PROJECT ABSTRACT

IoT Pothole Detection using Ultrasonic Sensor

Vehicle-mounted sensing unit that detects potholes and bumps: downward-facing HC-SR04 road profiling, MPU6050 jolt cross-check, NEO-6M GPS tagging and ESP32 MQTT telemetry to a live map dashboard. Built-to-order student kit with firmware, report, PPT and viva Q&A.

01. Title

IoT Pothole Detection using Ultrasonic Sensor

02. Introduction / Background

Potholes damage vehicles and cause accidents, yet road-condition surveys in most cities are still manual, infrequent and subjective. A low-cost sensing unit on ordinary vehicles could make defect reporting continuous and location-accurate: measure the road profile, flag sudden dips and bumps, attach GPS coordinates, and stream the events to a map. This project builds the sensing-and-telemetry half of that vision at student scale: an ultrasonic sensor profiles the road, an accelerometer confirms the jolt, and an ESP32 publishes geo-tagged events to a live dashboard — the real architecture such systems use, on a model-vehicle demonstrator.

03. Problem Statement

Municipal road surveys rely on inspectors driving stretches and noting defects by eye — slow, infrequent, and without precise locations. Students learning IoT and sensor fusion rarely get a project that combines continuous sensing, event detection, geo-tagging and cloud telemetry in one pipeline. The project addresses this by building a vehicle-mounted unit that detects potholes and bumps, verifies them with a second sensor, geo-tags them, and streams them to a live map, with an honest demo-scale scope.

04. Objectives

- Build a vehicle-mounted sensing unit: HC-SR04 ultrasonic road profiler, MPU6050 accelerometer, NEO-6M GPS and ESP32 controller with microSD backup.
- Implement fusion logic: rolling road-distance baseline, depth-threshold candidate events, and MPU6050 vertical-jolt confirmation to filter false positives.
- Publish geo-tagged events as JSON over Wi-Fi/MQTT to a live Node-RED/Blynk map dashboard; log to SD when offline.

- Make pothole depth and jolt thresholds configurable without firmware changes, with a documented tuning procedure.
- Deliver unit, firmware, dashboard guide, report, PPT and viva Q&A.

05. Proposed Methodology

The HC-SR04 continuously measures the distance from the vehicle underside to the road. A rolling baseline is maintained; deviations beyond the configured depth threshold start a candidate event. The MPU6050's vertical acceleration is checked for a matching jolt spike in the same window — sudden distance increase plus jolt classifies a pothole, sudden decrease plus jolt a bump. The ESP32 reads the NEO-6M GPS, packages the event as JSON, publishes it over MQTT and appends it to the microSD log. The dashboard subscribes to the event topic and drops a marker on the live map with depth, jolt and timestamp.

06. System Architecture / Working

Sensing: downward-facing HC-SR04 (2-400 cm, ~±3 mm typical) plus MPU6050 triaxial accelerometer. Positioning: NEO-6M GPS over UART (~2.5 m CEP, open sky). Processing: ESP32-WROOM-32 runs the baseline, threshold and fusion logic in Arduino-framework firmware. Telemetry: Wi-Fi to a Mosquitto MQTT broker; Node-RED/Blynk dashboard renders the live map. Backup: microSD event log for offline stretches. Power: 5 V from vehicle USB or a 12 V buck converter. GSM uplink via SIM800L is a documented optional customization.

07. Hardware / Software Requirements

- ESP32-WROOM-32, firmware in Arduino IDE (C++)
- HC-SR04 ultrasonic sensor (~15° beam); MPU6050 accelerometer
- u-blox NEO-6M GPS module (UART, NMEA)
- Mosquitto MQTT broker; Node-RED/Blynk live map dashboard
- microSD card module; adjustable model-vehicle mounting bracket
- 5 V vehicle power (buck converter from 12 V); Wi-Fi hotspot for live telemetry

08. Expected Outcomes

A working sensing unit that detects potholes and bumps on a demo vehicle, a live map dashboard with geo-tagged event markers, and a threshold-tuning procedure the student applies to their test surface. The deliverable is validated at demo-vehicle speeds: real-road, traffic-speed operation would need a faster sensor, rugged mounting and field trials, stated as future scope. The kit includes commented firmware, wiring diagram, dashboard setup guide, report, PPT and viva Q&A.

09. Applications

- Smart-city road-monitoring concept demonstrations
- Sensor-fusion and threshold-detection coursework
- Geo-tagged IoT telemetry teaching (GPS + MQTT + dashboards)
- Civic-tech project exhibitions

10. Future Scope

- SIM800L GSM uplink for hotspot-free telemetry
- ML-based classification of defect types from the sensor signatures
- Camera confirmation snapshots attached to events
- Real-vehicle trials with ruggedized mounting