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PRESSURE AND SENSOR-BASED RAILWAY TRACK OBSTACLE DETECTION WITH GPS AND REAL-TIME SMS ALERT TO FOLLOWING TRAINS

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ABSTRACT—

Railway tracks are hard to watch continuously, and a missed obstacle or weak spot can put a train at risk. Staff cannot realistically inspect every stretch of track all the time. This paper describes a low-cost embedded system that picks up signs of abnormal pressure and obstacles on a railway track. Piezoelectric sensors read by an Arduino UNO sense abnormal pressure, while IR and ultrasonic sensors read by an ESP32 add train-presence and obstacle information. A GPS NEO-6M module supplies latitude and longitude, and a buzzer gives an immediate local warning. We also propose a GSM stage that would send an SMS with the obstacle location to the following train. The prototype demonstrates pressure-based detection, GPS location and local alerts; the SMS stage is proposed and has not yet been tested. Final figures for detection accuracy, range, response time and false alarms still have to come from testing the prototype.

Index Terms—*Railway track monitoring, piezoelectric sensor, obstacle detection, ESP32, Arduino UNO, GPS, IR sensor, ultrasonic sensor, SMS alert, railway safety.*

INTRODUCTION

Railways carry a large share of the world's passengers and goods, and safe operation depends on the condition of the track. Cracks, weakened sections, misalignment and objects lying on the rails can all create danger for an approaching train, often with very little time to react.

In most places, track is checked by people walking or riding along it at set intervals. That takes a lot of effort, cannot cover every section all the time, and leaves a gap between a problem appearing and someone noticing it. Some cases will inevitably slip through.

An automated system can help by watching for abnormal conditions and raising an alert right away, so staff do not have to keep an eye on every stretch of track. With embedded electronics, the same alert can also carry the location of the problem.

We built an embedded system around an ESP32 microcontroller, an Arduino UNO, piezoelectric pressure sensors, IR and ultrasonic sensors and a GPS module. A piezoelectric sensor produces a voltage when force or vibration acts on it, so an unusual reading can point to a disturbance, defect or obstruction. GPS ties that event to a position, and the IR and ultrasonic sensors add information about train movement and objects ahead. When an abnormal condition is found, a buzzer gives an immediate local warning.

The main extension we propose is to go beyond a local alarm. When an obstacle is detected, the system would attach the GPS position to a warning and send it by SMS so the following train can slow down, stop or change route where possible. This part is a proposal, not a tested result.

The system is meant to support railway staff, not replace them. Piezoelectric output depends on mounting and loading, and ultrasonic and IR sensing can be affected by surroundings, so careful threshold selection and experimental validation matter more than any single component.

LITERATURE SURVEY

Researchers have tried many ways to monitor railways automatically, including pressure, vibration, strain, ultrasonic and acoustic sensing, and data analysis of track geometry.

A. Peinado Gonzalo reviewed data analytics for condition monitoring of railway track geometry [1]. It shows how valuable measured track data is, but it is about analysing data, not about a small low-cost unit that raises an alert on the spot.

M. Kostrzewski and R. Melnik carried out a bibliometric and systematic review of condition monitoring in rail transport [2]. It maps the field well, but a review does not give a working circuit.

M. Sol-Sanchez studied smart rail pads for the continuous monitoring of sensed railway tracks [3]. Sensors built into the track give continuous data, but they need installation work along the line.

J. M. Castillo Mingorance et al. reviewed sensors for continuous monitoring of smart and sustainable railway infrastructure [4]. It compares sensor types, which supports using several kinds together, as we do. Being a review, it does not describe a working alert unit. Table I summarizes these approaches.

TABLE I. SUMMARY OF RELATED APPROACHES

Approach	Strength	Limitation
Track-geometry data analytics [1]	Makes use of measured track data	Analysis focus, not an on-site alert unit
Review of condition monitoring [2]	Broad view of methods in the field	Review only, no working system
Smart rail pads [3]	Continuous sensing of the track	Needs installation in the track
Review of monitoring sensors [4]	Compares many sensor types	Review only, no working system
This work	Pressure, IR, ultrasonic and GPS with local alert, low cost	SMS to following train proposed, not yet tested

PROBLEM STATEMENT

Railway tracks can have obstacles, abnormal pressure, cracks, misalignment or weakened sections that put trains at risk. Manual inspection cannot watch every stretch of track all the time, so there is a delay between a problem occurring and someone finding it.

There is a second problem. Even when an obstacle is found, the following train may not hear about it early enough. That creates a need for an automated system that detects abnormal pressure or obstacles, finds their location, raises an immediate alert, and has a way to warn the following train.

OBJECTIVES

The main objectives are:

- to monitor railway track pressure in real time using piezoelectric sensors;
- to find the location of a fault using GPS;
- to detect train movement using IR sensors;
- to detect obstacles using ultrasonic sensors;
- to process sensor data on an ESP32 and give an immediate local alert;
- to propose a real-time SMS warning with location to the following train; and
- to keep the design low-cost and scalable, so it can support preventive maintenance and faster decisions.

PROPOSED SYSTEM

The system has four main parts: sensing, processing, location and alerting, and communication [1]-[4].

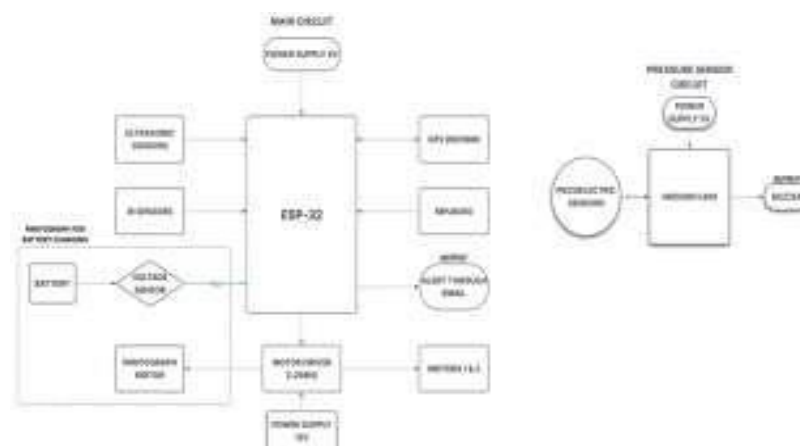
A. System Architecture

Piezoelectric sensors monitor pressure or vibration on the track, and an Arduino UNO reads them. IR and ultrasonic sensors give extra information about train presence and objects ahead, and an ESP32 handles them along with GPS, motor control and the other monitoring functions. The thresholds are chosen experimentally, based on how the sensors behave under normal conditions and under controlled abnormal conditions.

When pressure crosses a chosen threshold or an obstacle is identified, the controller raises a warning condition. The GPS position is attached to the event and a buzzer gives the local alert. The proposed GSM stage would carry the same warning and position to the following train by SMS. Fig. 1 shows the block diagram.

The sensors feed the controllers as separate inputs; they are not connected in series. The final block diagram should match the actual connections in the prototype.

Fig. 1. Block diagram of the proposed system



B. Key Components

ESP32 Microcontroller: The main controller for the multi-sensor section. It reads the ultrasonic and IR sensors, processes the GPS data, compares readings with thresholds, and drives the outputs.

Arduino UNO: Used in the pressure-sensing circuit to read the piezoelectric sensors on its analog inputs.

Piezoelectric Sensors: Produce a voltage when force or vibration acts on them. The output depends on how they are mounted and how much force is applied, so calibration is needed.

GPS NEO-6M: Gives latitude and longitude for a detected event. Accuracy depends on signal availability.

IR and Ultrasonic Sensors: IR sensors detect the presence of a train or object. Ultrasonic sensors measure distance and help with obstacle detection. Both have limited range, and readings change with distance and surroundings.

Output Indicator: The buzzer gives an audible local warning without anyone having to watch a screen.

GSM/SMS Stage (proposed): Would send the warning and GPS position to the following train. It needs reliable GSM coverage and has not been built or tested yet.

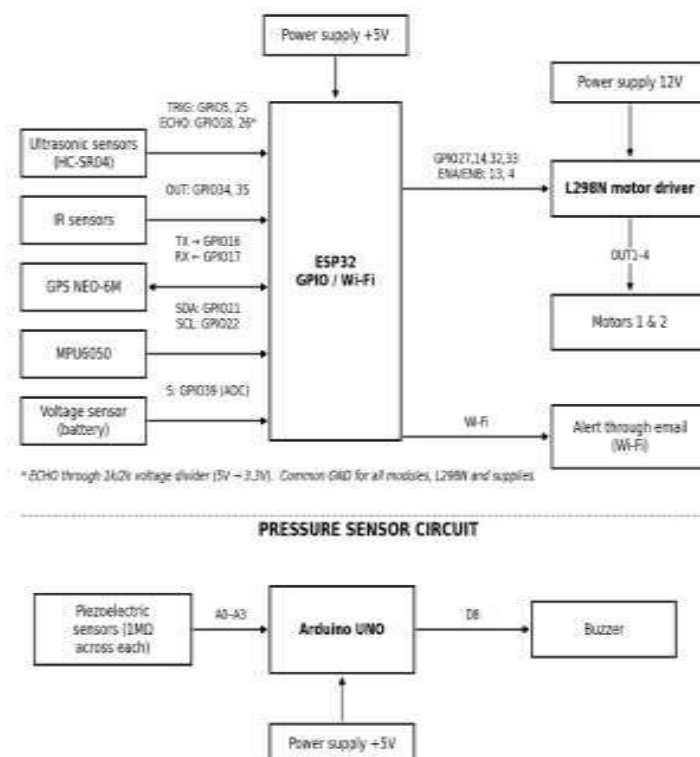
IMPLEMENTATION

A. Hardware Implementation

The prototype uses an ESP32 as the main controller for the multi-sensor section. Ultrasonic sensors at the front detect obstacles, and IR sensors give additional detection. A voltage sensor monitors the battery level, the GPS NEO-6M supplies latitude and longitude, and an L298N motor driver controls the DC motors that move the prototype. Fig. 2 shows the connection layout.

The track pressure-sensing circuit uses an Arduino UNO and several piezoelectric sensors connected to analog inputs, so the voltage produced by applied pressure can be measured. A 1 MΩ resistor is used in the sensor circuit. When the Arduino sees a sudden rise in sensor voltage, it turns on the buzzer as a local warning. The piezoelectric readings stay with the Arduino, and the ESP32 handles the other sensors.

Fig. 2. Circuit connection diagram



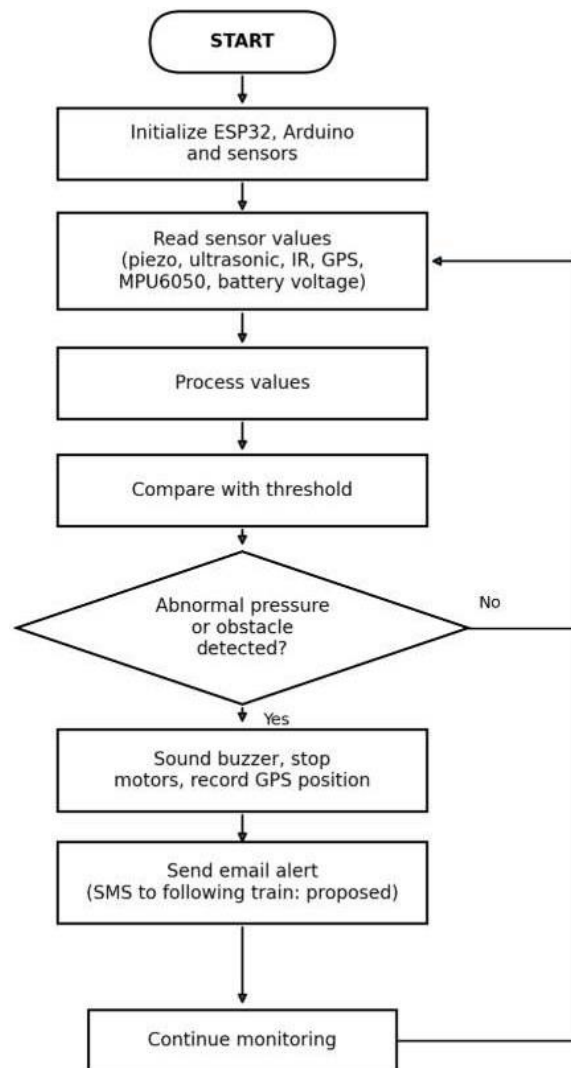
B. Software Implementation

The software is written in the Arduino development environment. On power-up, the controllers initialize the sensors, output devices, GPS communication and other interfaces. They then read the piezoelectric, ultrasonic and IR sensors continuously. Piezoelectric readings are compared with a predefined threshold, IR and ultrasonic readings are used for obstacle and movement detection, and GPS data is processed to get latitude and longitude. The flow is Sensor Reading → Signal Processing → Threshold Comparison → Detection Decision, as shown in Fig. 3:

1. Initialize ESP32, Arduino and sensors.
2. Read pressure and obstacle values.
3. Process the values.
4. Compare with the threshold.
5. If an abnormal condition or obstacle is found, sound the buzzer, stop the prototype and record the GPS position.
6. Prepare the proposed SMS warning with the position.
7. Return to step 2 and keep monitoring.

The SMS-to-following-train function is the proposed extension. It is not part of what has been demonstrated in the project report.

Fig. 3. Flow diagram



C. Sensor Calibration and Threshold Selection

Choosing thresholds is one of the most important parts of this system. A fixed value should not be picked without testing, because readings change with mechanical loading, vibration, distance, surroundings and sensor placement.

The process starts by recording readings under normal track conditions. Next, readings are collected under controlled abnormal pressure and obstacle conditions. That data is used to pick a threshold, which is then validated by repeated testing before use. When the pressure, IR and ultrasonic readings are used together, a combined decision rule can be developed to make detection more reliable.

RESULTS AND DISCUSSION

The prototype shows the basic operation of track monitoring with piezoelectric pressure sensors. Under applied pressure, the sensors produce measurable voltage changes, and when an abnormal pressure condition is detected the buzzer sounds as a local warning.

The GPS NEO-6M module gives coordinates that can be tied to a detected condition, so the system can report where an abnormal event happened instead of only that one happened. The prototype also uses IR and ultrasonic sensing for movement and obstacle detection. Together, pressure sensing and GPS show that detecting an abnormal condition and finding its location automatically is feasible.

The project report has no measured accuracy figures, so Table II lists the tests and the behaviour we expect. The measured column should be filled with real readings once the experiments are done; no values are claimed here.

TABLE II. RECOMMENDED TESTS (RESULTS TO BE RECORDED)

Test Condition	Expected Decision	Measured Result
Normal track, no load	No alert	To be measured
Controlled abnormal pressure on piezoelectric sensors	Voltage above threshold, buzzer on	To be measured
Object placed in front of ultrasonic sensor	Obstacle detected, prototype stops	To be measured
Train or object passing IR sensor	Presence detected	To be measured
Abnormal event with GPS fix	Latitude and longitude recorded	To be measured
Abnormal event with weak GPS signal	Behaviour without a fix noted	To be measured

The SMS stage would add a further safety layer by sending the warning and GPS position to the following train, which is meant to cut the delay between detection and warning. The project report lists GSM as an objective and wireless communication as future work, so SMS-to-following-train performance is not claimed as verified here. The final report should also include detection accuracy, range, response time, and false-alarm and missed-detection rates. needs reliable GSM coverage and would have to be integrated with proper railway communication and signaling systems before any real deployment.

IX. CONCLUSION AND FUTURE SCOPE

A. Conclusion

This paper presented a railway track monitoring system built from piezoelectric sensors, IR and ultrasonic sensors, GPS and embedded controllers. The prototype demonstrates abnormal pressure detection, GPS-based location, obstacle sensing and local alerts, which give a base for automated railway safety monitoring and preventive maintenance. The proposed SMS stage would extend this from local detection to early warning for the following train. Since pressure and distance sensing depend on the setup, proper calibration and experimental validation are essential.

B. Future Scope

A few directions seem worth pursuing next: actual GSM/SMS integration and testing; train-to-train communication; better sensor calibration and a combined decision rule; machine learning to separate real obstacles from false triggers; cloud-based monitoring and data logging; long-range communication; weatherproofing for outdoor use; and integration with railway signaling systems.

ADVANTAGES AND LIMITATIONS

A. Advantages

The system monitors the track continuously and detects abnormal pressure automatically. GPS gives the fault location, IR and ultrasonic sensors add obstacle detection, and the buzzer gives an immediate local alert. The ESP32-based design is low-cost and compact, and the SMS stage could give real-time warnings to following trains.

B. Limitations

Piezoelectric output depends on the mechanical arrangement and applied force, so calibration is important. GPS performance varies with signal availability. IR and ultrasonic sensors have limited range. The SMS stage

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