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A Survey on Onboard Computing Network based Railway Gate Monitoring System

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Abstract: The Railway Gate Monitoring System using onboard computing techniques is designed to enhance safety and automation at railway level crossings. It employs onboard units installed on trains, which are equipped with GPS, RFID, and wireless communication modules to continuously track the train's location, speed, and direction. This real- time data is transmitted to a microcontroller-based gate control unit situated near the crossing. As the train approaches, the gate automatically closes, remains shut while the train passes, and opens only after it has safely crossed. The system minimizes human intervention, reducing the risk of human error. Onboard computing enables fast and accurate decision-making based on sensor data and predefined logic. Additional sensors like IR or ultrasonic detectors can be used to identify obstacles at the crossing. CCTV integration can further monitor and record gate activity for safety audits. This project is cost-effective, scalable, and ideal for remote or unmanned crossings. Overall, it significantly improves safety and efficiency in railway transportation systems.
Keywords: Onboard Computing, Automatic Gate Operation, GPS and RFID, Human Error Reduction.

I. INTRODUCTION

Railway level crossings are among the most vulnerable points in railway networks, often witnessing accidents due to delayed gate operations, human error, or lack of real-time monitoring. To address these challenges, the integration of onboard computing and intelligent monitoring systems has become a key research and development area. By leveraging embedded controllers, sensor networks, and wireless communication technologies, modern gate monitoring systems ensure timely operation, reliable data exchange, and enhanced safety for both trains and road users.

Railway gate monitoring systems are crucial for enhancing safety and efficiency at level crossings, mitigating the inherent risks associated with the convergence of vehicular and railway traffic. Technologies on of onboard computing techniques, particularly Field- Programmable Gate Arrays (FPGAs) and microcontrollers, along with various sensor technologies, have revolutionized the capabilities of these systems.

Onboard computing enables the real-time processing of sensor data, allowing systems to automatically detect train movement, measure speed and distance, and monitor the presence of obstacles near gates. Combined with communication technologies such as IR and GSM, these systems can transmit information efficiently over short and long ranges, making them suitable for both urban and remote railway crossings. The use of infrared, ultrasonic, and thermal sensors further enhances the accuracy of detection, while microcontrollers such as Arduino provide a cost-effective and flexible platform for decision-making and control. The integration of these components into a networked framework facilitates autonomous gate operations, where gates are opened and closed based on train arrival and departure times without human intervention. Moreover, real-time alerts and monitoring capabilities extend beyond gate control to include track condition assessment, obstruction detection, and safety warnings for locomotive pilots.

Overall, railway gate monitoring using onboard computing networks represents a holistic and reliable solution to improving safety at level crossings. By combining automation, communication, and intelligent sensing, these systems minimize human error, optimize response time, and significantly reduce the risk of accidents, contributing to the development of safer and smarter railway infrastructure.

II. RELATED WORK

Veit Wiese et al.[1] presents an FPGA-based railway axle damage monitoring system, lauded for its high precision, real-time capabilities, and reconfigurability that enhance safety and reduce costs. However, the system faces challenges in verifying damage detection due to increasing SHM complexity, and its reliability could be improved by incorporating parameter checks and better data transfer mechanisms for analysis**.**

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Kottnana Janakiram's et al.[2] paper introduces an innovative system using IR and PIR sensors to automate railway gate operations, enhancing safety by real-time train detection and obstacle monitoring, thereby reducing accidents and improving efficiency. The system is described as cost-effective and reliable, suitable for remote areas. While effective, future work suggests potential for integration with AI, machine learning, and more advanced sensors like radar for improved prediction and robustness.

Mrs.D. Priyadharshini et al.[3] propose an IoT-based railway gate control system utilizing LoRa communication, IR, and ultrasonic sensors for advanced train tracking and hazard mitigation at crossings. This system aims to enhance safety by providing real-time alerts and automating gate operations. While comprehensive, the paper implies future scope for integration with AI/ML for more advanced control and the development of a comprehensive real-time monitoring dashboard, suggesting areas for further enhancement.

Husna Tabassum et al.[4] proposes an IoT-enabled railway system for asset monitoring and optimization. This comprehensive solution integrates various sensors, Arduino, and Zigbee to detect track cracks, monitor platform availability, manage train movement, and automate level crossings, significantly enhancing safety and efficiency. While promising, the paper does not explicitly detail drawbacks, implying potential future considerations for scalability, environmental robustness, or advanced security measures.

Prince Kumar et al. [5] provides a comprehensive review on automatic protection systems and risk mitigation in railways. Their paper synthesizes existing technologies like GSM-based track crack detection and automatic gate control, highlighting advancements aimed at preventing

accidents and enhancing safety. As a review, it offers broad insights but doesn't present novel experimental results or detailed technical evaluations of the reviewed systems' specific limitations.

Polepogu Rajesh et al.[6] propose an Arduino-based advanced safety method for automatic railway gate control, specifically targeting accident reduction in developing countries. Their system aims to enhance safety and prevent fatalities at crossings through automation. While the paper focuses on a straightforward and efficient solution, it does not explicitly detail drawbacks, implying potential limitations related to scalability or robustness in diverse environmental conditions that typical sensor-based systems might encounter.

Surya et al.[7] proposes an Arduino-based railway gate automation system using IR sensors for train detection and motor drivers to operate gates. This cost-effective and easily implementable system aims to reduce accidents and enhance efficiency by automating gate operations without human intervention. While effective for its stated purpose, the paper doesn't explicitly detail limitations, potentially implying challenges with scalability or robustness in diverse environmental conditions for the sensor-based approach.

Ghulam Fiza Mirza et al.[8] critically review existing railway level crossing systems, highlighting their drawbacks like manual control's human error, camera systems' cost and environmental limitations, and sensor-based systems' short range. Their paper emphasizes the significant loss from accidents and the need for smarter solutions, indirectly advocating for technologies like IoT/LoRa. However, as a review, it primarily identifies problems with current methods rather than proposing or detailing a new system's specific advantages or limitations.

Puja Bhowmik et al.[9] designed an IoT-based automated railway level crossing system. This system uses ultrasonic sensors for train detection, a servo motor for automatic gate control, and a GSM module to alert train operators about obstacles like stuck vehicles or humans at the crossing. While effectively enhancing safety and traffic management, the paper does not explicitly detail the system's limitations, which might include challenges with environmental robustness or large-scale deployment.

Shankha Banerjee et al.[10] propose a GPS-based algorithm for automating railway level crossings. This system uniquely eliminates the need for track-side hardware, significantly reducing maintenance costs and vulnerability to vandalism by relying on GPS for train position, distance, and velocity to control gates. While offering a cost-effective and efficient solution, the paper does not explicitly discuss potential limitations such as GPS signal reliability in varied environments or the latency involved in real-time data processing.

Narasimha Kulkarni et al.[11] proposes an unmanned automated railway level crossing system integrating robust backup mechanisms. Their design employs IR sensors for train detection and a Raspberry Pi with an SSD algorithm and camera for primary obstacle detection, supplemented by backup IR sensors if the vision system fails. This multi-layered approach significantly enhances safety at crossings by providing redundancy. However, the paper doesn't explicitly detail limitations, which might include the impact of adverse weather on camera performance or the computational demands of real-time image processing in dense environments.

Gauransh Singh et al.[12] propose a machine learning-based security system for railway crossings to mitigate accidents caused by manual operation and obstacles. Their system employs deep learning (SSD) on a Raspberry Pi with a camera and IR sensors for obstacle detection, enhancing automation and safety, and utilizes a GSM module for alerts. While promising, the paper does not explicitly detail drawbacks, which may include challenges with deep learning performance in varied environmental conditions or the

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real-time computational demands on the Raspberry Pi.

Marwa M. Eid et al.[13] presents an automated railway security system prototype based on Arduino UNO. This comprehensive model integrates IR, ultrasonic, and gyroscope sensors for automatic gate control, track switching, and line crack detection, complemented by a web camera for real-time status updates to the control room. While aiming to enhance safety and communication by automating crucial functions and overcoming manual observation limitations, the paper doesn't explicitly discuss drawbacks, implying potential challenges with large-scale deployment or sensor robustness in varied environments.

Chaithra N. et al. [14] propose an IoT-based railway crossing system that efficiently automates gate operations and alerts authorities in real time. The main advantage of their approach is its ability to reduce accidents by using sensors and GSM messages. However, the system depends on strong network signals and may suffer from interference under poor conditions. Nonetheless, it offers a cost-effective and scalable solution for improving railway safety.

Dr. Velayutham. R et al. [15] propose a GPS and smartphone-based railway gate control to reduce human intervention and accidents. The main advantage of their approach is its ease of control and cost-efficiency in implementation. However, the system depends on GPS signals and network connectivity, which may affect its reliability. Nonetheless, it offers a simple and effective solution for automated railway gate operations.

Indhuja et al. [16] propose an automated rail track monitoring and fault reporting system to enhance railway safety. The main advantage of their approach is real-time defect detection, reducing human intervention and maintenance cost. However, the system depends on sensors and communication signals, which may be affected by environmental conditions. Nevertheless, it offers a reliable and cost-effective solution for improving railway operations.

E Amarnatha Reddy et al.[17] propose a smart railway gate control system using IoT to reduce accidents and human intervention. The main advantage of their approach is automated gate operations with enhanced safety and low-cost implementation. However, the system depends on sensor signals and power supply, which may affect its reliability. Nevertheless, it provides a flexible and effective solution for securing railway crossings.

G. Hemanth Kumar et al.[18] propose a smart railway gate control system using GPS and D2D communication to track trains in real time. The main advantage of their approach is automated gate operations, reducing human intervention and accidents. However, the system depends on strong network signals and hardware components, which may affect its reliability. Nevertheless, it offers a flexible, cost-effective, and efficient solution for railway crossing safety.

The reviewed papers present a variety of innovative systems aimed at enhancing railway gate safety and automation through advanced technologies. Key approaches include FPGA-based monitoring for axle damage, IoT systems utilizing sensors like IR and ultrasonic for real-time train detection, and GPS-based solutions for automated gate control. Many studies emphasize the integration of machine learning and communication technologies to improve efficiency and reduce human intervention. However, common challenges include reliance on sensor accuracy, environmental robustness, and network connectivity, which may affect system reliability. Future work often suggests the potential for further enhancements through AI integration and comprehensive monitoring dashboards. Overall, these advancements highlight a significant shift towards automated and intelligent railway safety solutions.

III. COMPARISON AMONG MODELS

This comparison model analyzes various railway gate monitoring systems, focusing on their technological approaches and effectiveness in enhancing safety and automation. By evaluating key metrics such as detection methods, communication technologies, gate control mechanisms, response times, and system complexity, the study aims to identify the most promising solutions for modern railway operations.

Table-1: Comparison Among Models

Reference	Detection method	Communication Technology	Gate control Mechanism	Response Time	System complexity	Remarks
ese et al. (2024)	trasonic + Encoder Triggering	FPGA-based Internal Comm	Hardware- triggered System	Real-time.	Very High	able for axle and track monitoring, not just gate control.
nakiram et al.(2024)	IR + PIR Sensors	Wired / Basic Control Logic	Servo Motor (based on IR & PIR)	Moderate	Low	Affordable and suitable for unmanned crossings

riyadharshini et al. (2024)	IR Sensors + Ultrasonic Sensors	Ra (Long Range)	Relay- controlled gate via Arduino	Fast	Medium	Reliable for long-range use; good for remote areas
Husna Tabassum et al. (2024)	IR, Ultrasonic, Image Processing, Crack & Fire Sensors	Zigbee + NodeMCU (IoT)	DC Motors with Relay Control	Fast	High	Multi-functional system suitable for smart rail networks
rince Kumar et al. (2023)	IR + Ultrasonic + Arduino	GSM + Local Microcontroller	Stepper Motor via Microcontroller	Moderate	Medium	Covers gate control, crack detection, in one embedded solution
Polepogu Rajesh et al., (2023)	Ultrasonic + Thermal sensors	Basic alert system (non- IoT), Arduino-based	Servo motors controlled by Arduino	Near real-time (sensor- triggered)	Moderate (Arduino + multiple sensors + indicators)	Adds safety with thermal sensors to detect living beings on track
Surya S et al., (2023)	IR sensors	-	Servo motor via Arduino + motor driver	Real-time (IR-triggered, ~100 ms polling)	Low (basic IR + servo setup)	Cost-effective, automation, no external communication.
ɪarwa M. Eid et al., (2019)	IR, Gyroscope,Ultrasonic, Camera	Bluetooth , Android app	ervo motors & track switch via Arduino	Real-time	High	Highly integrated; camera feed & track switching
ithra N. et al., 2018	IR sensors + CCTV + road sensors	IoT (Wi-Fi, GSM, Thingspeak)	Servo motors controlled by Arduino	Real-time (speed-based)	High	Smart countdown system intrusion alert
Dr. Velayutham R. et al., 2017	GPS tracking via smartphone app	IoT via smartphone + GPS	Gate controlled by driver through app	Real-time (manual trigger)	Moderate	Driver-based control reduces manpower, needs app authentication
Indhuja et al., 2017	Ultrasonic, IR, Accelerometer, GPS	GSM or Wi-Fi	DC motor via ARM controller	ime with alert	High	Adds in-service track fault detection + obstacle warning
Amarnatha Reddy et al., 2017	IR, Vibration, Magnetic Pressure sensors	IoT with Arduino, GSM	Stepper motor via AT89C52 MCU	Real-time	Moderate	Emphasizes unmanned gate automation with safety alerts
G. Hemanth Kumar et al., 2017	PS + Voice Commands	Bluetooth (OneSheeld + Smartphone)	Servo motors (voice-commanded	nual voice- triggered	Moderate	Adds emergency spike barrier system for ambulances

IV. CONCLUSION

The Railway Gate Automation System using onboard computing networks provides an effective and intelligent solution to enhance safety and efficiency at railway level crossings. By utilizing onboard units equipped with GPS, RFID, and wireless communication, the system enables real-time tracking of train movement and automates gate operations without human intervention. This significantly reduces the chances of accidents caused by delays or manual errors. Additional features like IR and ultrasonic sensors help detect obstacles on the track, while CCTV integration supports monitoring and auditing. Cost-effective, scalable, and reliable, the system is well-suited for deployment in remote or unmanned locations, contributing to a safer and smarter railway infrastructure.

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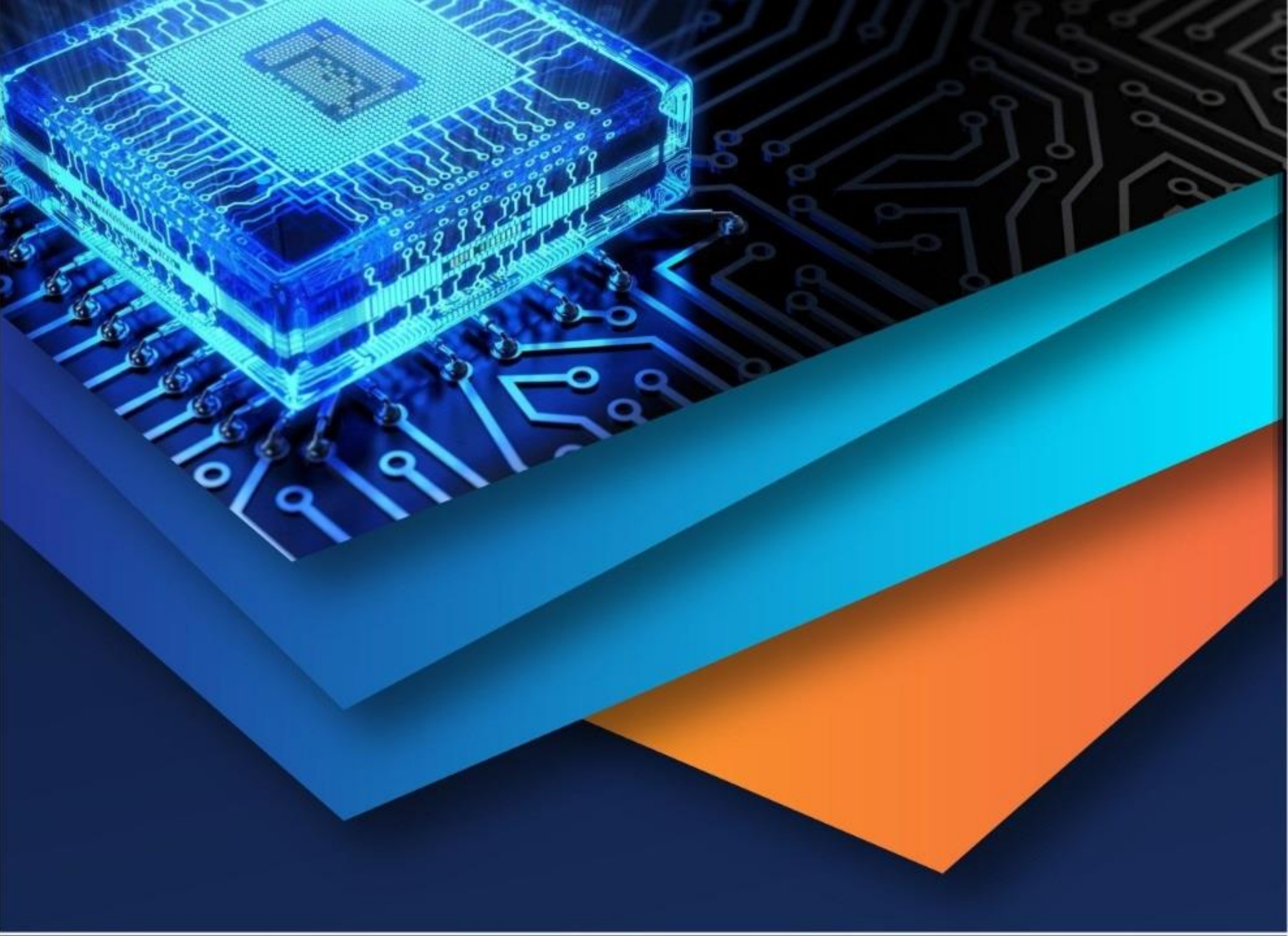

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