Acoustic Sensor Based Rail Road Defect Detection

by

Sai Likhitha G
Roll No. 224G1A3278

Venkata Balaji Sai R
Roll No. 234G5A3213

Ganganna G
Roll No. 234G5A3205

Pranay Kumar Reddy V
Roll No. 214G1A3277

Under the guidance of

Dr. P.Chitralingappa M.Tech, Ph.D
Associate Professor & HOD

Department of Computer Science and Engineering

Srinivasa Ramanujan Institute of Technology

Autonomous

Rotarypuram Village, B K Samudram Mandal, Ananthapuramu – 515701.

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Review - 0 comments

- System architecture was improved with **clear planning and design separation.**
- Design block diagram was updated to show **sensor, controller, communication, and cloud layers.**
- Literature survey was shortened and aligned to **proposed system**
- Reviewer questions on **sensor range, placement, and scalability** were addressed.
- Project roles and individual contributions were clearly defined

Contents

Abstract

This project proposes a cost-effective and reliable rail defect detection system that utilizes acoustic wave technology to identify cracks, fractures, and surface wear in real time. The solution integrates IoT-enabled acoustic sensors with an ESP32 microcontroller and LoRaWAN communication to provide continuous monitoring of railway tracks. By transmitting data wirelessly over long distances, the system enables early detection of defects and supports predictive maintenance practices. Designed to be scalable and robust in harsh outdoor environments, the proposed approach enhances railway safety, reduces the need for manual inspections, and lowers overall maintenance costs.

Keywords: Rail defect detection, Acoustic sensors, IoT, ESP32, LoRaWAN.

Introduction

- Railways are a vital mode of transportation, requiring safe and reliable track infrastructure
- Rail tracks are exposed to continuous mechanical stress, heavy loads, and environmental effects, leading to defects such as cracks, fractures, and surface wear.
- Traditional rail inspection methods are mostly manual, time-consuming, and not suitable for real-time monitoring.
- Early detection of rail defects is essential to prevent accidents and reduce maintenance costs.
- This project proposes an IoT-based rail defect detection system using acoustic wave technology for real-time monitoring and improved railway safety.

Literature survey

[1]. M. Rezaei, S. Eck, S. Fichtenbauer, J. Maierhofer, R. Klambauer, A. Bergmann, D. Künstner, D. Velic and H.-P. Gänser, "Real-Time Detection and Quantification of Rail Surface Cracks Using Surface Acoustic Waves and Piezoelectric Patch Transducers," *Sensors*, vol. 25, no. 10, pp. 3014, May 2025.

Rezaei et al. [1] proposed a real-time rail crack detection system using surface acoustic waves and piezoelectric sensors. The method accurately detects small surface cracks by analyzing acoustic wave behavior. However, the system does not include IoT integration or long-range communication, which motivates the use of ESP32 and LoRaWAN in the proposed system.

Contd..

[2]. Y. Zhang, L. Wang and H. Chen, [2]. Y. Zhang, L. Wang and H. Chen, "Rail Surface Defect Detection Using Acoustic Signal Processing Techniques," *Measurement*, vol. 224, pp. 113956, Jan. 2024.

Zhang et al. [2] proposed a rail surface defect detection approach using acoustic signal processing techniques. Acoustic signals generated during rail operation were analyzed to identify surface-level defects such as cracks and wear. The results showed that acoustic-based analysis is effective for detecting rail defects under operational conditions, supporting the use of acoustic sensors in real-time monitoring systems.

Contd..

[3]. R. Kumar and P. Singh, "IoT-Based Railway Track Crack Detection and Monitoring System," *Proceedings of the International Conference on Intelligent Computing and Communication (ICICC)*, pp. 1–6, 2024.

Kumar and Singh [3] proposed an IoT-based railway track crack detection and monitoring system in which sensors are used to detect track abnormalities and transmit data wirelessly to a remote monitoring platform. The system enables real-time monitoring and early fault detection, reducing the need for manual inspection. This study highlights the importance of IoT integration in railway safety applications.

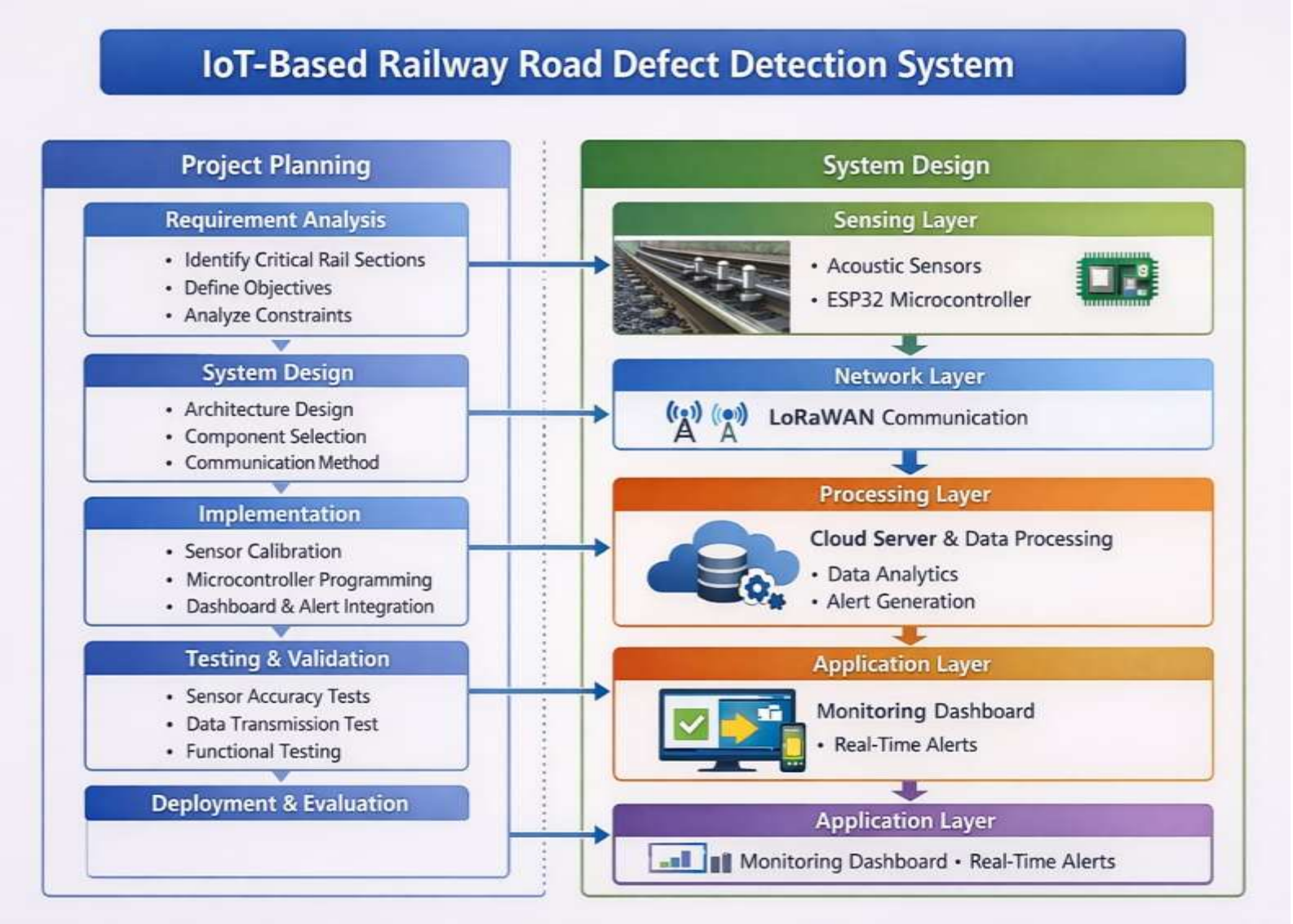
Existing System

- Railway track inspection is mainly performed using manual visual inspection and scheduled maintenance.
- Conventional systems use ultrasonic or vision-based methods, which require complex equipment and high cost.
- Many existing monitoring systems lack real-time detection and depend on offline data analysis.
- Short-range communication technologies (GSM/Wi-Fi) limit coverage over long railway tracks.
- Advanced acoustic and SAW-based systems provide high accuracy but do not integrate low-cost IoT and long-range communication for scalable deployment.

Proposed System

- Proposes a cost-effective rail defect detection system using acoustic wave sensors for identifying cracks, fractures, and surface wear.
- Integrates IoT-enabled acoustic sensors with ESP32 microcontroller for real-time data processing.
- Uses LoRaWAN communication to transmit defect data over long distances with low power consumption.
- Enables continuous monitoring and early detection of rail defects, supporting predictive maintenance.
- Designed to be scalable, reliable, and suitable for harsh outdoor railway environments, reducing manual inspections and maintenance costs.

Planning & Design



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[1]. M. Rezaei, S. Eck, S. Fichtenbauer, J. Maierhofer, R. Klambauer, A. Bergmann, D. Künstner, D. Velic and H.-P. Gänser, “Real-Time Detection and Quantification of Rail Surface Cracks Using Surface Acoustic Waves and Piezoelectric Patch Transducers,” *Sensors*, vol. 25, no. 10, pp. 3014, May 2025.

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Thank You!!!