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Team 1366

Pathfinder*: *Sees. Speaks. Protects.
Innovates for Inclusion

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Team Presentation

Our team, The Pathfinders, is made up of Aaditya Nair and Nevaan Parikh from Mumbai. We have been friends since we were very young and have always shared a curiosity for how things work. For this project, Aaditya focused on coding and CAD design, while Nevaan led the research and creative development.

As we worked on Pathfinder, we realised that the challenge was not only technical but also about making a real difference for people with visual impairments. To understand their needs, we studied reports, watched interviews, and even tried navigating blindfolded. These experiences showed us how difficult everyday mobility can be and guided us to design features that are practical and genuinely helpful.

We faced many setbacks, code that failed, CAD models that needed reworking, and hardware that broke. Each challenge taught us how to problem-solve, collaborate, and think like designers responsible for real users.

What started as a competition entry has grown into something more meaningful. Pathfinder has become a mission for us: to use robotics not just for innovation, but for inclusion and independence.

Why Pathfinder?

Every year, the world celebrates breakthroughs in technology , from driverless cars that navigate highways to rovers exploring distant planets. Artificial intelligence can answer complex questions, and robots can perform surgeries with precision. Yet, despite these incredible advances, millions of people who are blind or visually impaired still rely on a simple white cane , a tool that has changed little in over a century. This imbalance raises an important question: if we can design machines to drive cars or land on Mars, why are people with visual impairments still left to depend on such a basic aid for something as essential as mobility? It shows how unevenly the benefits of innovation are distributed.

For us, this is not just a technical challenge , it is a question of fairness and inclusion. We believe that true innovation must also be inclusive innovation. If technology can transform industries, it must also transform lives. Pathfinder was created from this belief: that robotics should bridge gaps in society, not widen them.

Our research showed that while existing solutions like the SmartCane are steps forward, they often stop at detection and the other technologically advanced versions were out of reach for most visually impaired people due to high costs.
We believe that innovation is not complete without inclusion. The real test of technology is not only how advanced it is, but how well it improves everyday lives.

Pathfinder is a smart cane that makes moving around safer, clearer, and more independent. Instead of just tapping the ground, Pathfinder:

- Detects obstacles with LiDAR sensors.
- Speaks to the user with simple voice alerts like “step ahead” or “obstacle to your left.”
- Sends location updates to a caregiver every 5 minutes.
- Allows one-button emergency calls without needing Wi-Fi or a smartphone.
- Includes smart sunglasses that help with orientation and reduce stigma.

Project Summary

Pathfinder is a modern reimagining of the traditional white cane, an iconic but limited tool used by individuals who are blind or visually impaired. While the conventional cane functions solely through physical contact to identify immediate ground-level obstacles, Pathfinder reimagines the traditional white cane as a smart, voice-narrating mobility system. Instead of relying only on touch, it combines LiDAR sensors, voice guidance, and emergency support into one integrated device.

With Pathfinder, a user can:

- Detect obstacles at ground level and above the knees using LiDAR.
- Hear simple voice narration such as “Step down ahead” or “Wall to your left”, instead of interpreting confusing vibrations.
- Call a caregiver instantly with a single button, even without Wi-Fi or a smartphone.
- Provide caregivers peace of mind with automatic GPS location updates every five minutes.
- Use stylish smart sunglasses that improve orientation and reduce stigma.

Globally, 43 million people are blind and 295 million live with visual impairment. For most, the only mobility tool is still the white cane — a design nearly 100 years old that cannot detect steps, potholes, or overhead obstacles. This gap leads to accidents, limited mobility, and reduced independence.

Pathfinder directly addresses this challenge. It is affordable, scalable, and designed with inclusion in mind. More than a tool for obstacle detection, it restores confidence, dignity, and independence to people with visual impairments.

Robotic Solution

Early Ideas We Explored

When we first started brainstorming, we thought of big projects. One was a water-rescue drone that could spot people struggling in rivers or lakes and send help. Another was a submarine robot that could clean plastic waste from rivers. Both ideas sounded exciting, but when we thought deeper, we realized they were not practical. The drone would need complex deployment systems, and the submarine would need too much power and maintenance.

These projects taught us an important lesson: innovation has to balance ambition with practicality. We wanted to build something we could actually design, test, and use; something that could truly improve people's lives. That is how we shifted from large environmental projects to a human-centred solution: Pathfinder, a smart cane for the visually impaired

Finalizing Pathfinder

Once we started focusing on inclusion and independence, Pathfinder became the clear choice. The white cane is widely used, but it has limits. It cannot detect obstacles above the knee, sudden steps, or potholes. By combining robotics and empathy, we set out to redesign the cane into something integrated, smart, and simple to use. Pathfinder is our way of making mobility safer, more reliable, and more dignified.

Challenges We Faced

Pathfinder was not easy to build. Our code often refused to compile.
Our CAD files missed holes for wires, forcing redesigns. Our sensors sometimes failed completely.
At first, each failure felt like a setback. But over time, these challenges became lessons. We learned to debug like engineers, redesign like makers, and collaborate like teammates. Every obstacle made Pathfinder stronger.

What Makes Pathfinder Unique

There are already some “smart canes” in the world. The most famous is the SmartCane from IIT Delhi, which uses ultrasonic sensors and vibrations. While useful, it has two big drawbacks:

- It is an add-on module that has to be attached to a regular cane, which can be difficult for older or less tech-comfortable users.
- It uses vibrations to signal obstacles, which can be confusing, tiring, and hard to interpret in crowded or noisy environments.

Pathfinder was designed to solve these problems:

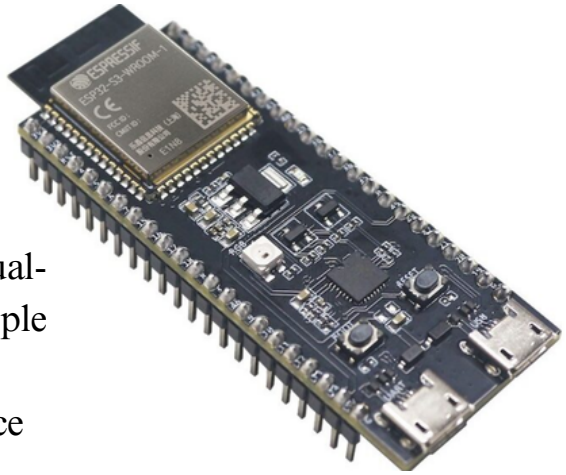
- It is a fully integrated system — everything is built into the cane and sunglasses. No add-ons needed.
- Instead of vibrations, Pathfinder gives clear voice narration like: “Step down ahead” or “Wall on your left.”
- It includes a GSM module for one-button caregiver calls and automatic SMS with GPS every five minutes.
- Smart sunglasses reduce stigma and add orientation support.
- All electronics are neatly housed inside, making it durable, simple, and weather-resistant.

In short, Pathfinder doesn’t just detect obstacles it gives users a voice, a safety net, and independence with inclusion for all not just those who are privileged.

Core Electronics and Components

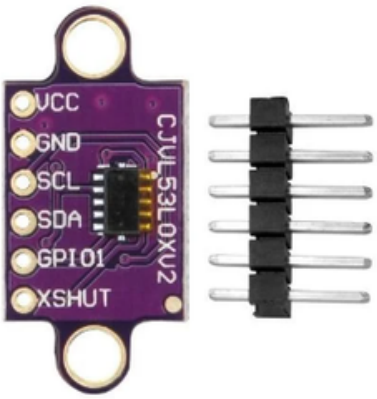
All of Pathfinder's electronics , LiDAR sensors, GSM module, microcontroller, and power system , are integrated neatly inside the cane shaft. This protects them from the environment and keeps the cane's design simple and familiar. Unlike other smart canes where modules are strapped on, Pathfinder looks and feels like a single, complete device.

THE ESP32 MICROCONTROLLER



At the heart of Pathfinder is the ESP32 microcontroller, chosen for its reliability, dual-core processing, and ability to handle multiple inputs at once. It processes sensor data, manages decision-making, and triggers voice outputs in real time.

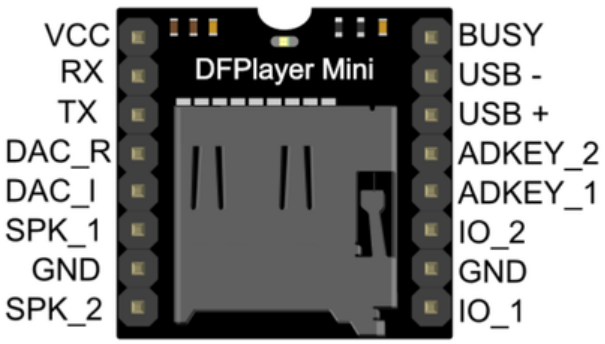
VL53L0X LIDAR - SENSOR



For obstacle detection, Pathfinder uses five VL53L0X LiDAR sensors, arranged at different angles to monitor both ground-level hazards (like potholes) and mid-body obstacles (like table edges or signboards). These sensors provide accurate short-range distance measurements, which the ESP32 translates into clear voice alerts such as "Obstacle to your right" or "Step ahead."

DFPLAYER MINI

Voice narration is handled by a DFPlayer Mini module and a compact speaker. Pre-recorded audio messages are short and context-specific, so the user receives precise guidance without needing to interpret vibrations or signals.



Core Electronics and Components

GSM MODULE (EC200U)

Pathfinder also includes an integrated GSM module (EC200U) for emergency support. With one button, the user can call a caregiver or send automatic SMS updates with their live GPS location every five minutes. This feature works without Wi-Fi or a smartphone, making it reliable even in rural or low-connectivity areas.

LI-ON BATTERY & TP4056

Power is supplied by a rechargeable Li-Ion battery that provides 6–8 hours of continuous use. A built-in protection circuit prevents overcharging, and a low-battery voice alert warns the user when recharging is needed. Charging is simple through a standard USB-C connection.

For power management, Pathfinder uses a TP4056-based charging module with built-in overcharge, over-discharge, and short-circuit protection. The cane can be recharged via a standard USB-C port, allowing compatibility with common phone chargers

HOW THEY WORK TOGETHER

ESP32 MICROCONTROLLER:

- Controls all inputs and outputs in real time.
- Reads sensor data, makes decisions, and triggers voice messages or emergency actions.

LIDAR SENSORS:

- Five VL53L0X sensors positioned at angles.
- Detect ground-level hazards (potholes, steps) and mid-level obstacles (tables, walls, signboards).
- Data sent directly to ESP32 for processing.

DFPLAYER MINI + SPEAKER:

- Plays short, pre-recorded MP3 messages like “Step down ahead.”
- Gives clear, natural language guidance instead of vibrations.

GSM MODULE EC200U:

- Sends automatic SMS with GPS every 5 minutes.
- One-button emergency call to caregiver — works without Wi-Fi or smartphone.
- Operates via SIM card, reliable even in rural/low-connectivity areas.

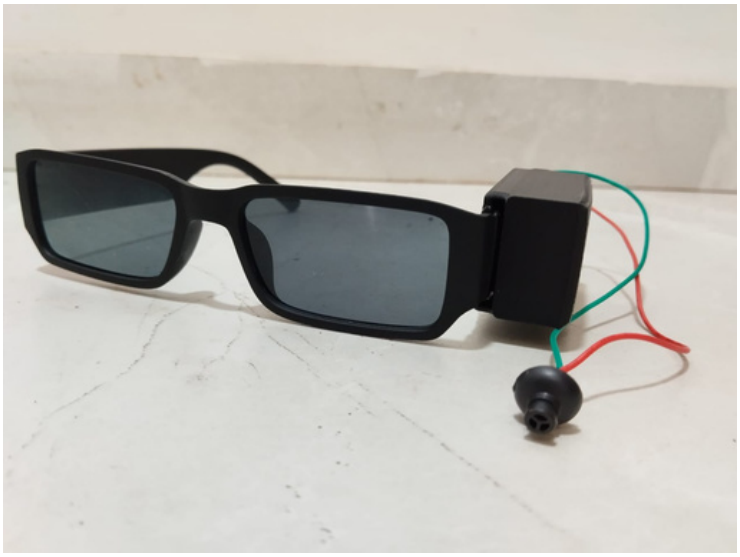
POWER SYSTEM:

- Rechargeable Li-Ion battery with 6–8 hours of use.
- Safe charging circuit (overcharge/short-circuit protection).
- Low-battery voice alert + USB charging.

INTEGRATION:

- All modules are embedded inside the 3D printed cases
- Weather-resistant housing protects electronics.
- System works seamlessly: LiDAR detects → ESP32 decides → Voice narrates or GSM alerts.

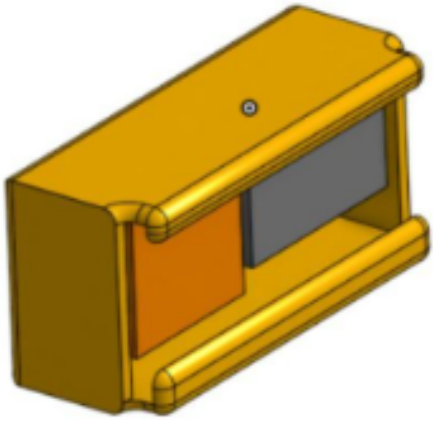
SMART SUNGLASSES



Pathfinder incorporates a unique pair of custom sunglasses. These glasses feature advanced communication capabilities. They utilize ESP-NOW technology. This system is akin to Bluetooth. ESP-NOW offers a longer communication range. It links the sunglasses to the central cane module.

The sunglasses serve a dual function. Firstly, they act as a visual identifier. They clearly signal to the public that the wearer is visually impaired. This promotes greater social awareness and understanding. It helps create a more inclusive environment. People can readily offer assistance or adjust their interactions..

Secondly, these sunglasses house outward-facing sensors. These sensors are designed for future technological enhancements. Potential applications include camera-based vision systems. These could interpret visual information for the user. Another future possibility is the integration of auditory AI. This could process sound cues and provide audio feedback.



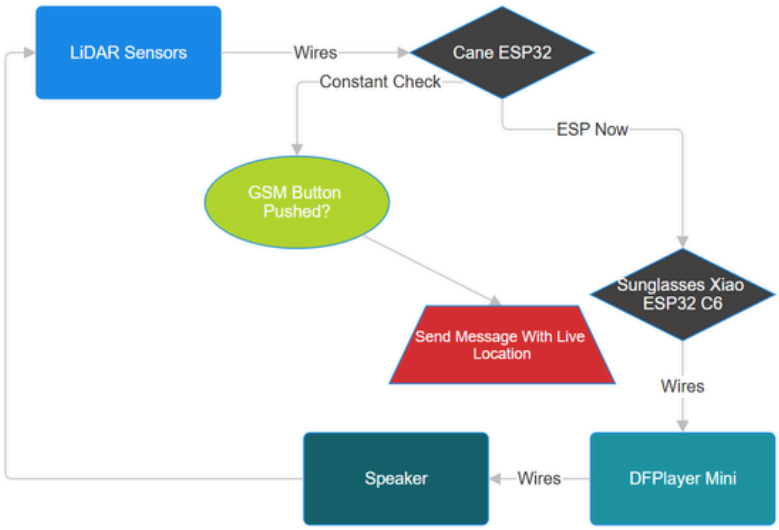
Currently, the glasses provide a significant benefit for user orientation. They actively assist in guiding the user's experience. The system helps align narration cues. This alignment is based on the user's head direction. It ensures that spoken guidance corresponds accurately. This feature enhances the user's spatial awareness. It makes navigation more intuitive and reliable

SOFTWARE SYSTEM

The software backbone integrates multi-sensor fusion, obstacle priority logic, and condition-based response triggers. It's written in C++ using the Arduino IDE, and runs on an ESP32 microcontroller. Each LiDAR sensor feeds distance data into a central logic system, while modules like the GPS and GSM handle location tracking and communication. The program checks for distance, direction, and user movement before deciding what feedback to give.

For example:

- If an obstacle is within 0.5m directly ahead, the system issues a high-priority voice alert immediately.
- If the user keeps moving toward the obstacle, the same alert will only repeat after a short cooldown period, preventing spam.
- If no obstacle is detected, the system continues scanning without giving unnecessary updates.
- A separate interrupt listens for the emergency button. If pressed, it overrides all normal logic to trigger a GSM call + SMS with GPS.




```
WiFi.mode(WIFI_STA);
esp_now_init();
esp_now_add_peer(&peerInfo);

esp_now_send(receiverMAC,
    (uint8_t*)&sensorData,
    sizeof(sensorData));
```

```
if (digitalRead(BUTTON_PIN) == LOW &&
    millis() - lastButtonPressTime > debounceDelay) {
  sendSMS();
  lastButtonPressTime = millis();
}
```

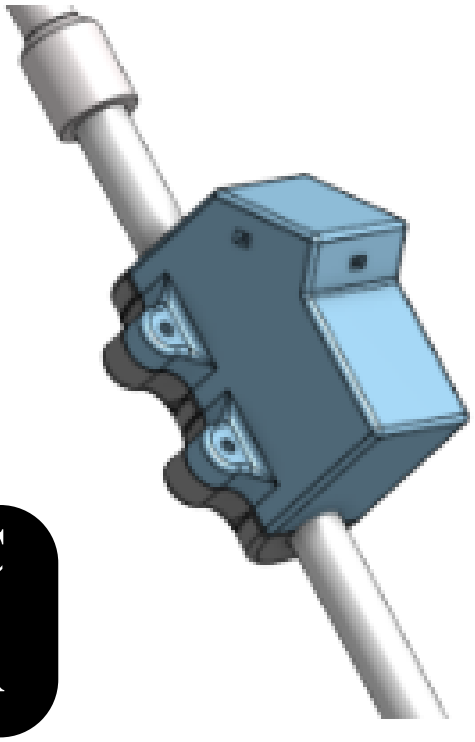
```
for (int i = 0; i < SENSOR_COUNT; i++) {
  sensors[i].rangingTest(&measure, false);
  sensorData.distances[i] = (measure.RangeStatus != 4) ?
      measure.RangeMilliMeter : 0xFFFF;
}
```

STRUCTURAL AND PHYSICAL DESIGN

The cane's physical design was carefully optimised for comfort and efficiency. Using trigonometric calculations based on average arm length and hanging angle, we determined that an ideal resting and usage angle for the cane was approximately 51 degrees. This ensures that the user can hold the cane naturally without strain while maintaining accurate sensor positioning and forward visibility. To further improve usability and eliminate the need for constant tapping, common with traditional white canes, we incorporated a caster wheel at the base. This allows the user to glide the cane smoothly across the ground while maintaining contact, improving balance, terrain detection, and comfort during longer use. Our system is also highly modular and fully preassembled, unlike existing smart canes like the IIT SmartCane, which requires a chassis to be clipped onto traditional canes. Pathfinder eliminates this setup complexity, offering a plug-and-play experience right out of the box. Additionally, by replacing vibration cues with voice narration, we sidestep the ambiguity and interpretation errors associated with ultrasonic-based systems.

STRUCTURAL AND PHYSICAL DESIGN

CAD MODEL OF PATHFINDER



ELECTRONIC HUB OF THE PATHFINDER

SOCIAL IMPACT AND INNOVATION

The Global Need

Pathfinder is a breakthrough mobility solution that reimagines the traditional white cane for blind and visually impaired individuals. By integrating advanced obstacle detection and voice guidance, Pathfinder turns navigation into an active, autonomous process rather than a passive experience. Through real-time spatial awareness, it empowers users to move independently and confidently in complex environments.

Globally, this is a pressing need. According to the World Health Organization (2023), over 44 million people are blind and 295 million are moderately to severely visually impaired. These individuals often face significant barriers to education, employment, and participation in society. The World Bank notes that visual impairment is closely tied to poverty and social exclusion. The United Nations Convention on the Rights of Persons with Disabilities calls for enabling technologies that foster autonomy and inclusion, an ideal that Pathfinder embodies.

Unlike standard canes or even ultrasonic SmartCanes, Pathfinder is a fully integrated system designed from the ground up. Many existing “smart” aids use vibration feedback, which can be unclear in noisy, crowded settings. Others require users to strap additional components onto existing canes, making them impractical for older or less tech-savvy users. Pathfinder addresses these problems through simplicity and completeness. It uses LiDAR sensors to detect obstacles and provides natural language voice alerts such as “object to your left” or “step down ahead.” It removes the ambiguity of vibrations and communicates clearly, enabling the user to make safe and confident choices in real time.

In emergencies, Pathfinder also includes a GSM module that can call a caregiver with the press of a button. This feature ensures peace of mind for both users and their families, especially in unfamiliar or high-risk locations.
The device includes a pair of smart sunglasses that help with orientation and make the technology more intuitive to use. Combined with a caster wheel and a carefully engineered 51-degree angle optimized through trigonometry, Pathfinder is easy to maneuver, even for extended use.

SOCIAL IMPACT AND INNOVATION

Real-World Scenarios

Its effectiveness is especially clear in high-traffic environments like Mumbai's Chhatrapati Shivaji Maharaj Terminus, where millions of people navigate through narrow platforms, unexpected drop-offs, and dense pedestrian flows. A traditional cane might miss obstacles above the waist or fail to detect a sudden step, but Pathfinder's voice alerts make such dangers clear before they happen. If the user becomes disoriented, the GSM system allows them to call a trusted contact for assistance.

Pathfinder is equally useful in other settings. A blind college student could navigate a campus without needing a guide. An employee in a tech park could travel independently to meetings or lunch. In rural areas with poor infrastructure, Pathfinder detects road edges, irregular terrain, and ditches, providing a reliable safety net.

Empowering Lives

Beyond navigation, Pathfinder has broader social and emotional impacts. Institutions like the Perkins School for the Blind have shown that mobility independence significantly boosts mental health, self-esteem, and long-term well-being. It also reduces the burden on caregivers, who often spend hours each day assisting with basic movement. In hospitals and eldercare facilities, Pathfinder can reduce the need for mobility support staff, freeing up resources for critical care tasks.

Alignment With Global Goals

The World Health Organization's World Report on Vision emphasizes the growing need for assistive technologies like Pathfinder. It recommends integrated, people-centered solutions to meet global eye care demands. Pathfinder fits within this model as a rehabilitative tool that supports user health, dignity, and inclusion. It also directly supports global development goals like SDG 3 (Good Health and Well-Being), SDG 4 (Quality Education), SDG 10 (Reduced Inequality), and SDG 11 (Sustainable Cities and Communities).

SOCIAL IMPACT AND INNOVATION

Cost, Scale, and Deployment

Pathfinder is also designed with scalability and affordability in mind. It uses cost-effective components like the ESP32 microcontroller, VL53L0X LiDAR modules, and GSM chips to keep prices accessible for users in both high and low-income settings. The total cost excluding components that broke was around 6,500 Indian Rupees. As production scales, it can be distributed through public healthcare systems, blind schools, government accessibility programs, or assistive tech platforms. Initiatives like India's Accessible India Campaign and the US Department of Transportation's Accessibility Strategic Plan emphasise inclusive infrastructure and mobility innovation. Pathfinder naturally fits into such efforts and can be deployed in public transit systems, urban centers, or educational institutions without significant adaptation.

In summary, Pathfinder is not just a smart cane; it is a reinvention of mobility. With a focus on clarity, safety, and ease of use, it closes critical gaps in current assistive technology. It helps people move freely, access education and employment, and participate fully in society. By doing so, Pathfinder doesn't just improve lives; it upholds the right to accessibility as a fundamental part of human dignity.

Pathfinder: Sees. Speaks. Protects.
Innovates for Inclusion

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