UNSEEN CHALLENGE (For Visually Impaired Users)

TEAM NAME: 09-LUMINIOR

PROBLEM STATEMENT

Visually impaired individuals face serious challenges in safe and independent navigation due to the presence of obstacles at **floor, body, and head levels** in everyday environments. These obstacles include steps, curbs, potholes, furniture, hanging objects, boards, and branches, which often lead to collisions, falls, and injuries.

Most existing assistive devices and electronic aids:

- Detect only **forward-facing or ground-level obstacles**
- Rely heavily on **audio feedback**, which can be distracting, socially intrusive, and unsafe in noisy environments
- Depend on **internet connectivity**, reducing reliability in rural, indoor, or emergency situations
- Lack **integrated emergency support** in case of falls or accidents

Additionally, current solutions do not provide **clear separation of obstacle information by height**, leading to confusion and increased cognitive load for users.

CORE CONCEPT

The core concept of the proposed system is to create a **multi-level tactile perception system** using **haptic feedback**.
Instead of relying on sound or vision, the system translates environmental information into **distinct vibration patterns** at different body locations, enabling intuitive and low-cognitive-load navigation.Each obstacle level (floor,

body, head) is sensed independently and communicated through **localized haptic motors**, creating a form of **3D tactile awareness**.

PROPOSED SOLUTION

The proposed solution is a **modular wearable assistive system** consisting of three coordinated sensing and feedback modules:

1. **Shin Module (Floor-Level Awareness)**
2. **Haptic Belt (Body-Level Awareness & Central Processing)**
3. **Head Band Module (Head-Level Awareness)**

All modules operate **offline**, communicate locally, and work together to provide complete spatial awareness.

FLOOR LEVEL AWARENESS — SHIN MODULE

The Shin Module is designed to detect **floor-level hazards before foot placement**, enabling visually impaired users to avoid accidents such as tripping, slipping, or falling. By positioning the sensing system near the shin and ankle region, the module provides **early and reliable detection** of ground-level obstacles that are often missed or detected too late by traditional white canes.

COMPONENTS

- **Ultrasonic Sensor (HC-SR04)**
  Mounted facing downwards to continuously measure the distance between the foot and the ground.
- **Time-of-Flight Sensor (VL53L0X)**
  Mounted facing straight forward to detect upcoming floor-level obstacles such as steps and curbs.
- **ESP32 Microcontroller**
  Acts as the local processing unit for sensor data and vibration control.

- **MPU-6050 IMU Sensor**
  Used for fall detection by monitoring sudden acceleration and orientation changes.
- **Haptic Vibration Motor (DC Motor)**
  Mounted near the ankle/shin region to deliver tactile warnings.
- **ULN2003 Motor Driver Module**
  Protects the ESP32 from high current draw and safely drives the vibration motor.
- **Li-ion Battery (3.7V)**
  Provides portable power for wearable operation.
- **TP4056 Charging Module (with protection)**
  Enables safe battery charging and protects against overcharging and deep discharge

Working Principle

The Shin Module uses **dual-distance sensing** to achieve robust floor-level awareness:

- The **ultrasonic sensor**, fixed downward, continuously scans the ground to detect:
    - Potholes
    - Sudden drops
    - Uneven surfaces
    - Missing steps
- The **Time-of-Flight (ToF) sensor**, fixed facing forward, detects:
    - Steps
    - Curbs

- Low-lying obstacles in the walking path

Sensor data is processed locally by the **ESP32**, ensuring fast response and offline operation. When a hazardous condition is detected, the ESP32 activates the vibration motor through the **ULN2003 driver**, producing a clear tactile alert at the ankle.

The **MPU-6050 IMU** continuously monitors motion patterns. In the event of abnormal acceleration or orientation changes indicating a fall, the module flags the event for emergency handling by the central system.

Output and User Feedback

- **Immediate vibration at the ankle** indicates floor-level danger
- Feedback is **silent**, avoiding reliance on audio cues
- Hazard information is intuitive and location-specific
- Early detection allows users to react **before foot contact**

BODY LEVEL AWARENESS - HAPTIC BELT

Purpose

The **Haptic Belt Module** is designed to detect and communicate **body-level (mid-level) obstacles** that are typically missed by floor-focused assistive devices. These obstacles include furniture edges, table corners, people, poles, walls, and other objects located between the waist and chest level.

In addition to obstacle detection, the belt functions as the **central processing unit (central brain)** of the entire wearable system, coordinating data from the shin module and smart glasses while managing emergency detection and alerts.

COMPONENT

- **ESP32 Microcontroller**
  Acts as the central controller responsible for sensor fusion, decision-making, and haptic feedback generation.
- **Time-of-Flight Sensor (VL53L0X)**
  Mounted facing forward on the belt to detect mid-level obstacles in the walking path.
- **Haptic Vibration Motors (360° Arrangement)**
  Multiple vibration motors placed around the belt to provide **directional feedback** (left, right, front).
- **MPU-6050 IMU Sensor**
  Used for **fall detection** by analyzing sudden acceleration, tilt, or impact.
- **GPS Module (NEO-6M)**
  Captures the user's location when an emergency or fall is detected.
- **Li-ion Battery with TP4056 Charging Module**
  Provides safe, rechargeable power for continuous wearable operation.

WORKING PRINCIPLE

The Belt Module operates using multi-sensor fusion and event-based control, enabling real-time perception and response.

• Mid-Level Obstacle Detection

- The central ToF sensor continuously scans the frontal walking path to detect mid-level obstacles such as walls, people, poles, or barriers.
- The left and right ultrasonic sensors monitor side obstacles, reducing blind spots and improving spatial awareness.

• Directional Haptic Feedback

- When an obstacle is detected:
  - Left obstacle → Left vibration motor activates

    - Right obstacle → Right vibration motor activates
    - Front obstacle → Both motors activate
- Vibration patterns vary based on obstacle proximity, enabling intuitive interpretation by the user.

• Fall Detection & Emergency Handling

- The MPU-6050 IMU monitors acceleration and orientation changes.
- Upon detecting a sudden impact combined with abnormal tilt:
    - The system classifies the event as an extreme fall
    - The buzzer is activated for nearby alert
    - GPS coordinates are captured
    - Location data is transmitted to a paired smartphone via Bluetooth

• Central Coordination Role

- The belt module also acts as a **decision coordinator**, integrating information from peripheral modules (such as the shin module) and ensuring synchronized, non-conflicting feedback.

OUTPUT AND USER FEEDBACK

- Directional belt vibration conveys obstacle location (left, right, or front)
- Silent haptic feedback ensures privacy and usability in noisy environments
- Audible buzzer alert activates during emergency conditions
- Bluetooth-based emergency message provides real-time location sharing
- Status LED confirms active system operation

HEAD LEVEL AWARENESS — HEADBAND MODULE

The Head Level Awareness Module is designed to detect obstacles and hazards located at or above the user’s head height, such as hanging objects and protruding structures, which pose a serious risk of injury to visually impaired users. By mounting the sensing system directly on a lightweight headband, the module maintains a natural field of detection aligned with the user’s head orientation, enabling accurate and timely hazard awareness.

COMPONENTS

• **Time-of-Flight Sensor (VL53L0X) – Forward Facing**
Mounted facing straight ahead to detect obstacles directly in the user’s forward path at head level, such as walls, poles, or approaching structures.

• **Time-of-Flight Sensor (VL53L0X) – Upward Facing**
Mounted with an upward tilt to detect overhead and hanging hazards above the user’s head, such as tree branches, signboards, low ceilings, and cables.

• **ESP32 Microcontroller**
Acts as the local processing unit, reading sensor data, determining hazard severity, and controlling vibration intensity.

• **Haptic Vibration Motors (Mini DC Motors)**
Mounted near the head or upper body region to deliver distinct tactile alerts corresponding to detected hazard levels.

• **ULN2003 Motor Driver Module**
Safely drives the vibration motors while protecting the ESP32 from high current loads and voltage spikes.

• **Li-ion Battery (3.7V)**
Provides portable and rechargeable power suitable for continuous wearable operation.

• **TP4056 Charging Module (with Protection)**
Ensures safe battery charging and includes protection against overcharging, over-discharging, and short circuits.

Working Principle

The Head Level Module employs **dual ToF-based distance sensing** to achieve reliable detection of head-level and overhead hazards:

• The **forward-facing ToF sensor** continuously measures the distance to obstacles located straight ahead at head height, detecting:

- Walls
- Poles
- Standing objects
- Approaching structures

• The **upward-facing ToF sensor** monitors the space above the user's head to detect:

- Hanging tree branches
- Low signboards
- Overhead cables
- Low ceilings or protrusions

Both sensors operate independently of ambient lighting, ensuring reliable performance in daylight, darkness, and indoor environments.

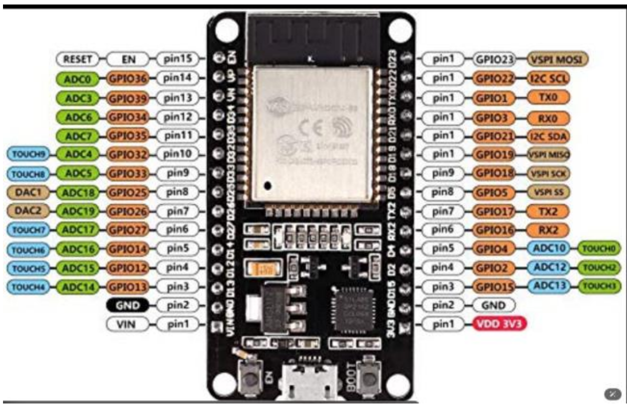
Sensor readings are processed locally by the ESP32 using Arduino-based firmware. Based on the detected distance and severity of the hazard, the ESP32 determines the appropriate alert level and activates the vibration motors via the ULN2003 driver.

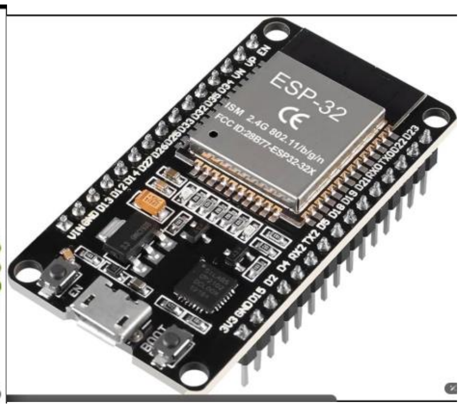
Output and User Feedback

• **Graduated vibration intensity** indicates hazard proximity (far, near, immediate)
• Alerts are **silent**, avoiding audio dependency
• Feedback is **location-specific**, clearly indicating head-level danger
• Early warning allows users to slow down, stop, or adjust posture before impact

COMPONENTS USED IN THE UNSEEN SYSTEM

ESP32 MICROCONTROLLER — MAIN BRAIN





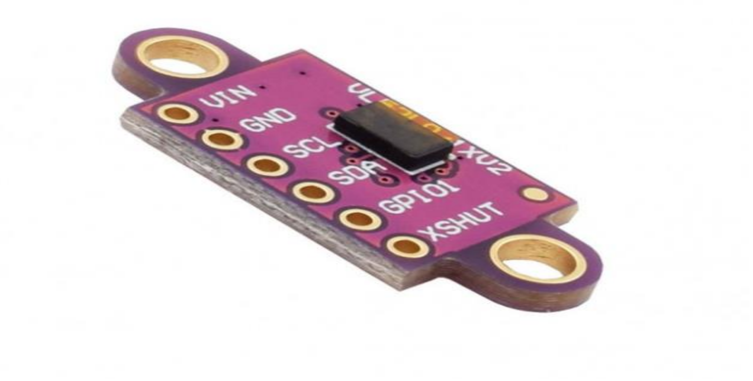
What it is:
A small but powerful microcontroller board.

What it does in your project:

- Reads sensor data (ToF, Ultrasonic, MPU6050)
- Makes decisions (obstacle / fall detected or not)
- Controls vibration motors
- Sends Bluetooth emergency alert
- Works offline — no internet needed

Simple idea: It is the **brain** of each module.

TIME-OF-FLIGHT SENSOR (VL53L0X) — DISTANCE SCANNER



What it is:
A laser-based distance sensor.

Used in your system for:

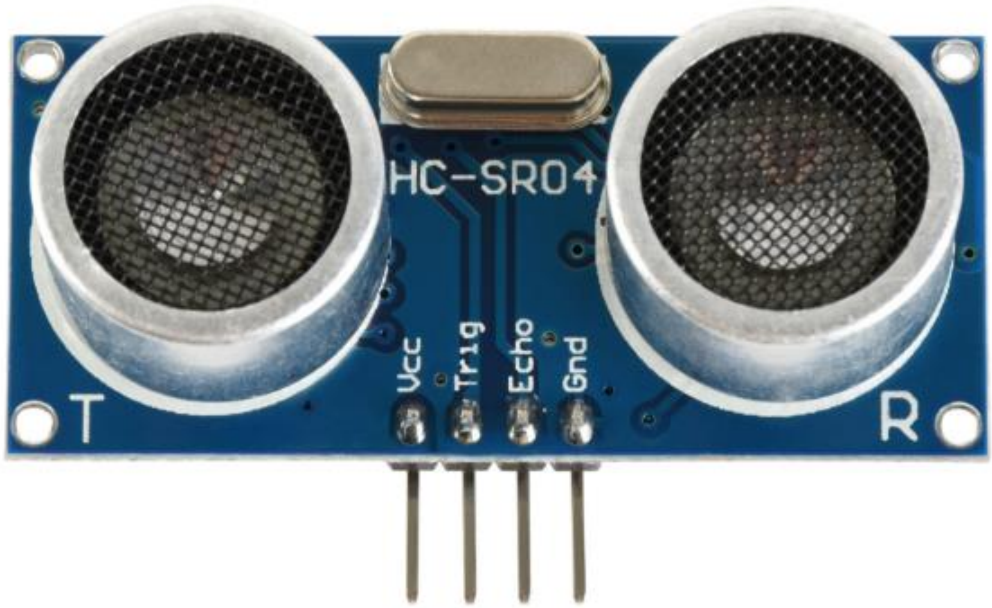
- Floor obstacle detection
- Body obstacle detection
- Head-level hazard detection
- Overhead object detection

Why it's good:

- Very accurate
- Works in dark/light
- Fast response
- Small size → good for wearable

Simple idea: Measures **how far an object is** in front or above.

ULTRASONIC SENSOR (HC-SR04) — ECHO DISTANCE SENSOR



What it is:
A sound-wave distance sensor.

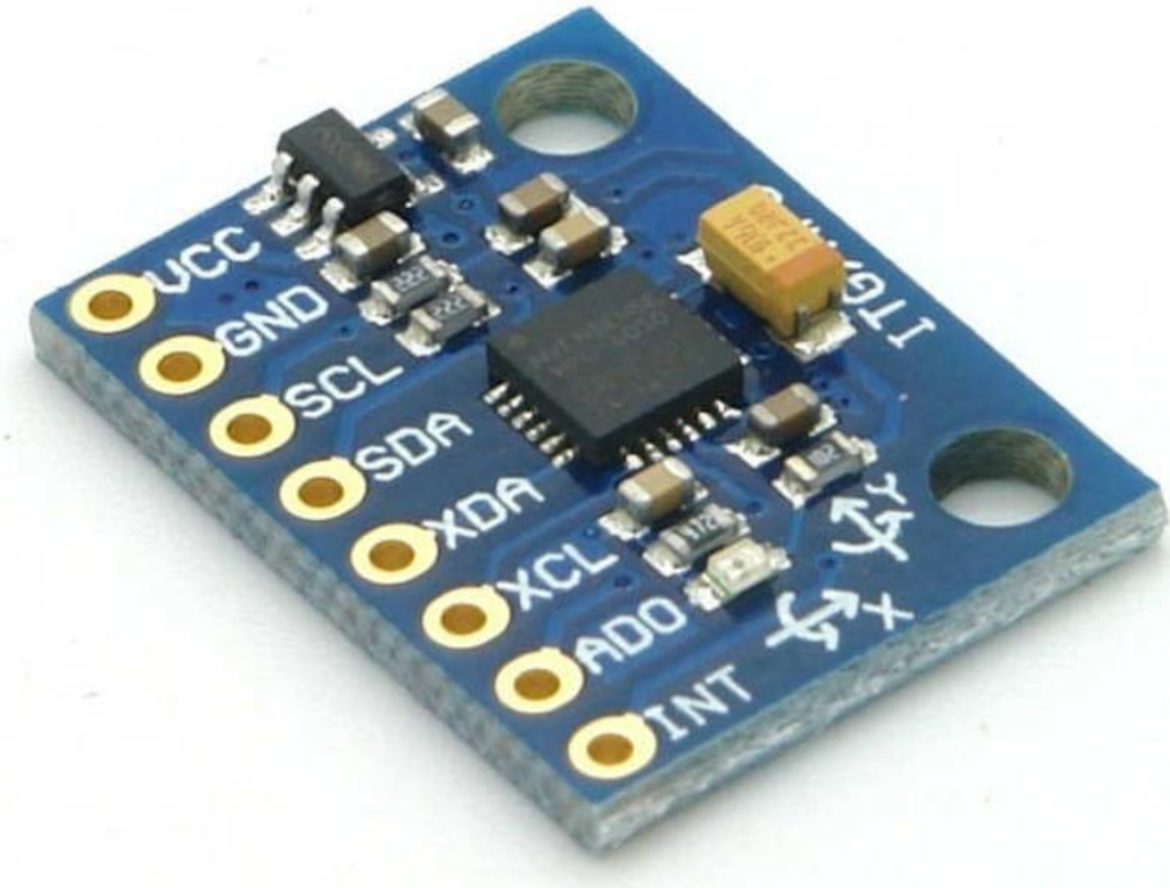
Used in your shin & belt modules for:

- Ground drop detection
- Side obstacle detection
- Step & pothole sensing

How it works:
Sends sound → waits for echo → calculates distance.

Simple idea: Like a **mini bat sonar**.

MPU6050 IMU — FALL DETECTION SENSOR



What it is:
Motion + tilt + acceleration sensor.

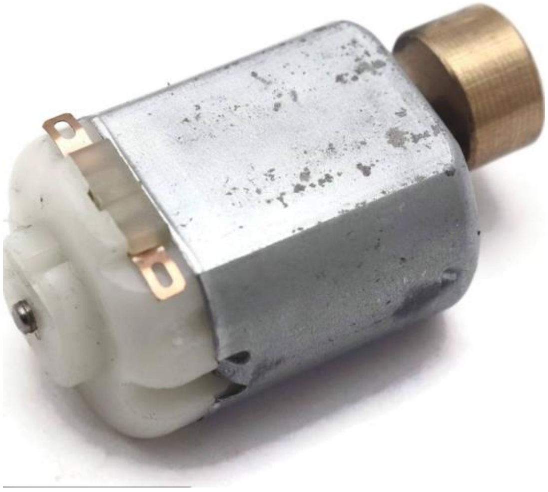
Used for:

- Fall detection
- Sudden impact detection
- Orientation change monitoring

In your project:
If sudden tilt + strong acceleration → system marks **fall event**

Simple idea: Detects **body movement & sudden drops**.

VIBRATION MOTOR — TACTILE FEEDBACK



What it is:
A tiny motor that vibrates instead of spinning normally.

Used for:

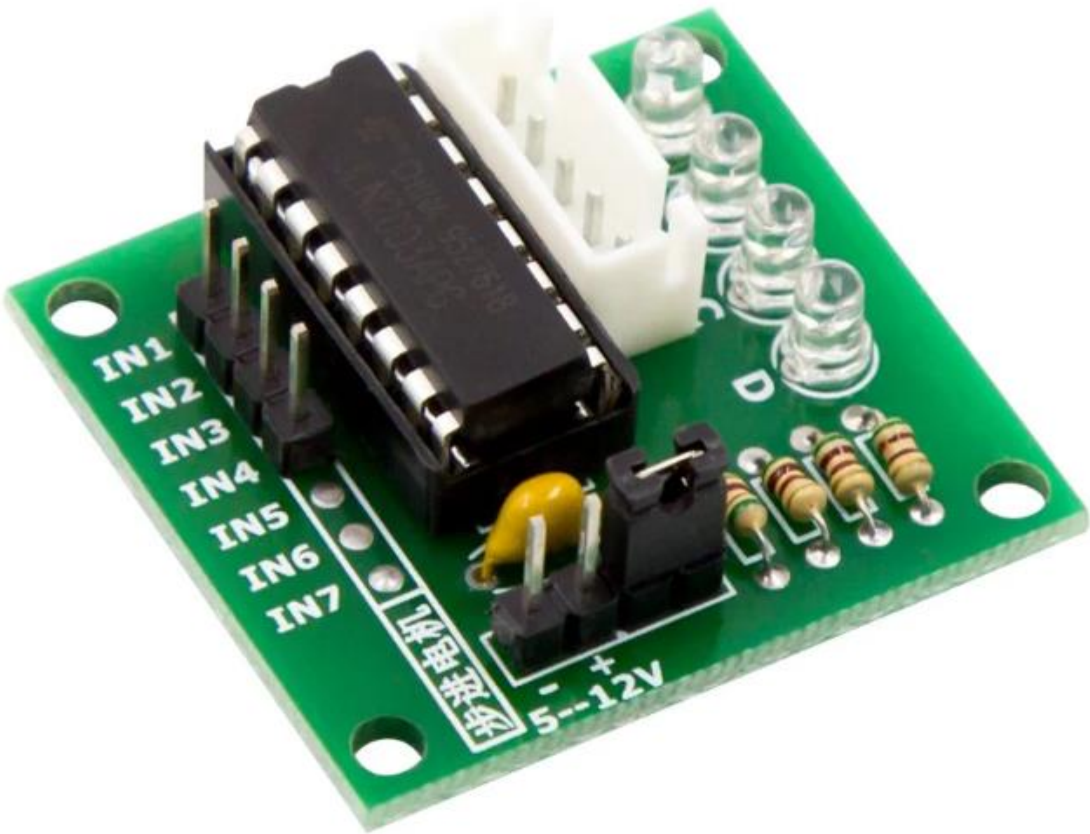
- Silent alerts
- Direction feedback
- Level-based obstacle warning

In your system:

- Shin vibration → floor danger
- Belt vibration → body obstacle direction
- Head vibration → head hazard

Simple idea: Converts warning into **touch signal instead of sound**.

ULN2003 DRIVER — MOTOR PROTECTOR



What it is:
A driver circuit for motors.

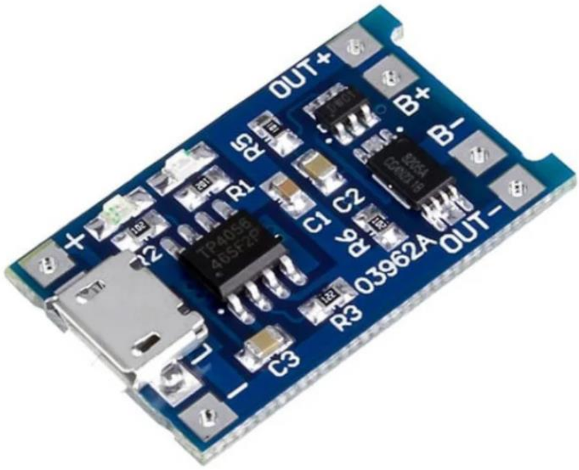
Why needed:
ESP32 cannot safely power motors directly.

Used for:

- Driving vibration motors
- Protecting ESP32 from high current
- Stable motor control

Simple idea: Acts like a **power switch helper**.

LI-ION BATTERY + TP4056 CHARGER



What it is:
Rechargeable battery + safe charging board.

Used for:

- Portable wearable power
- Safe charging
- Overcharge protection
- Deep discharge protection

Simple idea: Gives **portable energy** to your wearable modules.

GPS MODULE (NEO-6M) — LOCATION SENDER

What it is:
Satellite location receiver.

Used in belt module for:

- Getting coordinates after fall
- Sending emergency location
- Offline GPS tracking

Simple idea: Finds **where the user is**.