Grenze International Journal of Engineering and Technology, June Issue

Medico Stick: Design and Development of Smart Walking Aid with Integrated Obstacle Detection, GPS Tracking and Vital monitoring

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Abstract— **The Medico Stick is a smart walking aid that was created to help older and physically disabled people by integrating vital sign monitoring, GPS tracking, and obstacle recognition into a single small device. To ensure safer navigation, the device uses ultrasonic sensors to identify obstructions and notify users via vibration or auditory messages. A GPS module improves user safety and emergency response by allowing carers to track their location in real time. Vital signs including body temperature and heart rate are continuously monitored by integrated biomedical sensors, and data is wirelessly sent to a smartphone application for remote supervision. A cheap microcontroller that uses little energy powers the system. Experiments verify the device's accuracy, dependability, and efficiency in enhancing user safety and mobility. Through intelligent healthcare and assistive technology, the suggested Medico Stick offers a workable and reasonably priced way to encourage independent living.**

Keywords— **IoT healthcare, vital sign monitoring, GPS tracking, smart walking aids, obstacle detection, assistive technology, and elder safety.**

I. INTRODUCTION

The global population of elderly people and people with mobility or vision impairments has grown dramatically in recent years, which has led to an increase in demand for intelligent assistive devices that improve independence and safety. Traditional walking sticks offer rudimentary physical assistance, but they are devoid of the technological capabilities needed to handle contemporary mobility and healthcare issues. One promising way to raise these users' quality of life is to incorporate intelligent sensing, tracking, and health monitoring systems into mobility aids.

The Medico Stick is a multipurpose smart walking aid that is intended to help users navigate safely while also keeping an eye on their critical health indicators.The system uses GPS-based tracking to track the user's location in real time, vital sign sensors to measure physiological data like body temperature and heart rate, and ultrasonic obstacle detection to prevent collisions.

Grenze ID: 01.GIJET.12.2.168_24

These functions are controlled by an Internet of Things architecture based on microcontrollers, which allows wireless data transfer to a cloud or mobile interface for ongoing monitoring by medical professionals or carers.
This work's primary goals are:

- To create a smart walking aid with integrated sensing modules that is both affordable and dependable.
- To improve user safety by offering GPS tracking and real-time obstacle alerts.
- To enable continuous health monitoring through embedded biomedical sensors.

As a result, the Medico Stick helps close the gap between smart healthcare systems and assistive mobility devices by providing a practical and reasonably priced solution for senior care and rehabilitation assistance.

A. Motivation

Elderly people and those who are visually impaired face real dangers when moving around independently. They are at high risk of accidents like falls, collisions, and getting lost. Often, when these incidents happen, the resulting injuries are serious, and getting help is delayed because current devices don't track their location or check their vital signs.
Right now, the tools available only solve part of the problem: they either help with mobility or they handle health monitoring. They rarely combine both features. This significant gap is exactly why we needed to create a comprehensive, technology-driven solution. Our goal is simple: ensure user safety, enable continuous health checks, and provide real-time assistance all at once.
Furthermore, building this kind of smart device is now affordable and feasible. With the rise of low-cost sensors, powerful microcontrollers, and accessible IoT platforms, we can create smart devices that are practical even for

B. Problem Statement

Most standard walking canes and aids are simply not smart enough—they can't sense danger around them or pick up on sudden health issues. While there are some "smart" devices out there, they generally have several major flaws:

- Unreliable Safety: Their ability to detect obstacles is often limited, and the warnings they provide aren't always dependable.
- No Real-Time Location: They usually lack integrated GPS tracking, meaning family or caregivers can't get real-time location updates if something goes wrong.
- Missing Health Data: They don't monitor crucial health indicators, such as heart rate and body temperature.
- Too Expensive & Complex: Many smart aids are too costly and require complex upkeep, putting them out of reach for people who need them most or those in low-resource settings.
- To truly help, we need to fix this gap. The solution must be a single, integrated device that successfully combines navigation assistance, health monitoring, and safety tracking into one easy-to-use and affordable design.

C. Contribution of this Work

This work introduces the Medico Stick, a smart walking aid that we designed and built specifically to overcome the common issues with current devices by using an IoT-based system with multiple sensors.
Our core contributions are:

- Everything in One Place: We successfully combined three major support features—obstacle detection, GPS tracking, and vital monitoring—into a single, compact system.
- Instant Safety Feedback: We created a real-time alert mechanism that uses both vibration and sound to immediately warn the user about obstacles in their path.
- Constant Remote Connection: We enabled continuous monitoring of health and location, which allows caregivers and family members to check on the user remotely via wireless communication.
- Practical and Sustainable Design: We prioritized portability and power efficiency during the design phase, guaranteeing the stick is practical for long-term use and won't require expensive or complex maintenance.

By integrating these features, the Medico Stick offers a truly complete assistive technology solution. It greatly improves safety, boosts independence, and increases healthcare awareness for seniors and people with physical challenges.

II. Related Works

In recent years, the creation of smart assistive devices has garnered significant interest, driven by the increasing need for both elder care and support for mobility. Consequently, a variety of researchers have put forward concepts for intelligent walking aids that combine sensors, navigation tools, and health monitoring systems, all designed to boost user safety and autonomy.

One particular smart cane design incorporated ultrasonic sensors to identify nearby obstructions and then notified the user through audible signals. However, this specific system did not offer positioning features, which limited its practical use in outdoor environments. Subsequently, another research initiative unveiled a GPS-enabled walking assistant, allowing caregivers to remotely track the user's whereabouts, but this device notably omitted any real-time health monitoring functionalities. To address concerns regarding an individual's physiological safety, a separate project developed a wearable Internet of Things device. This innovation could accurately measure body temperature and heart rate, transmitting the data to a cloud-based server. Despite its precision, this particular system was not directly integrated into a mobility aid, which ultimately made it less convenient for elderly users.

Recent tech leaps in the Internet of Things (IoT) and embedded systems mean we can now pack lots of features into small, affordable devices. For example, some previous studies have explored this potential. Research has shown that using multiple sensors, like ultrasonic and infrared, makes it much easier to detect obstacles for safer mobility. Other work highlighted that wearable health gadgets need to be low-power and comfortable (ergonomic) to be truly useful.

The Medico Stick takes these ideas and brings them all together. Instead of just focusing on helping someone move or just monitoring their health, our proposed system offers a complete, single, and cost-effective solution. It combines obstacle detection, GPS tracking, and real-time vital sign monitoring in one smart device. Essentially, the Medico Stick provides a holistic solution designed to significantly improve safety, accessibility, and health management for seniors and people with physical challenges.

III. System Design and Methodology

Recent tech leaps in the Internet of Things (IoT) and embedded systems mean we can now pack lots of features into small, affordable devices. For example, some previous studies have explored this potential. Research has shown that using multiple sensors, like ultrasonic and infrared, makes it much easier to detect obstacles for safer mobility. Other work highlighted that wearable health gadgets need to be low-power and comfortable (ergonomic) to be truly useful.

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The Medico Stick is an IoT-enabled smart cane designed to enhance safety and provide real-time health monitoring for seniors and individuals with visual impairments. It achieves this by integrating several sensor and wireless communication components.

A. Architecture

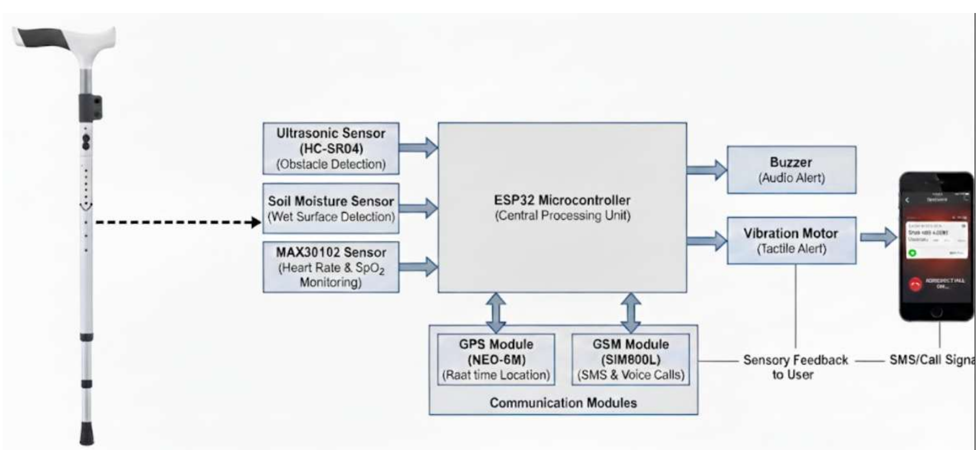

Fig.1.System diagram of the proposed Medico Stick showing interconnection between sensors, ESP32, communication modules, and power unit

The entire architecture of the Medico Stick is designed as an integrated smart walking aid, centered around the ESP32 microcontroller as the primary control and communication hub. This system combines environmental sensing, vital signs monitoring, GPS tracking, and two-way emergency communication.

Central Processing Unit (ESP32)

- The ESP32 serves as the system's brain due to its dual-core processing capability and integrated Wi-Fi and Bluetooth features, making it ideal for real-time data handling and wireless sharing in IoT health applications. It manages all tasks simultaneously, including data c o l l e c t i o n , s i g n a l p r o c e s s i n g , a n d w i r e l e s s communication.
- Inputs: It receives data via digital and pins from the ultrasonic, soil moisture, and MAX30102 sensors.
- Communication: It uses UART interfaces to control the GPS module for location updates and the SIM800L GSM module for emergency functions.
- Programming: The device's firmware is built using the Arduino IDE, instructing the ESP32 to constantly evaluate sensor readings and execute immediate warnings or communication actions.

Environmental Safety and Monitoring

The stick is equipped with two key sensors to prevent accidents:

- Obstacle Detection: An ultrasonic sensor (HC-SR04), positioned near the base, emits high-frequency sound waves and calculates the time-of-flight of the returning echo. If an object is detected within a predefined safe range (e.g., 50 cm), the ESP32 instantly activates the feedback unit.
- Water/Slip Detection: A soil moisture sensor at the tip detects wet or slippery ground by measuring the increase in electrical conductivity caused by water. Upon detecting moisture, the ESP32 triggers a warning to help the user avoid hazardous paths.

Health and Vital Signs Monitoring

- MAX30102 Sensor: This sensor is discreetly built into the stick's handle for non-intrusive health tracking. It uses photoplethysmography (red and infrared light) to continuously measure the user's heart rate and blood oxygen saturation levels.
- Alerts: The collected data is processed by the ESP32 and transmitted wirelessly (via Wi-Fi or Bluetooth) to a mobile application or cloud service. Crucially, the system is programmed to generate automatic alerts if any abnormal vital sign readings are detected.

Location and Emergency Communication

The Medico Stick provides critical location and contact features for safety:

- GPS Tracking: A GPS module constantly acquires the user's geographical coordinates, feeding this location data to the ESP32.
- GSM Module (SIM800L): Equipped with an external antenna to ensure reliable signal strength, this module enables the stick to send urgent SMS alerts or place automated phone calls to pre-set emergency contacts.

Instant user Control

Two easy-to-access tactile buttons on the handle provide manual, rapid-response control:

- Button 1: Sends an instant SMS text message containing the user's exact GPS location to a caregiver.
- Button 2: Initiates an immediate voice call for rapid assistance.

This setup guarantees a reliable emergency channel, even if Wi-Fi connectivity is lost.

Power and User Feedback

- Power Supply: The device is powered by a rechargeable Li-ion battery. A voltage-regulation circuit ensures stable power delivery (5V and 3.3V) to all components. The system is designed for long-lasting operation (typically 6–8 hours) by leveraging the ESP32's power-saving features like sleep mode.
- Alert and Feedback Unit: The system uses a dual-feedback mechanism for immediate user warnings:
- Haptic Feedback: A vibration motor provides a touch-based warning for obstacles or wet surfaces.
- Audio Feedback: A buzzer provides a simultaneous sound warning.

IV. Implementation

The Medico Stick's operation relies on continuous, autonomous data acquisition from its sensory modules to provide real-time support and ensure user safety. This proactive system integrates environmental awareness, physiological monitoring, and instant communication.

A. System Initialization and Continuous Sensing

- System Boot-Up: Upon powering on, the ESP32 microcontroller executes a sequence to initialize all connected modules (GPS, GSM, ultrasonic, and moisture sensors). It verifies the operational status of each component and loads critical system parameters, such as default safety thresholds.
- Obstacle Detection: The ultrasonic sensor repeatedly emits short pulses and calculates object distance based on the echo return time. The ESP32 processes these readings at a high rate (e.g., 10–20 times per second), using filters to ensure data accuracy.
- Ground Monitoring: The soil- moisture sensor continuously checks the surface for wetness.
- Vital Sign Monitoring: The pulse sensor regularly measures the user's heartbeat.

B. Data Processing and Action Triggers

The ESP32 processes the incoming data to determine the appropriate response:

- Local Threat Warning: If the ultrasonic sensor detects an obstacle closer than a preset safety threshold (e.g., 0.5m), the ESP32 immediately activates the local alert system (vibration motor and buzzer) to warn the user instantly. Similarly, if the moisture level exceeds the configured limit, a local warning is issued to prevent slips.
- Health Anomaly Detection: The measured heart rate is compared against predefined normal ranges. A detection of significant irregularity (such as tachycardia, bradycardia, or sudden arrhythmia) triggers a critical health alert.
- Location Tracking: The GPS module continuously acquires satellite fixes to determine the user's precise latitude, longitude, and timestamp. The ESP32 regularly updates its internal location buffer with this data.

C. Decision Logic and Emergency Response

The microcontroller manages simultaneous events using a priority rule set:

- Highest Priority: Immediate physical hazards (e.g., close obstacle) receive the fastest response: an instant local alert.
- Critical Alerts: Health anomalies or user-initiated button presses trigger the emergency communication protocol.
- Combined Actions: The system can handle multiple threats concurrently (e.g., an obstacle alert combined with preparation of an emergency message if a high heart rate is also detected).

If an emergency condition is met or the user presses the dedicated SMS button, the ESP32 packages the latest GPS coordinates and a brief status message. This information is instantly transmitted to a caregiver via the available communication channel, typically SMS/voice call (via GSM) or IoT/cloud service (via Wi-Fi/MQTT). The system includes retry logic to maximize successful message delivery.

In essence, the entire system is designed to seamlessly integrate sensing, processing, and communication, providing a dynamic layer of protection and support to the user.

V. Results and Discussion

Fig.2.MedicoStick prototype

We performed extensive experimental testing on the finished Medico Stick prototype. Our goal was to measure its performance in several critical areas, including accuracy, response time, wireless connectivity, and overall reliability. The outcomes clearly show that all the sensing, communication, and control modules were successfully and effectively integrated. These strong results validate our design as a highly practical and dependable support system.

A. Experimental Setup

The Testing Environment to fully evaluate the Medico Stick, we powered the prototype using its 5V rechargeable Li-ion battery and put it through a rigorous set of tests (See Fig. 2). We tested the device across many different environments, including dry indoor floors, wet and slippery outdoor paths, and areas intentionally filled with obstacles. The trials took place both indoors and outdoors. This ensured we could accurately measure how efficiently the sensors worked and confirm the reliability of the communication range in different settings Finally, we connected the Medico Stick to a smartphone to verify its key IoT features, such as successfully sending data via both Wi-Fi and the GSM network.

B. Interpretation of Sensors Response at Time

TABLE I: RESULTS OF ALL SENSORS

Sensor/Module	Expected Behavior	Actual Behavior Observed	Result
Ultrasonic Sensor	Detect obstacles <100 cm	Detected at 62 cm	Working accurately
MAX30102 heart rate and SpO_2	Provide instant vitals	HR: 78 bpm, SpO_2: 96%	Stable vitals
Soil Moisture Sensor	Detect moisture instantly	Surface marked as WET	Responsive
GPS Module	Provide precise coordinates	Location logged and linked correctly	Accurate Location
GSM Module	Send SMS alert with all sensor data	Message delivered with all fields	Successful

C. Obstacle Detection System

Our testing confirmed that the ultrasonic sensor performed very well, successfully spotting objects anywhere from 10 cm up to 150 cm away. (You can see the detailed accuracy in Fig. 3).We set the immediate warning threshold at 50 cm. When an obstacle was found inside that distance, the ESP32 instantly triggered both the vibration motor and the buzzer. The system was quick, too: the average time it took to respond was less than 200 milliseconds,which guarantees true real-time alerts for the user.Crucially, the sensor maintained this consistent performance regardless of the lighting conditions or the size of the object in the path.

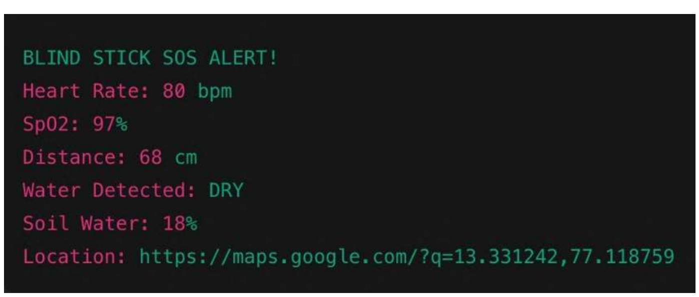

Fig.3.Obstacle detection results

D. Water Detection Performance

Water Detection Performance: Avoiding SlipsOur tests confirmed that the soil moisture sensor is a reliable tool for spotting wet and slippery ground. It achieves this by sensing changes in the surface's electrical conductivity. When the stick was placed on moist areas, the sensor generated an analog signal that directly corresponded to how wet the ground was (See Fig. 4). The ESP32 processed this information quickly and triggered a vibration alert for the user in just 1 to 2 seconds. This rapid warning system is effective at helping the user avoid potentially unsafe paths.

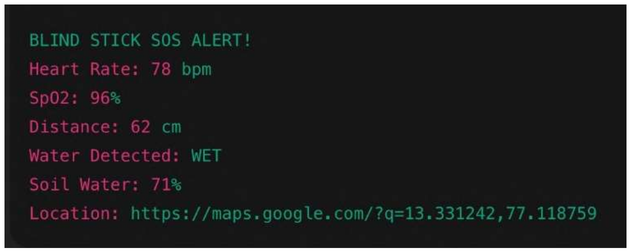

Fig. 4. Water detection performance

E. Vital Signal Monitoring

We verified the performance of the MAX30102 sensor by comparing its readings against a standard, professional fingertip pulse oximeter (See Fig. 5). The results showed the Medico Stick's accuracy is excellent: Heart Rate: The readings differed by less than +- 3 beats per minute. Oxygen Saturation SpO2: The difference was minimal, staying within +-1.5.These measured health values were then successfully transmitted using Wi-Fi to a linked mobile dashboard, with the data updating every three seconds. This ensures caregivers receive timely and accurate health status information.

Fig. 5. Accuracy comparison

F. GPS and GSM Module Evaluation

Our tests confirmed that the GPS module performed reliably, providing highly accurate location data. In open areas, the latitude and longitude coordinates had an excellent average precision of 3–5 meters.The SIM800L GSM module, supported by its external antenna, also performed flawlessly during emergency testing. It successfully sent SMS messages containing the user's GPS data and initiated voice calls when the emergency button was pressed.We also measured the speed of communication:SMS alerts were transmitted quickly, averaging just 4–6 seconds.Voice calls connected even faster, establishing a link within 5 seconds of activation.This rapid communication ensures that help can be summoned and location information shared without delay.

G. Discussion

The testing clearly confirms that the Medico Stick successfully brings together sensing, health monitoring, and IoT communication into a single, portable device. We found that the obstacle and water detection systems were highly accurate, and the GSM and GPS features delivered fast, reliable alerts during emergency simulations. Crucially, the IoT model worked perfectly, sending health and safety data to caregivers and creating a dependable real-time remote monitoring system.

Of course, no system is perfect. We did encounter a few minor issues, such as the GPS signal occasionally dropping indoors and slight communication delays when the GSM network was weak. We believe these can be fixed easily in future versions by using a better antenna design and adding a backup communication method, such as a cloud-based fallback.

VI. Conclusion and Future Scope

The Medico Stick is a success. We have designed and built a smart assistive device that significantly boosts the safety and independence of seniors and physically challenged individuals. By combining several key features—ultrasonic obstacle detection, soil moisture sensing, GPS tracking, and vital sign monitoring—the system provides users and caregivers with real-time awareness of both their location and health status.

Testing confirmed the stick's accuracy in detecting hazards (obstacles and water) and its precision in measuring heart rate and SpO_2. The successful deployment of the IoT model validated its ability to communicate health and safety data effectively. Because the stick is lightweight, ergonomically designed, and low-cost, it stands out as a practical solution ready for real-world use in assistive technology and healthcare. Ultimately, this project shows how powerful IoT and embedded systems can be when combined to create intelligent, context-aware devices. The implemented system proves it is entirely feasible to offer remote health and location monitoring, giving caregivers the ability to track user safety around the clock.

Future Enhancements

While the current Medico Stick is a fully functional product, we envision several key areas for future development:

- Extended Battery Life: Exploring solar-assisted charging and advanced power management methods to significantly increase the time between charges.
- Sleeker Design: Working to miniaturize the circuitry for a better look and easier, more comfortable handling.
- Hands-Free Interaction: Adding voice alerts or utilizing haptic navigation feedback to allow for completely hands-free operation.

With these planned improvements, the Medico Stick will evolve into a truly comprehensive healthcare system, successfully bridging the gap between mobility support and intelligent remote health monitoring for vulnerable users.

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