iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IV **Month of publication:** April 2025

DOI: https://doi.org/10.22214/ijraset.2025.68600

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

A Novel Machine Learning Framework for Real-Time Railway Crack and Squat Detection

Sowmya S[1], SurendharR[2], Karthikeyan[3], Manoj R[4], Priyanka S[5]
Electronics and Communication Engineering J.N.N. Instituteof Engineering Tiruvallur, India

Abstract: Preventing accidents and maximizing maintenance efforts require secure railway infrastructure. This study introduces a machine learning-based method for detecting cracks in railway tracks that makes use of computational intelligence and image processing techniques. The system analyses and tracks photos, extracts fault features, and accurately classifies abnormalities using MATLAB. The suggested system efficiently detects fractures, squats, and structural flaws by combining deep learning algorithms, edge detection methods, and pattern recognition models. Furthermore, a hardware module based on Arduino analyses identified defects and sends real-time notifications to a central monitoring system, allowing for prompt remedial action. By enabling proactive resource allocation and ongoing track monitoring, this connection improves predictive maintenance, which in turn raises railway safety and operating effectiveness.
Keywords: Railway infrastructure, crack detection, machine learning, image processing, predictive maintenance, Arduino.

I. INTRODUCTION

To ensure the safe and effective flow of both passengers and freight, railway tracks are crucial to modern transportation. However, the integrity of the railway is threatened by structural flaws including cracks and squatters, which could result in derailments and serious interruptions. To minimise maintenance expenses and prevent accidents, early problem diagnosis is essential.
Conventional manual inspections are insufficient for extensive monitoring since they are time-consuming, labour--intensive, and prone to mistakes. Furthermore, because trains move constantly, real-time crack detection is difficult, making automated solutions necessary for effective railway maintenance. The problem of railway track flaws is introduced in this study, emphasizing the necessity of automated monitoring. It describes the goal and parameters of the project, which focuses on a MATLAB-based crack and squat detection system. Large-scale implementation to increase railway safety and efficiency, predictive maintenance, and improved problem diagnosis with machine learning (ML) and image processing are some of the primary topics covered. Track fault detection has been transformed by recent developments in machine learning and image processing. To increase accuracy and simplify maintenance, this study offers a MATLAB-based framework that integrates various technologies. Through constant track condition monitoring, the system guarantees prompt fault detection, decreasing the need for manual inspections while improving operating effectiveness and safety. Its efficacy for large-scale predictive maintenance is confirmed by experimental results, guaranteeing the sustainability of railway infrastructure over the long run.

II. LITERATURESURVEY

1) Railway track crack detection & obstacle detection system.

Transportation is a critical driver of economic growth that enables trade and connectivity. In India, rail transport serves as the backbone of economic expansion. However, safety and reliability remain major concerns. Despite having the fourth-largest railway network globally, India is yet to meet international safety standards. To address these challenges, researchers have explored various automated track-crack detection techniques. Traditional methods primarily utilize infrared (IR) sensors that transmit sine waves to detect tracking defects. When a crack is identified, the system activates a GPS module to pinpoint the location of the defect and sends alerts to railway authorities via Wi-Fi and microcontroller-based systems. Some studies have also integrated webcams for real-time monitoring to enhance the detection accuracy. However, existing sensor-based approaches face several challenges. Environmental factors often interfere with the sensor signals, leading to inaccurate readings. Additionally, these methods struggle to detect minor or deep cracks, thereby limiting their reliability. Furthermore, the dependence on multiple interconnected modules results in slower real-time processing, which reduces the overall efficiency of the defect-detection system.

2) Designing of Improved Monitoring System for Crack Detection on Railway Tracks.

Railroads offer several advantages to people, such as economical travel and easy access to destinations.

This is one of the most popular forms of public transport because of its many advantages. In recent years, Indian railways have seen several incidents, such as rail cracks and other issues. Therefore, it is risky to use trains for transportation. The current control system used by Indian Railways has shown to be unsuccessful. A robust monitoring system has been suggested in light of the shortcomings of the current rail surveillance system for spotting cracks. This study also discusses automated monitoring and warning systems as a means of preventing animal injuries and deaths on railway tracks[1].

3) Implementation of Railway Track Crack Detectionand Protection N.Karthick1, R.Nagarajan2, S.Suresh3, R.Prabhu4

In this study, a sensor-based system for detecting railway cracksandpreventingaccidentswillbepresented.Numerous techniques have been put out to identify cracks, prevent collisions, and stop derailments because railway safety is so important. By detecting track cracks early, sensor-based systems—which include infrared, ultrasonic, and image processing techniques—help lower risks. By identifying incoming trains and automatically applying brakes, train collision avoidance uses RFID, GPS, and wireless communication to prevent collisions. When instability is discovered, train operators are alerted via Bluetooth-based monitoring devices to avert derailments. Sensor-based methods are more dependable than laser-based crack detection,whichhasbeeninvestigatedbuthaspooraccuracy because to dust, misalignment, and reflection problems. A saferrailwaynetworkcanbeensuredbyfuturedevelopments inmachinelearningandAI-drivensurveillance,whichcan[2] increase detection precision. Predictive maintenance and real-timedata processing canalso improve systemefficiency[3].

III. METHODOLOGY

A. Data Collection

The installation of a fixed camera system next to the railroad track is shown in Figure 1, guaranteeing ongoing track condition monitoring. The camera is firmly fixed in the best possible location to take crisp pictures regularly[4]. After that, these pictures are sent to a processing unit, which applies sophisticated image analysis methods like contrast enhancement, edge identification, and noise reduction. The technology can accurately identify cracks, surface abnormalities, and structural defects by continuously evaluating these images.

The fixed camera arrangement makes the monitoring process more economical and efficient by enabling real-time surveillance and reducing the need for human checks. To find any anomalies, the taken pictures can be compared to a pre-made model that is free of flaws. The technology notifies railway maintenance teams via an automated alert if a flaw is found. By combining computer vision and artificial intelligence, detection accuracy is significantly improved, guaranteeing that even little cracks are found before they become serious problems. Incorporating IoT connectivity also makes it possible for remote monitoring, which lowers the danger of accidents and improves railway safety by giving authorities real-time reports on track conditions.[6]

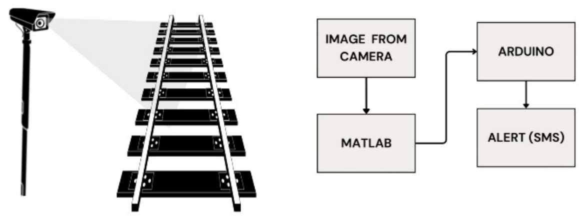


Figure1

By taking pictures at regular intervals, a single fixed camera can be firmly placed into the railroad track to continuously check its status. By sending pictures to a processing unit for in-depth examination, this camera will serve as a real-time surveillance system. To increase the accuracy of crack detection, preprocessing techniques such as noise reduction, edge detection, and contrast enhancement will be applied to the recorded images. The system will examine these photos to find surface anomalies like fractures, deformations, or structural flaws using machine learning models and computer ssvision algorithms. The system will determine the extent of the flaw and start the required safety procedures if a fracture is found[4].

An alarm mechanism will be activated to promptly notify railway maintenance workers of any defects found. The problem can be resolved quickly by sending the notice via a variety of channels, including a buzzer alarm, LED indications, or SMS notifications via a GSM module. This method can be further improved by integrating IoT technology, which enables remote monitoring via cloud-based platforms and gives railway authorities real-time updates. Furthermore, since angle sensor-based crack detection is the main emphasis of your research, integrating this method with a fixed-camera configuration can greatly increase detection accuracy. To decrease false positives and increase dependability, the angle sensor can identify variations in rail alignment, and the camera can offer visual confirmation. In addition to reducing the danger of accidents and guaranteeing passenger safety, this hybrid system offers a scalable, economical, and effective solution for railway track monitoring[6].

B. Real-Time Railway Crack Detection System Architecture

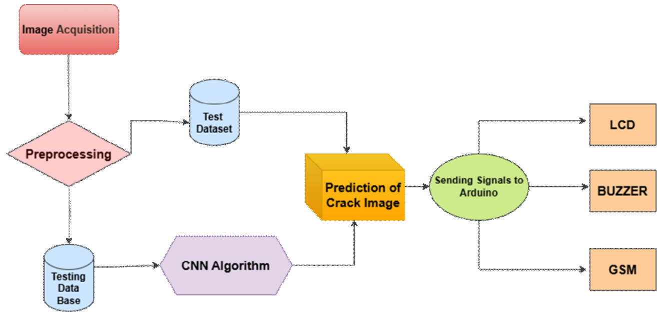


Figure 2: Flow chart

1) Image Acquisition Module

he main input for fracture identification is photographs of railroad tracks, which are taken by the Image Acquisition Module. Track conditions are continuously monitored by taking pictures using a high-resolution camera either in real-time or at regular intervals. Accurate analysis depends on the acquired images' quality and clarity. Stable picture-capturing methods, proper camera location, and suitable lighting all contribute to reduced distortions and improved detection accuracy. The gathered photos are subsequently processed for additional examination in the crack detection system or saved in a database[7].

2) Preprocessing Module

he main input for fracture identification is photographs of railroad tracks, which are taken by the Image Acquisition Module. Track conditions are continuously monitored by taking pictures using a high-resolution camera either in real-time or at regular intervals. Accurate analysis depends on the acquired images' quality and clarity. Stable picture-capturing methods, proper camera location, and suitable lighting all contribute to reduced distortions and improved detection accuracy. The gathered photos are subsequently processed for additional examination in the crack detection system or saved in a database[7].

All things considered, the preprocessing module improves the taken pictures, guaranteeing that the feature extraction and crack identification procedures that follow operate with extreme accuracy and dependability.

3) Feature Extraction Module

An essential part of the railway crack detection system is the Feature Extraction Module, which finds important features in the preprocessed photos that point to the existence of cracks. Extracting pertinent elements aids in distinguishing real cracks from non-crack structures like dirt, shadows, or small surface abnormalities because cracks can differ in size, shape, and texture.

Crack boundaries are highlighted using edge detection techniques such as Sobel, Canny, or Prewitt filters in conventional image processing approaches. By eliminating noise and improving the structure of the crack, morphological processes like dilation and erosion aid in the refinement of the edges that are detected. The severity of the identified cracks is ascertained by extracting additional parameters such as crack width, length, and orientation[7].

Convolutional Neural Networks (CNNs) are used in machine learning-based methods to automatically learn and extract hierarchical characteristics from images. Deeper layers of the CNN model identify more complicated structures and categorize cracks according to their form and intensity, whereas initial layers identify low-level patterns like edges and textures. By doing away with the necessity for manual feature selection, this automated feature extraction technique increases the accuracy of detection.

This module increases the system's overall reliability by extracting pertinent features that guarantee the subsequent classification process can correctly differentiate between railway tracks that are fractured and those that are not.

.

4) Crack Detection & Classification Module

The central component of the railway crack detection system is the Crack Detection & Classification Module, which analyzes the features that have been extracted to ascertain whether a crack is present. In order to differentiate between railway tracks that are cracked and those that are not, this module processes the revised picture data and uses classification techniques[8].

In conventional image processing methods, the image is segmented according to intensity changes using thresholding techniques. A crack is identified if a noticeable discontinuity in the track's surface is found. To improve crack classification, extracted features can also be used to train machine learning models like Support Vector Machines (SVM), Random Forests, or Decision Trees.

Convolutional Neural Networks (CNNs) are frequently employed in deep learning-based techniques to examine patterns in photos of railroad tracks. Key properties including fracture shape, width, and texture are identified by the model after it has processed the input image through several layers. In order to identify whether the detected structure is a normal surface or a fracture, the last classification layer assigns a likelihood score. CNNs are more accurate than conventional techniques because they can identify intricate patterns in vast amounts of data[9].

By ensuring that only real cracks are found, this module lowers the number of false positives brought on by surface irregularities, track joints, or shadows. The output module subsequently receives the classification result and generates any relevant reports or alarms.

5) Output & Decision-Making Module

The output and decision-making module is in charge of presenting the crack detection process's findings and initiating the required actions in accordance with the categorization result. Following the system's determination of the existence of a fracture, this module clearly and practically shows the results.

The algorithm may just log the outcome and move on to the next image analysis if no crack is found. But if a crack is found, the module can do several things, like,

- Visual Display: Operators can manually confirm the results by viewing the processed image with the identified cracks highlighted.
- Text-Based Alerts: The system interface shows a notification that a crack is present.
- Automated Reporting: To help railway maintenance workers plan repairs, the technology can produce comprehensive reports that include the position, severity, and date of the fracture.
- Alert Mechanisms: It can send SMS notifications, sound a buzzer, or send data to a central monitoring station for prompt action if it is connected to an alarm system.

This module makes proactive maintenance and accident prevention possible by guaranteeing that railway authorities receive information promptly. It is crucial to ensure that the entire crack detection system functions effectively and advances railroad safety[5].

6) CommunicationwithArduino

For real-time monitoring and warning creation, the last phase entails combining the crack detection system with an Arduino microcontroller. The system determines the crack's severity based on the categorization results and sends a signal to the Arduino via serial connection (COM port) that corresponds to that severity.

The system sends a signal to the Arduino and initiates a Text-to-Speech (TTS) alarm if a significant fracture is found. In turn, the Arduino can turn on safety features like warning lights or alarms. A distinct signal is sent for small cracks, enabling the necessary maintenance procedures.

By facilitating real-time structural monitoring and guaranteeing timely detection and intervention, this communication bridge between MATLAB and Arduino improves railway track safety.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

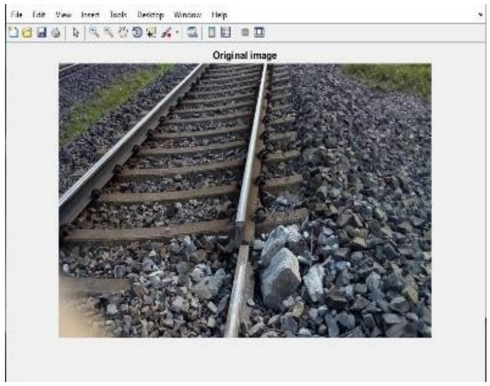


Figure3.1:InputImage

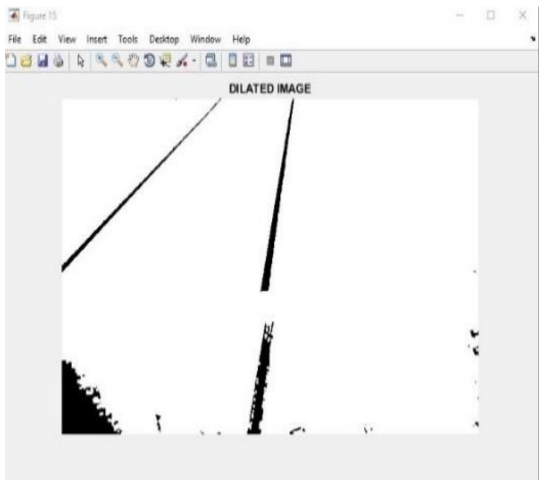


Figure 3.2:Output Image

C. Embedded System Integration

Tracks must be precisely and efficiently monitored to ensure railway safety. This system detects and categorizes cracks in railway tracks by combining MATLAB-based image analysis with an Arduino-controlled alarm mechanism.

The railway crack detection system combines MATLAB-based image analysis with Arduino-controlled safety features to guarantee real-time monitoring and automated alert systems. The Arduino receives the severity information via UART communication once MATLAB has processed the image and classified the found crack. To ensure prompt action, the system uses the GSM module to send an SMS alert to railway officials, regardless of how serious the crack is.

In both situations, a buzzer alarm is also set off to alert on-site railway staff. The system shows a warning on the LCD panel if a small break is found. The motor driver lowers the DC motor speed in the event of a significant crack in addition to generating a warning, emulating a train slowing down to avoid derailment. For accurate tracking, the SMS alert includes the specific location coordinates that are retrieved by the GPS module. Railway safety is greatly improved by this automated fault detection, classification, and communication system, which lowers the chance of accidents while requiring less human intervention.

IV. RESULT

This project focuses on detecting cracks in railway tracks using a camera module and a Convolutional Neural Network (CNN) for image classification. The system processes real-time images to identify and categorize defects, such as minor or major cracks. Once a defect is detected, a GSM module sends alerts to railway officials along with the location details, allowing quick action to prevent accidents. The model has shown high accuracy and can significantly boost railway safety.[10].

Figure 4.1:Display Output

The LCD display provides real-time feedback based on system output, allowing operators to understand the condition of the track. When a crack or disruption is detected, the GSM module automatically notifies nearby stations. The image processing system, driven by machine learning, accurately identifies track issues and displays messages like “Highly Crack Detected” or “Minor Crack Detected” on the LED screen. The Arduino also shows visual indicators to assist in quick and effective response.
[11].
The figure below shows how sms alerts sent to mobile phones include the coordinates latitude and longitude of detected cracks or obstructions the system uses a gsm module to enhance railway safety by enabling early warnings this module combined with sensors installed at both ends of the train detects track anomalies when a crack disrupts the signal the system immediately notifies the train operator allowing them to respond quickly and appropriately[12].

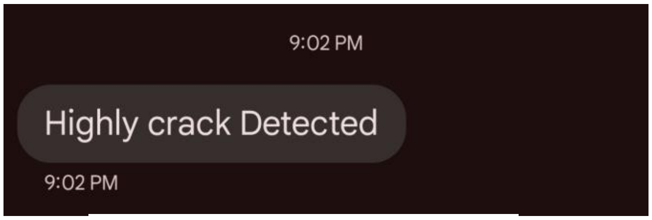


Figure 4.2:SMS Received through GSM

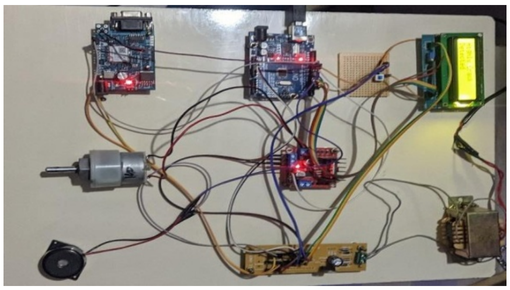


Figure4.3:Display Output

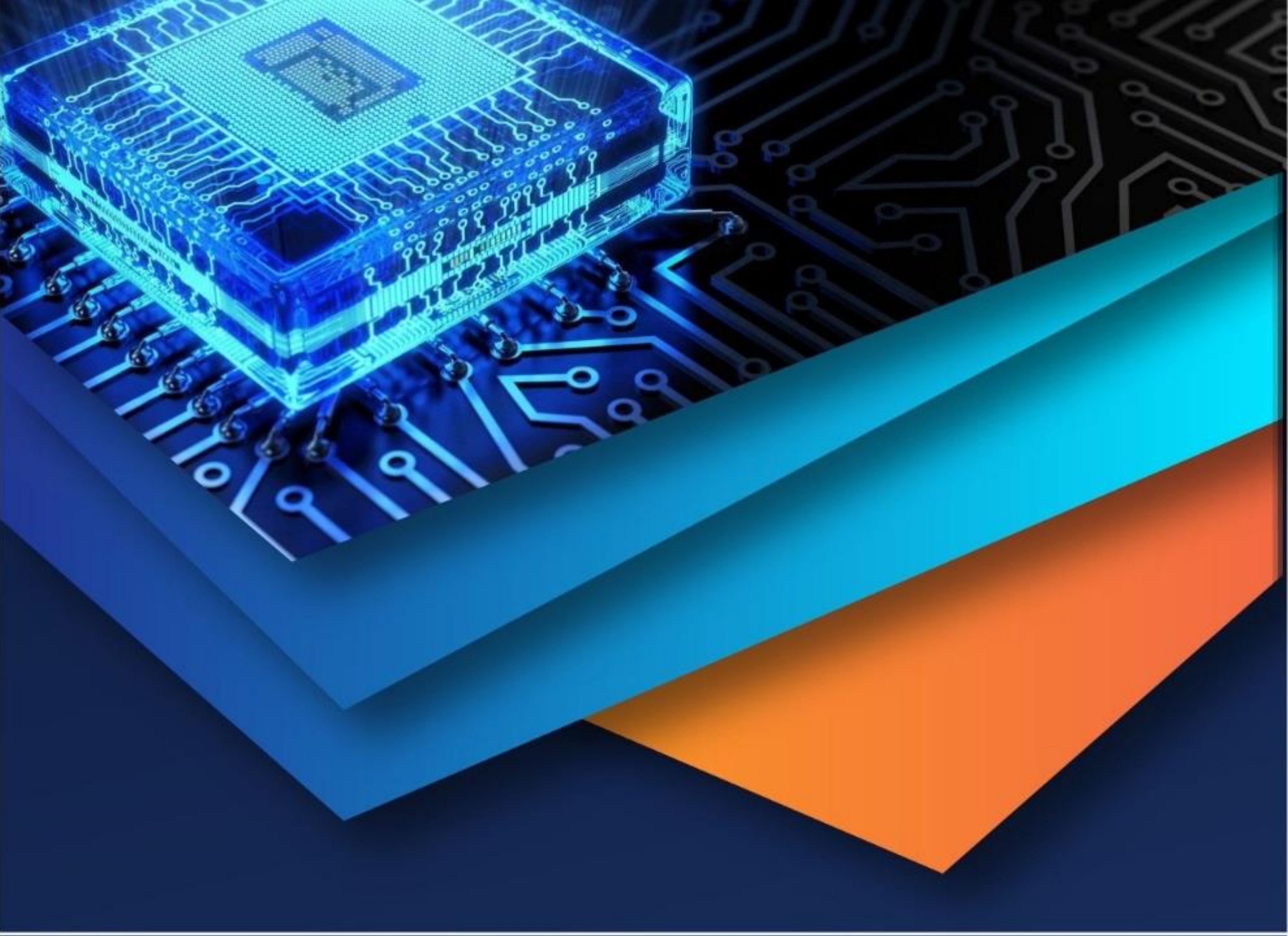
V. CONCLUSION

This study demonstrates how well an automated system based on machine learning can identify cracks in railway rails. Through the use of image processing algorithms, the system guarantees early crack diagnosis, reducing the likelihood of accidents and enhancing track maintenance. Railway safety and efficiency are further improved by combining automatic response systems, such as Arduino-based controls, with real-time monitoring. By drastically lowering the need for manual inspections, this method improves the scalability and dependability of railway monitoring. The accuracy of detection can be further increased with developments in machine learning, deep learning, and sensor technologies. Future developments in automated inspection systems and image processing will help create a safer and more effective railway network.

REFERENCES

[1] DevelopmentofRailwayTrackCrackDetectionSystem using Arduino Prof. Najma Siddiqui1, Prof. Akil Ahmed1, Tejas Thakre2, Sujyot Jibhe2, Yogesh Karnake2, Samir Sheikh2, Yash Sangole2, SohelrazaSheikh2,InternationalJournalofScientificResearchin Science and Technology

[2] Railway Track Crack Detection Arun Kumar R,Vanishree K, Shweta K,Nandini C, Shweta G Department of Computer Science and Engineering Tontadarya College of Engineering Gadag, India, International Journal of Engineering Research & Technology (IJERT)S
[3] Real-Time Obstacle Detection Over Railway Track using Deep Neural Networks Fahim Ur Rahmana, Md. TanvirAhmeda,Md.MehediHasana,NusratJahanb*a, bDepartment of CSE, Daffodil International University,Dhaka,Bangladesh,ScienceDirect
[4] IoT Based Railway Track Faults Detection and Localization using Acoustic Analysis and Signalling Likhith Chandra1 and Harsha V2 Department of Information Science and Engineering1,2 Global AcademyofTechnology,Bengaluru,India,International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
[5] Implementation of Railway Track Crack Detection and Protection N.Karthick1, R.Nagarajan2, S.Suresh3, R.Prabhu4, International Journal Of Engineering And Computer Science ISSN:2319-7242
[6] AUTOMATIC RAILWAY TRACK CRACK DETECTION SYSTEM USING IOT R. Dharanidaran1, S. Jagan2, B. Anandhakeerthi3, S. Kaveyen4, U. Gowtham5, International Research Journal of Engineering and Technology (IRJET)
[7] RAILWAY TRACK CRACK DETECTION USING DEEP LEARNING MODELS Mrs.G Sri Lakshmi, Assistant professor, Department of IT,sree.gpk@gmail.comG.Aihika,BTech, Department of IT,gundaaihika@gmail.comK.Sasidhar Reddy, BTech, Department of IT, sasidhar6898@gmail.com S.Reshma, BTech, Department of IT,shaik.reshu67@gmail.comK.Soniya, BTech, Department of IT,kurapatisoniya082@gmail.com, Journal of Engineering and Science
[8] A Deep Learning Approach Towards Railway Safety Risk Assessment, HAMADALAWAD 1,(Graduate Student Member, IEEE), SAKDIRAT KAEWUNRUEN 1,ANDMINAN2,IEEE Access.
[9] SCueU-Net: Efficient Damage Detection Method for Railway Rail JUN LU JI LIU 1,BOLIANG 1,2, QUJIANG LEI 2,JIE XU 2,XIUHAO LI 2,JUNHAOLIU 2, 2,ANDWEIJUN WANG 2, IEEE Access,IDPI
[10] Robust Automatic Railway Track Crack Detection using Unsupervised Multi-Scale CNN S. Nandhini1 , Mohammed Saif2 , Kailash Venthan P3 , Sridhar E4 Assistant Professor, Department of Computer Science and Engineering1 B. Tech Students, Department of Computer Science and Engineering2,3,4 International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
[11] Automated rail surface crack analytics using deep data-driven models and transfer learning Zhong Zheng, Haoyang Qi, Li Zhuang*, Zijun Zhang,Science Direct.
[12] Classification of Rail Track Crack using CNN with Pre-Trained VGG16 Model Shreetha Bhat School of Computer Science and Applications REVA University Bengaluru, Karnataka, India shreetha.bhat@reva.edu.in Vidya S School of Computer Science and Applications REVA University Bengaluru, Karnataka, India vidyadhare13@gmail.com Asha Gowda Karegowda Department of MCA Siddaganga Institute of Technology Tumkur, Karnataka, India asha_gowda@sit.ac.in Devika G Dept of Computer Science and Engineering, Government Engineering College, KR Pet. Karnataka, India. sgdevika@gmail.com. 2022 IEEE International Conference on Distributed Computing and Electrical Circuits and Electronics (ICDCECE)
[13] Designing of Improved Monitoring System for Crack Detection on Railway Tracks, Nilisha Patil1, Dipakkumar Shahare1, Shreya Hanwate1, Pranali Bagde1, Karuna Kamble1, Prof. Manoj Titre2 Proceedings of the Third International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV 2021). IEEE Xplore Part Number: CFP21ONG-ART; 978-0-7381-1183-4
[14] RAILWAY TRACK CRACK DETECTION & OBSTACLE DETECTION SYSTEM Sagar Kotkondawar*1, Samyak Meshram*2,AbhishekRangari*3, Dr. J.P.Sathe*4, Dipali Nankate*5, Eshakha Sarve*6International Research Journal of Modernization in Engineering Technology andScience.
[15] An Analysis Of Convolutional Neural Networks For Image Classification Neha Sharma,Vibhor Jain, Anju Mishra,An Analysis Of Convolutional Neural Networks



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY