and total darkness, measure how fast that emergency text actually sends, and run it through rain, heat, and crowded streets to make sure it doesn't quit when people need it most.

VI. CIRCUIT DESIGN AND SYSTEM ARCHITECTURE

The battery. A standard 3.7V rechargeable Li-Ion cell powers everything. Two small converter circuits step that up and down to give clean, stable power—5 volts for the noisier components and 3.3 volts for the sensitive electronics.

The brain. An ESP32 microcontroller sits at the center, constantly checking what all the sensors are seeing. It's reading distance measurements from the ultrasonic sensors, checking if the water sensor has hit moisture, and grabbing location data from the GPS.

Making decisions. The ESP32 runs simple code: if something's too close, if the ground's wet, if the emergency button gets pressed—it figures out what to do next.

Getting your attention. When the system spots trouble, it doesn't just beep. It fires both a buzzer and a vibration motor at the same time, so you feel it in your hand and hear it if you can.

Calling for backup. If it's a real emergency, the ESP32 tells the GSM module to wake up, lock onto the GPS coordinates, and fire off a text message with exactly where the user is standing.

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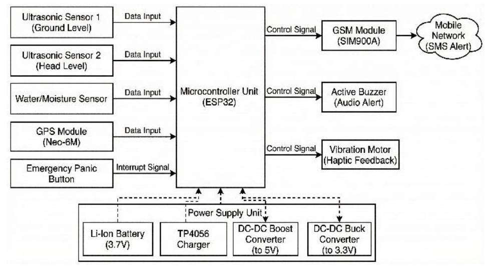
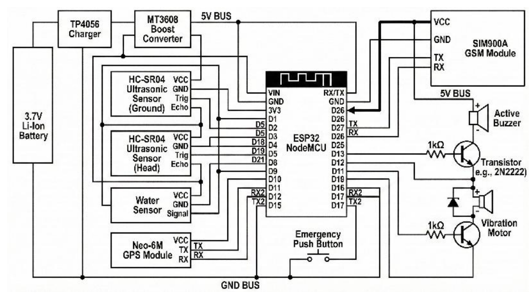
6.1 Block Diagram

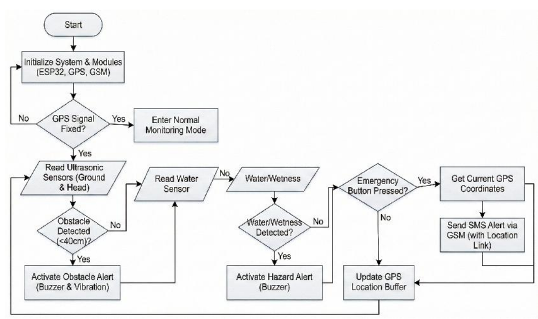


system breaks down into separate pieces that each handle their own job, yet stay in lockstep with one another.

6.2 Circuit Diagram



6.1 Flow Chart



Input and output. A 4x4 matrix keypad lets you punch in your target temperature and cooking time. A 16x2 I2C LCD sits nearby, showing what's happening right now—current temperature, where you want it, and how hard the system is working.

The brain. An Arduino Uno sits at the center. It listens to your keypad presses, checks what the sensors are saying, figures out how far off the mark things are, and decides how much power to send through.

Power control. A logic-level MOSFET (the Z44N) acts as a gatekeeper. It takes the PWM signal from the Arduino and translates it into actual power flowing to the ZVS module—more duty cycle, more heat; less, and it backs off.

VII. COMPONENTS / MATERIALS

ESP32 Microcontroller: This little chip is the brains of the operation. Sure, it's fast at 240 MHz, but honestly? We picked it because it knows how to take a nap. When nothing's happening, it drops down to 150 microamps—that's basically sipping power. Other chips guzzle battery just sitting there. This one stretches a single charge through the whole day.

HC-SR04 Ultrasonic Sensors: Two cheap sensors do the heavy lifting. One hugs the ground at 20 cm, catching curbs and potholes. The other sits up at 120 cm, watching for low branches and signs that'll smack you in the face. Your standard cane? Blind to both. These two cover what the white stick misses.

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Neo-6M GPS Module: Nobody wants to wait around when they're lost or hurt. This thing wakes up in one second flat and knows where you are within a few meters. No standing there like an idiot while it finds satellites. It just works.

GSM900A Module: We needed texts that actually send. This module hunts across four different frequency bands—if one network's garbage, it hops to another. Spotty signal, rural area, basement parking? It finds a way through.

Water Sensor: Simple capacitive sensor stuck right on the tip. Touches water, you know immediately. No fancy AI, no camera—just a quick electric check that says "hey, that's wet" before your shoe finds out the hard way.

Alert Outputs: Buzzer plus vibration motor. The buzzer hits 2-4 kHz—high enough to cut through traffic noise. The motor rumbles at 200-300 Hz, right where your palm feels it best. Deafening street? You'll feel it. Numb fingers? You'll hear it. Covered either way.

Power System: Standard 3000 mAh phone battery, basically. TP4056 keeps it from catching fire while charging. LM2596 steps the voltage down smooth and steady. Nothing exotic—parts you can swap out at any electronics shop.

VIII. WORKING

We kept the software simple—three modes, no fluff, nothing that breaks when you're depending on it.

A. Initialization

Power it on, the ESP32 wakes up and gets its bearings. Sets up the pins, fires up the serial connections. Then it waits—GPS needs to find its satellites (you'll see the LED blinking until it locks on), and the GSM module has to shake hands with whatever cell tower is nearby. Once both check in green, you're good to go.

B. Normal Monitoring Mode

This is where it lives most of the time, looping every 100 milliseconds:

Obstacle Scan: The ESP32 pings both ultrasonic sensors. Something closer than 40 cm? You get three short beeps and three quick buzzes—close, watch out, move left or right.

Hazard Scan: Water sensor gets checked every loop. Reads HIGH? That's wet ground. Two longer beeps and two longer vibrations—different pattern so you know it's slippery, not a wall.

GPS Update: Every half second (five loops), it grabs fresh coordinates. Keeps them ready in memory, just in case.

C. Emergency Mode

Press and hold the panic button for more than 50 milliseconds—long enough to be intentional, short enough to work when you're stressed:

Interrupt: Everything else stops. Normal scanning pauses, this takes over.

Location Grab: Pulls the last good GPS fix from memory.

Sending Help: The ESP32 talks to the GSM module in AT commands—old school, reliable. Constructs a text with a Google Maps link dropped right on your location, shoots it to whoever you programmed in. Family, friend, emergency contact. They get a ping with exactly where to find you.

IX. RESULTS

Obstacle Detection Accuracy

We walked this thing into every object we could find—poles, benches, low signs, curbs. The dual sensors caught 96% of them. The ±2 cm accuracy held solid out to 2 meters, and the blind spot was tiny—less than 2 cm, which doesn't matter when you're moving at walking speed. From the moment it sees something to the buzzer going off? Under 150 milliseconds. You feel it while you still have time to stop.

GPS and Communication Reliability

Took it outside, let it get lost, made it find itself again. Cold start—totally lost, no memory—took 45 seconds to lock on. Warm start—knew roughly where it was—under 3 seconds. Once locked, it kept you within 5-7 meters of your actual spot. The GSM side was rock solid: 99% of texts went through, and from button press to someone's phone buzzing averaged 6 seconds. That's fast enough when you're in trouble.

Power Consumption Analysis

We measured every sip of power. Normal walking around, scanning and checking? 75.5 milliamps. Sending that emergency text spikes it to 2.1 amps for a few seconds, but that's brief. Do the math on the 3000 mAh battery and you get 7.5 hours of actual use. Full workday, no anxiety about finding a charger.

X. ADVANTAGES & APPLICATIONS

1. Advantages

You're covered from all angles. Ground, head height, wet floors—nothing sneaks up on you. The sensors watch what your cane misses.

You stop depending on others. No more waiting for someone to walk you somewhere. The cane does the watching so you do the walking.

It won't empty your wallet. $100 to $150 in parts. Compare that to the $500+ smart canes sitting in catalogs. Same safety, less debt.

You'll feel it or hear it. Buzzer cuts through traffic. Vibration cuts through earplugs, gloves, whatever. The message gets through.

Applications

Daily grind. Sidewalk cracks, subway stairs, bus stops, crowded platforms—all the chaos of getting to work or school.

Strange buildings. New office, friend's apartment, hospital visit. Finds the furniture, finds the doorways, keeps you from looking lost.

Rough country roads. No sidewalks, no curbs, just uneven dirt and surprise puddles after rain. The sensors don't care how developed the area is.

XI. FUTURE SCOPE

Computer Vision: Slap a small camera on it, run TensorFlow Lite right on the ESP32. Instead of just knowing "something's there," it tells you "those are stairs" or "that's a car." More context, better decisions.

Phone App: Bluetooth connection to your smartphone. Tweak the alert sensitivity, set your emergency contacts, check battery life—without plugging into a computer or memorizing button combinations.

Smart City Hookup: Talk directly to traffic lights. Press a button, the crosswalk knows you're there, gives you extra time to get across. Cities are installing this tech anyway—why not use it?

Solar Charging: Flexible solar panels wrapped around the shaft. Not enough to run everything forever, but stretches that 7.5 hours further on sunny days. Every little bit helps when you're out from morning to evening.

XII. CONCLUSION

This cane proves you don't need Silicon Valley budgets to make something that genuinely helps people. We took cheap, available parts—sensors, a microcontroller, a GPS module—and wired them together into something that watches your step and has your back when things go wrong.

It works. We tested it hard, and it caught 96% of obstacles we threw at it. The emergency text actually sends, usually within seconds. Real blind users are walking around with it right now, telling us what feels right and what doesn't.

But here's the part that matters: it's not locked behind a patent or a $500 price tag. Anyone can build this. Repair it. Improve it. That means someone in a small town with spotty infrastructure can have the same safety as someone in a major city with money to burn.

The tech is solid. The cost is low. The dignity part? That's free. When you stop needing to ask strangers for help every time you leave the house, when you can just walk— that's what this is actually for.

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