SSRG International Journal of Computer Science and Engineering
ISSN: 2348–8387 / https://doi.org/10.14445/23488387/IJCSE-V13I4P101

Volume 13 Issue 4, 1-11, April 2026

Original Article

An Intelligent Multi-Sensor Navigation Aid for Safe and Independent Mobility Among the Visually Impaired

Esther Sunanda Bandaru*, M. Divya, L.V.L. Himani, M. Revathi, Sahukar Reshma, Kondeti Radha, Koppurotu Akhila, Surabattula Divya Sri, Tadi Sathwika

Information Technology and Computer Applications, Andhra University College of Engineering for Women.

**Corresponding Author : bonnie.sunanda@gmail.com*

Received: 21 February 2026 Revised: 28 March 2026 Accepted: 12 April 2026 Published: 27 April 2026

Abstract *- Every day, millions of people living with visual impairments rely on a simple white cane to move safely through the world. It has served its purpose for decades, but it only tells you what is directly in front of you. Everything else remains invisible: a puddle across the pavement, a sudden drop at a curb, a flight of stairs appearing without warning, or the terrifying moment of an unexpected fall. Rather than offering another incremental upgrade, MIRAI approaches assistive navigation differently. It identifies obstacles as they approach, recognizes water surfaces before contact, detects pits and steps in advance, and registers fall events the instant they happen. Real control is placed back in the user's hands — a deliberate shake gesture triggers an emergency alert immediately, while a single clap helps locate the device if misplaced. When a dangerous situation unfolds, MIRAI does not wait. It automatically sends the user's live GPS location by SMS to a trusted contact, ensuring help can arrive without delay. Clear voice alerts keep every interaction natural and easy to understand. MIRAI is not simply a device. It is a companion built around dignity, independence, and the deeply human need to move through the world without fear.*

Keywords *- Obstacle Detection, Fall Detection, Voice Alerts, GPS-GSM Emergency Communication, Gesture-Based SOS, Assistive Technology.*

1. Introduction

Visual impairment affects millions of people around the world, and for many, moving around safely is still not easy because most places are not designed for them (Bourne et al. 2017). The white cane has been useful for years, but it only detects objects on the ground and cannot warn about overhead obstacles or sudden dangers (Solanki et al. 2023). Studies also show that audio guidance can help users navigate more easily and confidently (Loomis et al. 1998).

Even though modern smart sticks use sensors and IoT to improve safety, most of them focus on just one feature at a time (Farooq et al. 2022; Chowdary et al. 2023). Some systems include fall detection and emergency alerts, but they still do not provide a complete solution (Akhil et al. 2022; K and Priya 2026). MIRAI solves this by combining multiple features into one system, offering continuous support and making it more reliable for real-life use (Swamy et al. 2023; Javed et al. 2024).

2. System Architecture

2.1. Overview

MIRAI does not rest. From the moment it switches on, it is already paying attention, not waiting for something to go wrong, but staying one step ahead so it never has to catch up (Farooq et al. 2022). Arduino Mega does not just process data; it keeps every component in sync, so another part can act on it straight away, without hesitation or delay (Grover et al. 2020). Every sensor, every module, every response is part of one ongoing conversation — system that is constantly reading the world around the user and adjusting the moment anything changes (Loomis et al. 1998). Not a device they have to manage, but a presence they can lean on (Ross and Blasch 2000).

2.1.1. Sensor Interface Layer

Before MIRAI can do anything, it needs to understand what is around the user — and that is exactly what the Sensor Interface Layer is built for (Sinaga et al. 2025). Ultrasonic sensors constantly measure the distance to nearby objects, using the time it takes for a signal to travel and return to catch obstacles before they become a real risk (Naidu et al. 2025). Rather than looking in just one direction, sensors are placed at multiple angles — because hazards do not always come from straight ahead (Pathak et al. 2021). And when it comes to the user's own movement, the MPU6050 tracks sudden shifts in acceleration that could signal a fall, catching what the eye cannot see (K and Priya 2026).

The overall acceleration is calculated using.

$$A = \sqrt{x^2 + y^2 + z^2}$$

takes the movement from each direction, it puts the movement from the x direction, the y direction, and the z direction together into one number. The MPU6050 sensor is what gets the movement from each direction. It gets the x movement, the y movement, and the z movement. This continuous data collection ensures that the system always has an updated understanding of the environment (Nowshin et al. 2017).

2.1.2. Processing Layer

Once the data is collected, the system begins to interpret it to understand the situation (Rp et al. 2020). Instead of treating each sensor input separately, all data is combined to form a complete picture of the surroundings (Gharghan et al. 2024). The system checks whether any values cross predefined safety limits and require attention. When multiple events occur at the same time, it prioritizes the most critical one and responds accordingly (Bhosle et al. 2022). This structured decision-making process ensures that the system responds quickly while maintaining accuracy (Akhil et al. 2022).

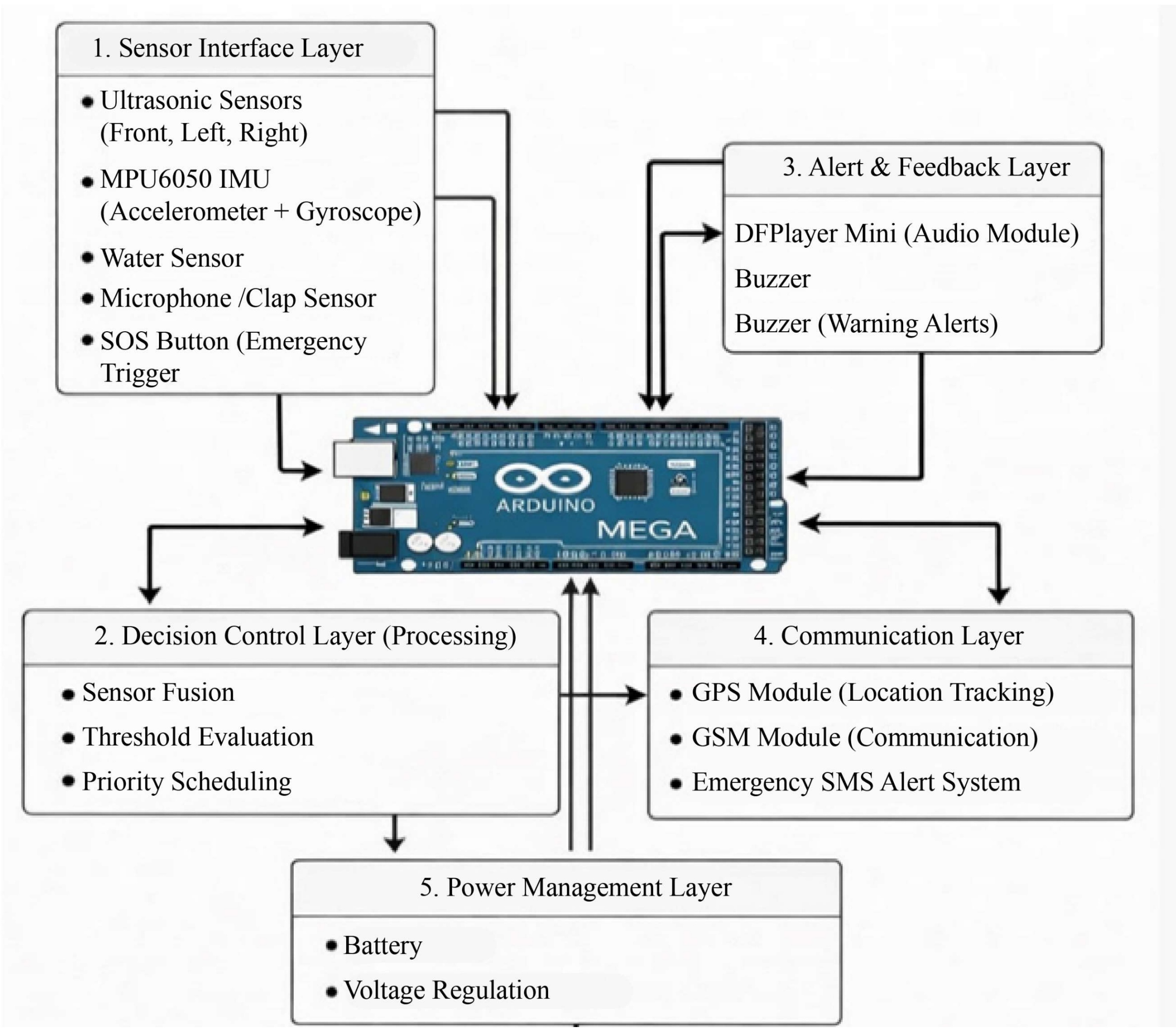

Fig. 1 Schematic Structure of MIRAI

Table 1. Priority-Based Decision Making

Priority	Event	Response
1	Push Button SOS	Stops GSM immediately
2	Fall Detection	GPS + GSM SMS Alert
3	Obstacle Detection	Voice + Buzzer Alert
4	Pit / Stair Detection	Specific Voice Alert
5	Clap Detection	Buzzer Localization

2.1.3. Alert and Feedback Layer

This layer communicates the system's decisions to the user in a clear and understandable way. Instead of relying only on simple buzzers, the system uses voice-based alerts to explain both the type and direction of the hazard (Loomis et al. 1998). These alerts are delivered instantly so that the user can react without delay (Mahalle 2014). Providing meaningful and easy-to-understand feedback helps improve user confidence and reduces confusion during navigation (Leporini et al. 2023).

2.1.4. Communication Layer

In a moment of crisis, the last thing someone should have to worry about is calling for help themselves — and this layer makes sure they never have to (Swamy et al. 2023). The moment an emergency is detected, the system retrieves the user's real-time location through GPS and sends it directly to a predefined contact via SMS, all without the user lifting a finger (Romadhon and Husein 2020). It happens automatically, because critical moments do not leave room for fumbling with a phone (Farooq et al. 2022). And to make sure that trust is never misplaced, a cancellation feature is built in — giving the system a way to correct itself and prevent unnecessary panic from a false alert (Gupta et al. 2015).

2.1.5. Power Management Layer

Power is easy to overlook until it fails — and for a system someone depends on throughout the day, that is not an option. A rechargeable battery keeps everything running, while voltage regulation circuits work quietly in the background to maintain a stable output and protect the more sensitive components (Bashar Najjar 2016). Some parts of the system, particularly the GSM module, draw more power the moment they transmit a signal, so energy usage is carefully managed to handle those spikes without disruption (Sathiyaseelan and Neethidevan 2022). That careful balance across every component is what keeps the system performing consistently, not just for an hour or two, but through an entire day of real use (Singh and Singh 2020) — ensuring the whole system runs smoothly without interruptions (Verma et al. 2024).

3. Proposed System

The whole point of building this system was simple — people who are visually impaired deserve to move through their day without constantly worrying about what might be around the next corner (Farooq et al. 2022). Getting from one place to another is never really one problem. It is a hundred small things happening at the same time, and the system was designed with that reality in mind (Grover et al. 2020).

So instead of demanding attention, it runs in the background, watching and waiting, and only comes forward when something actually requires it (Loomis et al. 1998). Done right, that kind of quiet presence stops feeling like a device and starts feeling like something the user can genuinely count on.

3.1. Sensor Fusion and Data Acquisition

No single sensor can tell the whole story, which is why the system pulls information from several of them at once (Sinaga et al. 2025). Ultrasonic sensors sweep the area continuously — not just straight ahead, but from multiple angles — because obstacles rarely announce themselves from one predictable direction (Sinaga et al. 2025). While that is happening, the system is also keeping an eye on how the user is moving, watching for anything sharp or sudden that might point to a stumble or fall (K and Priya 2026).

All of that incoming data gets brought together rather than read separately, which gives the system a much more grounded sense of what is actually going on (Aditya Bilware et al. 2024). Running this way without pause means nothing slips through, even when the environment changes in an instant (Nowshin et al. 2017).

3.2. Analysis and Hazard Detection

Collecting data is only half the work. What matters is what the system does with it (Rp et al. 2020). It looks at whether something is too close for comfort, whether the ground ahead seems questionable, or whether the way the user is moving has shifted in a way that does not quite add up (Javed et al. 2024). Wet floors and uneven surfaces get factored in too — the kinds of things that are easy to walk past without noticing but can cause real harm (Gharghan et al. 2024). Falls are handled carefully. One odd reading does not automatically trigger a response. The system watches how things develop before drawing any conclusions (Bhosle et al. 2022). That patience is what keeps unnecessary alerts from piling up and wearing down the user's trust (Akhil et al. 2022).

3.3. Decision Control and Priority Handling

When the system knows what it is dealing with, it figures out what to do next — and it takes that process one thing at a time (Mahalle 2014). If several issues surface together, there is no attempt to juggle all of them. Whatever poses the greatest risk gets handled first, full stop (Leporini et al. 2023). A fall gets immediate attention. Something minor can wait its turn. That kind of discipline in how responses are ordered keeps things from becoming chaotic or confusing for the person on the receiving end (Pathak et al. 2021).

3.4. Alert and Output Mechanism

When it comes to communicating with the user, clarity was the only real priority (Loomis et al. 1998). A vague beep in a stressful moment does not help anyone. So the system uses voice messages — actual words that say what is wrong and where — so there is no room for guesswork (Mali et al. 2025).

A buzzer runs alongside this for moments where something needs to land fast (Mahalle 2014). The goal was never just to make noise. It was to say something useful, at the right moment, in a way the user could immediately act on (Leporini et al. 2023).

3.5. Emergency Response and Communication

Serious situations cannot wait for the user to take the first step, and the system does not ask them to (Swamy et al. 2023). The moment something critical is detected, GPS pulls the location and GSM pushes it to whoever the user trusts most (Romadhon and Husein 2020). That matters because emergencies are often exactly the moments when a person is least able to reach out to themselves (Farooq et al. 2022). A cancel option exists for false alarms, because a system that cries wolf too many times eventually stops being believed (Gupta et al. 2015).

3.6. Continuous Operation

This system does not take breaks (Bourne et al. 2017). As long as the user is moving, it is sensing, processing, and responding — over and over, without any gaps (Mind et al. 2021). That unbroken loop is what makes it genuinely useful rather than just theoretically capable (School of C&IT, REVA University, Bengaluru, India, et al. 2019). And over time, that reliability builds into something more than function. It starts to feel like something that is simply always there (Vashist et al. 2022).

4. Key Features and Functionalities

MIRAI was not built by listing features — it was built by asking what someone with a visual impairment actually faces every single day, and what it would take for technology to truly have their back.

The answer shaped eight capabilities, each solving a real challenge, all woven into one system that stays alert so the user does not have to. Every detail — from sensor placement to how emergencies are handled automatically — traces back to that same question. Because when you are navigating the world without sight, the details are not minor.

Table 2. MIRAI Core Capabilities — Every function is being developed to be purposeful, precise, and built around one goal: keeping the user safe

Capability	Hardware Component	Operation	Response
360° Proximity Sensing	HC-SR04 Ultrasonic Sensors (Front, Left, Right)	It is designed to continuously scan the surrounding environment across 3 directions using time-of-flight measurement.	Directional audio alert + buzzer activation
Liquid Surface Recognition	Water Level Sensor	Being developed to identify moisture and water surfaces through electrical conductivity variation	"Caution! Water Ahead!" audio alert + buzzer activation
Terrain Irregularity Detection	IR Sensor	Being implemented to monitor the ground surface for sudden drop-offs, slopes, and stairways	Pre-recorded audio alert + buzzer activation
Impact & Auto Emergency Trigger	MPU6050 Accelerometer & Gyroscope	Being configured to recognize a deliberate double shake — two rapid acceleration peaks within 1.5 seconds	GPS coordinates acquired + Emergency SMS via SIM900
Hands-Free MIRAI Localization	Sound Sensor	Being trained to identify the double-clap amplitude pattern for hands-free localization of MIRAI	The buzzer activates immediately.
Multilingual Audio Guidance	DFPlayer Mini MP3 + SD Card + Earphones	Being integrated to deliver pre-recorded audio alerts in two languages for every detected hazard type	Clear voice message in the user's preferred language
Real-Time Location Broadcasting	NEO-6M GPS + SIM900 GSM	Being built to acquire real-time longitude and latitude, construct and transmit emergency SMS.	Emergency SMS delivered + Cancel button suppresses false alarm.

5. Block Diagram

The block diagram of MIRAI, shown in Figure 3, is being built around three functional blocks as the Input Modules, Processing Unit, and Output & Communication — each playing a clear role in making sure the user is never caught off guard.

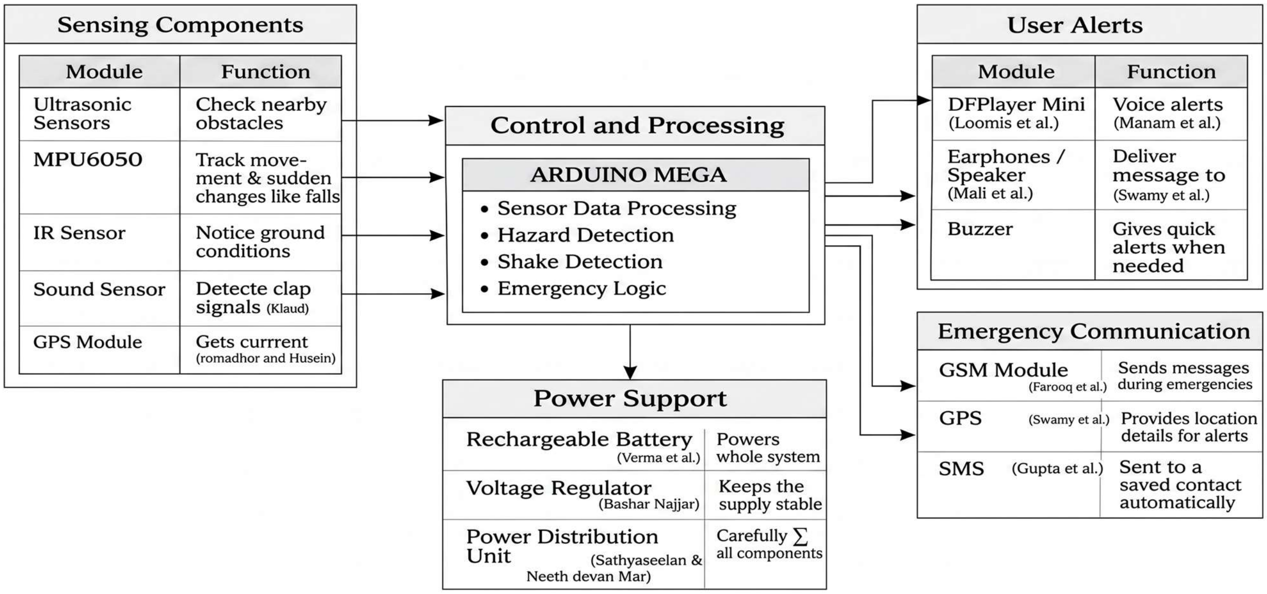

Fig. 2 Module Diagram of MIRAI[1]

5.1. Sensing Components
- Ultrasonic sensors are placed in front, left, and right to check nearby obstacles (Naidu et al. 2025).
- MPU6050 is used to track movement and sudden changes like falls (K and Priya 2026).
- Water or surface sensor to notice ground conditions (Pathak et al. 2021).
- Sound sensor to detect clap signals (Aditya Bilware et al. 2024).
- GPS module to get the current location (Romadhon and Husein 2020).

5.2. Control and Processing
- Arduino Mega handles all operations and connects every part (Grover et al. 2020).
- Sensor data is combined to understand the situation clearly (Gharghan et al. 2024).
- Values are checked with set limits to identify risks (Javed et al. 2024).
- Important events are handled first based on priority (Bhosle et al. 2022).

5.3. User Alerts
- DFPlayer Mini used to give voice instructions (Loomis et al. 1998).
- Earphones or speakers deliver the message to the user (Mali et al. 2025).
- Buzzer gives quick alerts when needed (Mahalle 2014).

5.4. Emergency Communication
- GSM module sends messages during emergencies (Farooq et al. 2022).
- GPS provides location details for alerts (Swamy et al. 2023).
- SMS is sent to a saved contact automatically (Gupta et al. 2015).

5.5. Power Support
- A rechargeable battery powers the whole system (Verma et al. 2024).
- Voltage regulator keeps the supply stable (Bashar Najjar, 2016).
- Power is distributed carefully to all components (Sathiyaseelan and Neethidevan 2022).

6. Working Principle
MIRAI operates through a continuous intelligent cycle as illustrated in Figure 4 — never stopping, never resting, always protecting.

6.1. Step 1: System Initialization and Configuration
Switching the device on is a simple act, but what follows matters more than most people realize. Each component takes a moment to power up and find its place before the system can do anything meaningful (Farooq et al. 2022). Behind the scenes, the controller is doing the quiet but critical work of making sure everything is properly linked — because if that connection is not right, nothing else falls into place the way it should (Grover et al. 2020).

6.2. Step 2: Real-Time Environmental Sensing
Once things are running, the system basically starts paying attention to the world around the user. The ultrasonic sensors do most of the heavy lifting here — they keep checking the surrounding space almost constantly, noting how close things are from different sides (Naidu et al. 2025). The motion sensor works a bit differently; it is less about what is around the person and more about the person themselves,

watching how they carry themselves and catching even slight wobbles or shifts that might not look serious right away (Pathak et al. 2021). Since no two environments are exactly the same, the system does not treat them that way either — it picks up on whatever it finds and works with that (Sinaga et al. 2025).

6.3. Step 3: Data Acquisition and Integration

The sensors do not take breaks, which means data is coming in constantly the whole time the system is active (Mann 1997). Handling all of that separately would be messy and incomplete, so the system brings it together instead — kind of like how you get a much clearer picture of something when you stop looking at the pieces individually and just step back to see the whole thing (Ross and Blasch 2000).

6.4. Step 4: Situation Analysis and Hazard Detection

This is really where the system earns its keep. It goes through everything it has collected and starts asking whether anything looks like a problem (Rp et al. 2020). Some hazards are obvious, but others are not — a slightly wet patch on the floor or a surface with a bit of a slope can be just as dangerous, so those get flagged too (Mahalle 2014).

When movement data starts looking unusual, the system does not immediately treat it as a fall. It takes a moment to actually look at what happened before drawing any conclusions (Swamy et al. 2023).

6.5. Step 5: Decision Making and Priority Handling

Knowing what is wrong is only half of it — the system also has to figure out what to do about it (Mali et al. 2025). Most of the time, that is straightforward, but when multiple things go sideways at once, it gets trickier. Rather than getting pulled in different directions, the system just zeroes in on whatever is most urgent and deals with that first (Leporini et al. 2023).

6.6. Step 6: Alert Generation and User Notification

The system does not keep the user in the dark. When something needs attention, it says so out loud — plainly, clearly, and with enough detail that the person knows exactly what they are dealing with and where it is coming from (Leporini et al. 2023). The buzzer backs this up, particularly in moments where a voice message alone might not cut through fast enough (Mahalle 2014).

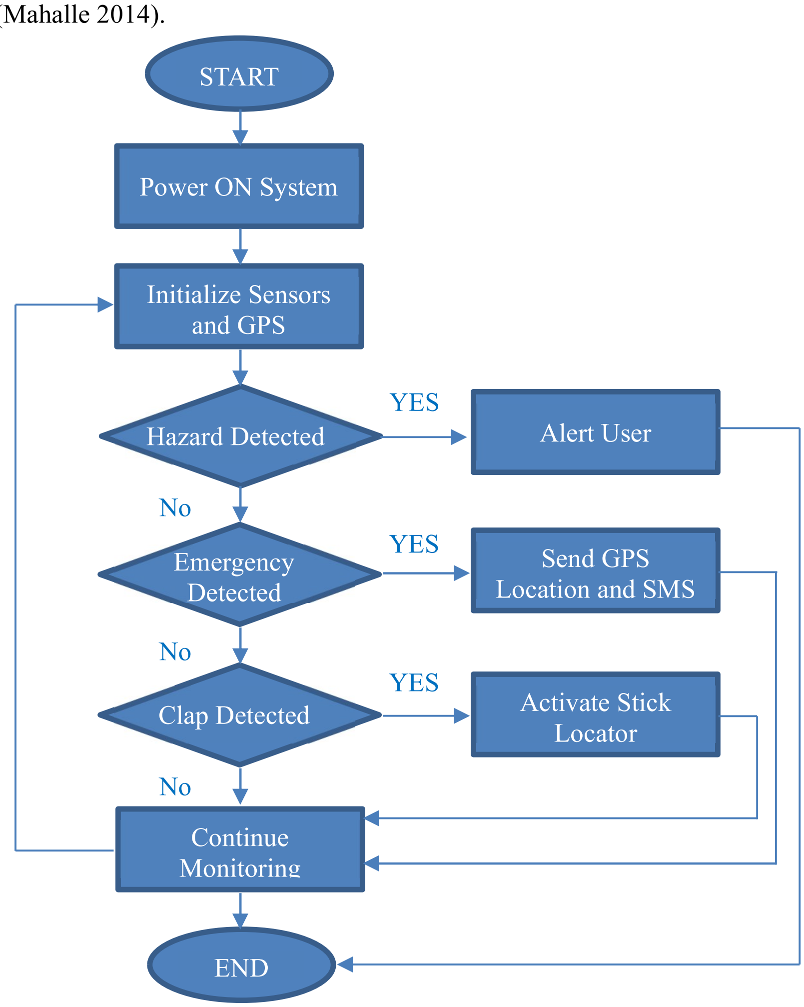

Fig. 3 Flow diagram of MIRAI

6.7. Step 7: Emergency Detection and Communication

A confirmed fall is treated completely differently from everything else. The normal cycle pauses, and the system shifts entirely into emergency mode (Swamy et al. 2023). It pulls the user's location through GPS and gets a message out to the emergency contact right away — no delays, no waiting for confirmation, because that is exactly the kind of situation where time is not on anyone's side (Farooq et al. 2022).

6.8. Step 8: Continuous Monitoring and System Loop

The whole thing just keeps going. There is no point where the system decides it has done enough and stops — it loops straight back and starts over, every single time (Sinaga et al. 2025). For the user, that means they never have to stop and wonder whether the device is still doing its job. It is just quiet and consistent, the entire time they have it on (Ross and Blasch 2000)

7. Results & Discussions

MIRAI is being tested across real outdoor environments, simulated hazard setups, and controlled environments.

Lab conditions — pushing every feature to verify it can reliably protect a user when it matters most.

Across every testing scenario, MIRAI is movement. When an emergency SMS is triggered during testing, it is consistently reaching the designated contact in under 8 seconds — fast enough to make a real difference in a genuine crisis. The existing solution being studied addresses only one concern and goes no further. GPS-GSM aids can transmit a location but carry no awareness of what surrounds the user. Every other solution out there solves one problem and stops. The white cane only feels what is directly underfoot. Ultrasonic sticks catch obstacles, but miss falls and emergencies entirely. GPS-GSM aids can call for help but have no idea what is around the user. Fall detection aids sense a fall but leave the user completely unaware of everything else. MIRAI is the only one that brings all eight capabilities together --- not as a prototype dream, but as a working, tested, real-world solution that is ready to make a difference in someone's life today.

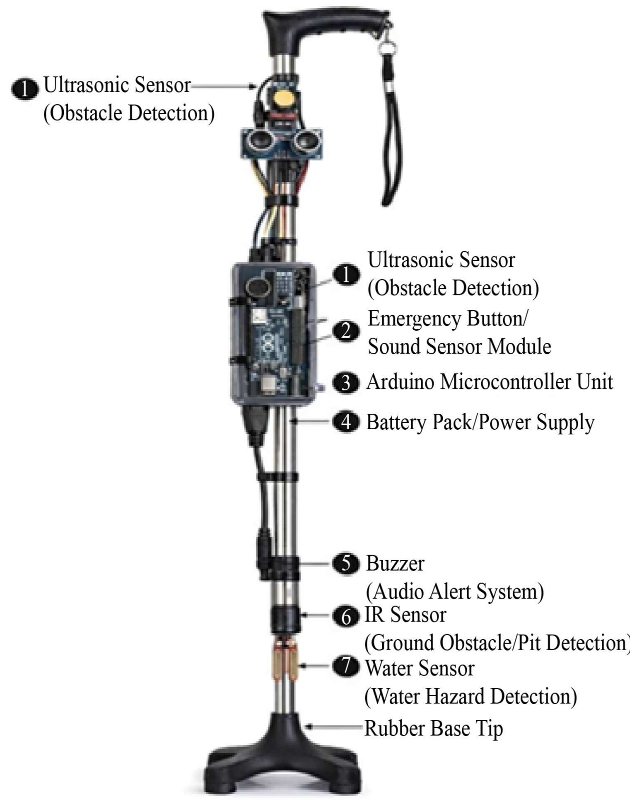

Fig. 4 MIRAI – Built-in Ready

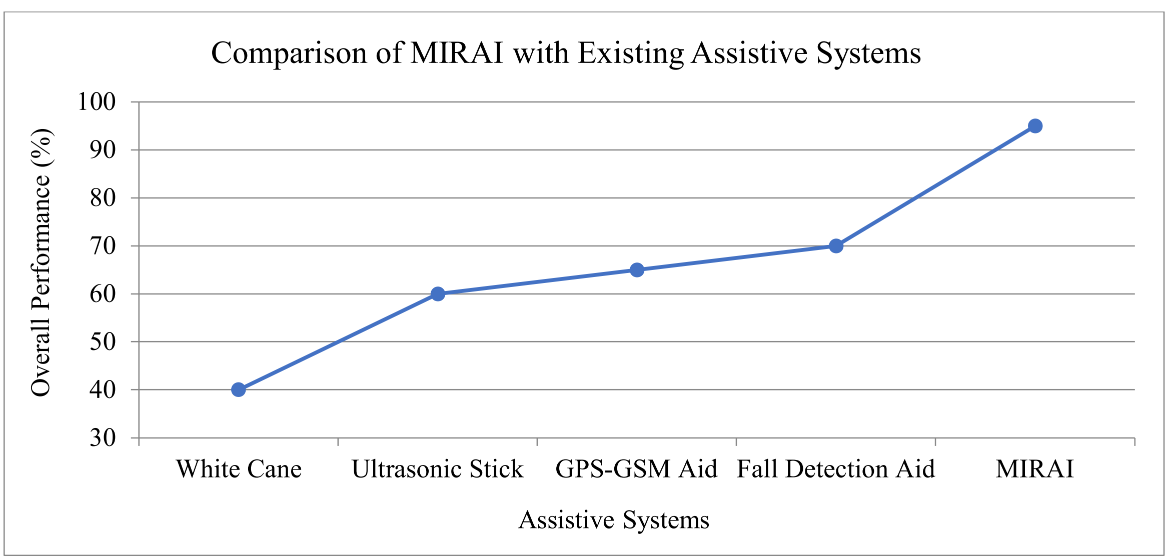

Fig. 5 Obstacle Detection Accuracy Comparison

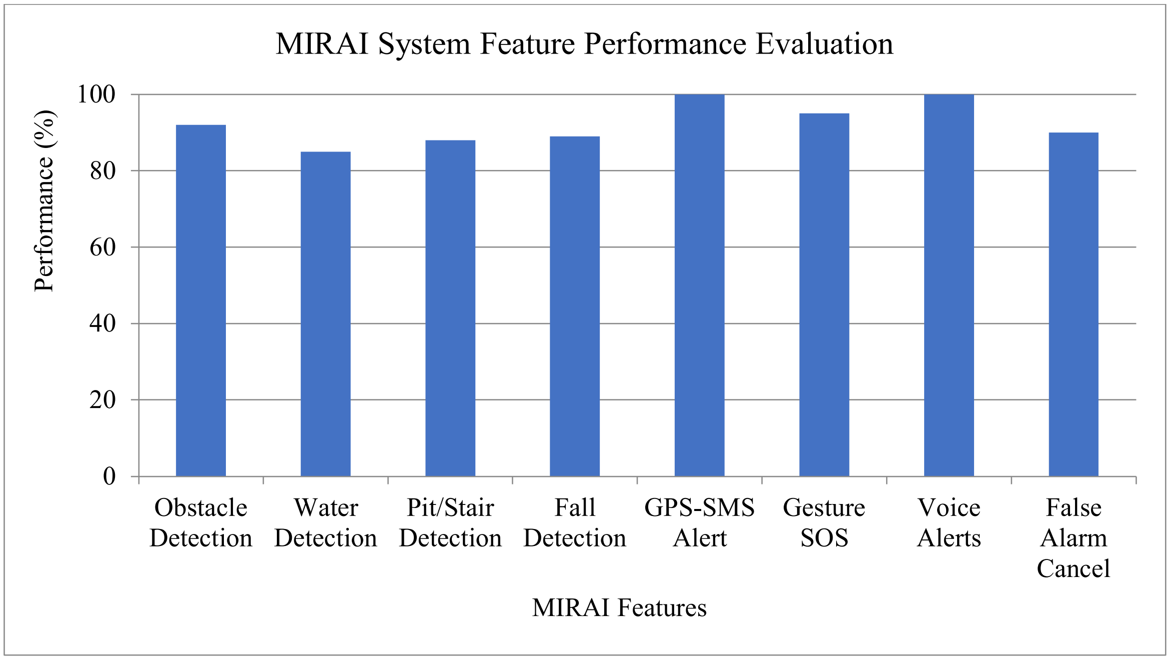

Fig. 6 Performance Evaluation of MIRAI System

How Does MIRAI Compare to What Already Exists?

Table 3. MIRAI vs Existing Assistive Systems

Feature	White Cane	Ultrasonic Stick	GPS-GSM Aid	Fall Detection Aid	MIRAI
Multi-Directional Obstacle Detection	✗	Partial	✗	✗	✓
Water Hazard Detection	✗	✗	✗	✗	✓
Pit and Stair Detection	Partial	✗	✗	✗	✓
Automatic Fall Detection	✗	✗	✗	✓	✓
GPS-GSM Emergency SMS	✗	✗	✓	✗	✓
Gesture-Based SOS	✗	✗	✗	✗	✓
Voice Alerts	✗	✗	✗	✗	✓
False Alarm Cancellation	✗	✗	✗	✗	✓

Most assistive systems handle only one or two things — warning you about obstacles or sending an alert when something goes wrong. MIRAI does it all. It detects obstacles, reads the ground ahead for wet or uneven surfaces, recognizes falls, automatically calls for help, and guides you with clear voice instructions — everything a visually impaired individual needs to move through the world safely, wrapped into one dependable system.

8. Advantages

1. Rather than leaning on a single sensor, pulling data from several at once paints a much fuller picture of what surrounds the user (Sinaga et al. 2025).
2. Things off to the side get noticed too — the user is not only protected from what is straight ahead (Naidu et al. 2025).
3. Since body movement is actually being tracked, spotting a fall becomes much harder to get wrong (Swamy et al. 2023).
4. The moment something serious is detected, an alert goes out — there is no waiting around when every second counts (Romadhon and Husein 2020).
5. With voice telling the user where to go, navigation stops being a guessing game (Loomis et al. 1998).

6. Stepping into a place you have never been before feels a lot less stressful when something is actively guiding you through it (Mali et al. 2025).
7. Loved ones do not need to be standing next to the user to know they are safe — remote monitoring handles that (Farooq et al. 2022).
8. Shaving even a little time off an emergency response is not a small thing — it can shift the outcome entirely (Ross and Blasch 2000).
9. The parts used are affordable, so building this stays within reach rather than being just a concept (Verma et al. 2024).
10. Improvements can be added down the road without tearing everything apart and rebuilding (Gharghan et al. 2024)
11. Anyone can get comfortable with it fairly quickly — it does not ask much from the user upfront (Mahalle 2014).
12. Wearing it through the day never really feels like a burden, which matters more than people think (Leporini et al. 2023).

9. Future Scope

1. The system holds up well for what it is meant to do right now, but there is definitely space to take it further. For one, it would be much more useful if it could actually learn over time. Right now, it reacts, but it does not adapt. If it could pick up on patterns from how it is being used and gradually adjust its responses, it would feel a lot less rigid (Gharghan et al. 2024).
2. The sensing could also go beyond just spotting obstacles. Knowing something is in the way is helpful, sure — but actually making sense of the environment around the user is a whole other level (Sinaga et al. 2025).
3. There is also the bigger picture of navigation. Immediate obstacle alerts are fine, but if someone is trying to move through an unfamiliar place, that alone is not enough. The system could do more to guide someone through a full space, not just flag what is a few steps ahead (Loomis et al. 1998).
4. The way it communicates could feel more human, too. Fixed alerts work, but they can get repetitive or feel out of place depending on the situation. If the feedback shifted based on context, it would be easier to understand and less jarring to act on (Mali et al. 2025).
5. Emergency support is already there, which is good — but it needs to be bulletproof. Any delay or inaccuracy in sharing location during a real emergency is the kind of thing that cannot be overlooked (Swamy et al. 2023).
6. Battery life is one of those things users notice quickly. The longer the system can run without needing a charge, the more practical it becomes for everyday use — and that comes down to smarter power management (Verma et al. 2024).
7. Bringing in a mobile or web connection would also add a lot. Remote monitoring, live updates, tracking — things that would make the system feel connected rather than isolated (Farooq et al. 2022).
8. Taken together, these are not just upgrades — they are what would turn this from a device people use into something people actually rely on (Ross and Blasch 2000).

10. Conclusion

MIRAI unites smart sensing, fall detection, and GPS emergency response into one device — giving visually impaired users safer, more confident, and truly independent movement through everyday life.

Author Contribution

ESB and MD were the guiding hands behind the project, keeping everything on track and well-directed throughout. KR and KA put in the hard thinking when it came to designing the system and working out how to bring it to life practically. SDS and TS got into the thick of it — building, testing, and making sense of how everything performed. When it came to writing, every member of the team sat down and contributed, and the final version reflects that shared effort from everyone involved.

Acknowledgement

We are truly grateful to Dr. Esther Sunanda Bandaru and Dr. M. Divya — their guidance meant more to us than we can put into words. They were there at every stage, and this project is better because of them. The Department of Information Technology and Computer Applications at Andhra University College of Engineering for Women gave us a place to grow this idea into something real, and we deeply appreciate that. Working through this together as a team, learning from each other, and leaning on research that came before us — all of it shaped what this project became.

References

[1] Aditya Bilware et al., “AI-Based Object Detection, Distance Measurement and Speaking System for Blind Stick,” *International Journal of Advanced Research in Science, Communication and Technology*, vol. 4, no. 2, pp. 162-172, 2024. [CrossRef] [Publisher Link]

[2] Premarajan Akhil et al., “Smart Blind Walking Stick with Integrated Sensor,” *Materials Proceedings*, vol. 10, no. 1. pp. 1-7, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[3] Bashar Najjar Lubna Alazzawi, “Automotive Mobile Control System to Monitor Teen Driving Behaviour,” *International Journal of Innovative Research in Computer and Communication Engineering*, vol. 4, no. 5, pp. 8805-8811, 2016. [CrossRef] [Publisher Link]

[4] Priyanka Bhosle et al., “Smart Navigation System Assistance for Visually Impaired People,” *International Conference on Futuristic Technologies*, pp 1-5, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[5] Rupert R.A. Bourne et al., "Magnitude, Temporal Trends, and Projections of the Global Prevalence of Blindness and Distance and Near Vision Impairment: A Systematic Review and Meta-Analysis," *Lancet Glob Health*, vol. 5, pp. e888-e897, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[6] Lekkala Mokshith Chowdary et al., "Android Based Smart Blind Stick Using Ultrasonic Sensor IoT," *International Journal for Research Trends and Innovation*, vol. 8, no. 11, pp. 183-186, 2023. [Publisher Link]

[7] Muhammad Siddique Farooq et al., "IoT Enabled Intelligent Stick for Visually Impaired People for Obstacle Recognition," *Sensors*, vol. 22, no. 22, pp. 1-20, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[8] Sadik Kamel Gharghan et al., "Smart Stick Navigation System for Visually Impaired Based on Machine Learning Algorithms Using Sensors Data," *Journal of Sensor and Actuator Networks*, vol. 13, no. 4, pp. 1-27, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[9] Sameer Grover et al., "Smart Blind Stick," *International Journal of Electronics and Communication Engineering*, vol. 7, no. 5, pp. 19-23, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[10] Sudeep Gupta et al., "Advanced Guide Cane for the Visually Impaired People," *1st International Conference on Next Generation Computing Technologies*, pp. 452-455, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[11] M.O.A. Javed et al., "Design and Development of Smart Blind Stick for Visually Impaired People," *IOP Conference Series: Materials Science and Engineering*, vol. 1305, pp. 1-13, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[12] K. Darshan, and A. Sathiya Priya "Standalone Wearable Fall Detection System Using ESP32 and GSM-Based Emergency Alerting," *International Advanced Research Journal in Science, Engineering and Technology*, vol. 13, no. 3, pp. 247-252, 2026. [CrossRef] [Publisher Link]

[13] Barbara Leporini et al., "Towards a Haptic-based Virtual Cane to Assist Blind People in Obstacle Detection," *Proceedings of the 16th International Conference on PErvasive Technologies Related to Assistive Environments. Association for Computing Machinery*, pp. 10-13, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[14] Jack M. Loomis, Reginald G. Golledge, and Roberta L. Klatzky, "Navigation System for the Blind: Auditory Display Modes and Guidance," *Presence: Teleoperators and Virtual Environments*, vol. 7, no. 2, pp. 193-203, 1998. [CrossRef] [Google Scholar] [Publisher Link]

[15] Shripad S. Bhatlawande, Jayant Mukhopadhyay, and Manjunatha Mahadevappa, "Ultrasonic Spectacles & Waist- Belt for Visually Impaired & Blind Person," *IOSR Journal of Engineering*, vol. 4, no. 2, pp. 46-49, 2014. [Google Scholar] [Publisher Link]

[16] Amey Mali et al., "Smart Blind Assistant Stick," *Journal of Engineering Science and Technology Review*, vol. 18, no. 1, pp. 110-119, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[17] S. Mann, "Wearable Computing: A First Step toward Personal Imaging," *Computer*, vol. 30, no. 2, pp. 25-32, 1997. [CrossRef] [Google Scholar] [Publisher Link]

[18] Pooja Mind et al., "Smart Stick for Visually Impaired," *International Journal of Engineering Research & Technology*, vol. 10, no. 6, pp. 196-198, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[19] GBSR. Naidu et al., "Smart Blind Stick for Visually Impaired People," *International Journal of Emerging Technologies and Innovative Research,* vol. 12, no. 8, pp. c718-c725, 2025. [Google Scholar] [Publisher Link]

[20] Nadia Nowshin et al., "An Intelligent Walking Stick for the Visually-Impaired People," *International Journal of Online and Biomedical Engineering*, vol. 13, no. 11, pp. 94-101, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[21] Akansha Pathak et al., "Rapid Response Smart Blind Stick with Obstacle Detection Using Arduino," *International Journal of Technical Research & Science*, vol. 6, no. 8, pp. 14-17, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[22] A.S. Romadhon, and A.K. Husein, "Smart Stick for the Blind Using Arduino," *Journal of Physics: Conference Series*, vol. 1569, pp. 1-6, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[23] David A. Ross, and Bruce B. Blasch, "Wearable Interfaces for Orientation and Wayfinding," *Proceedings of the Fourth International ACM Conference on Assistive Technologies*, pp. 193-200, 2000. [CrossRef] [Google Scholar] [Publisher Link]

[24] R.P. Soundarya et al., "Smart Blind Stick using Arduino," *International Journal of Advanced Research in Computer Science*, vol. 11, no. 1, pp. 229-232, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[25] R. Sathiyaseelan, and V. Neethidevan, "IoT based Blind Stick," *International Journal of Health Sciences*, vol. 6, no. S1, pp. 4491-4499, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[26] S. Pruthvi et al., "Smart Blind Stick using Artificial Intelligence," *International Journal of Engineering and Advanced Technology*, vol. 8, no. S5, pp. 19-22, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[27] Mikha Sinaga, Ayub Ibrahim, and Nita Sembiring, "Smart Assistive Stick with Arduino and Multidirectional Ultrasonic Sensors for Intelligent Obstacle Detection and Navigation," *CogITo Smart Journal*, vol. 11, no. 2, pp. 311-322, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[28] Shalini Singh, and Balwinder Singh, "Intelligent Walking Stick for Elderly and Blind People," *International Journal of Engineering Research & Technology*, vol. 9, no. 3, pp. 19-22, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[29] Vishal Solanki et al., “A Research Paper on Smart Blind Stick,” *International Journal for Research in Applied Science & Engineering Technology*, vol. 11, no. 4, pp. 2691-2694, 2023. [CrossRef] [Publisher Link]

[30] K.C.T. Swamy et al., “Development of Sophisticated Smart Blind Stick Using GSM and GPS,” *Atlantis Press*, pp. 11-17, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[31] Praveen Vashist et al., “Blindness and Visual Impairment and their Causes in India: Results of a Nationally Representative Survey,” *PLoS ONE*, vol. 17, pp. 1-14, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[32] Jai Krishan Verma, Rajeev Kanday, and Sachin Gupta, “Design and Development of Clap Based Switch Regulator in Relation to Smart Home Applications,” *E3S Web of Conferences*, vol. 556, pp. 1-6, 2024. [CrossRef] [Google Scholar] [Publisher Link]