Railway Track FaultDetection using IoT and Image Processing

Dr.V.Senthil kumaran[1] (Assistant Professor), V.Gokul Raj[2], R.Hariprasath[3],
Kukkala Vamsi[4], K.Maheshwaran[5]
Department of Electronics and Communication Engineering,
Mahendra Engineering College, Namakkal, Tamilnadu, India

Abstract - Railway track fault detection using Internet of Things (IoT) and image processing requires an innovative approach to ensuring the safety and effective of railway networks. Railroad track flaws have the potential to produce accidents that result in loss of life and money. Wear and tear, together with temporal, spatial, and meteorological factors, can result in ballast, loose bolts, misalignment, and cracks that cause accidents.Manual inspection of such defects is time-consuming and prone to errors. Automatic inspection provides a fast, reliable, and unbiased solution. This system leverages a network of interconnected sensors placed along the railway tracks to continuously monitor their condition. . An advanced railway track fault detection is intended for monitoring faults in railway tracks. In this proposed project, IoT based application of ultrasonic sensors and Deep Learning (DL) model for using micro camera based classification for Convolutional Neural Network (CNN) algorithms. The IoT application interface and Safety Information Management System(SIM) -based Global System for Mobile Communication (GSM) message communication to provide exact GPS location enabled via Google Maps on a mobile device.The purpose of this research is to develop an Internet of Things (IoT)-based railway track fault detection system to enhance the existing railway Monitoring system. This work contributes significantly to railway track fault defection, classification and location based on acoustic analysis. The results indicate that acoustic data can successfully assist in discriminating the track defects and locating the defects in real-time. The results show that Defects Liability Period (DLP) achieved the best results, with an accuracy of 99.4 percent.

I.INTRODUCTION

In today's rapidly growing world of transportation, railway systems serve as vital arteries of connectivity, enabling the efficient movement of people and goods across long distances. However, the integrity of railway tracks is paramount to guarantee the safety and reliability of these networks. To address this critical need, modern technology has ushered in a transformative era in railway track maintenance and monitoring.

Railway track fault detection systems, powered by the convergence of IoT and advanced Image processing, have emerged as powerful tools in the quest for heightened safety and efficiency. These systems are capable of real-time monitoring, early fault detection, predictive maintenance, promise to modernize the railway industry, minimizing disruptions, enhancing passenger, cargo transportation and ensuring the sustainability of this indispensable mode of transit. This discussion search into the profound impact of IoT and Image processing in safeguarding the integrity of railway tracks, mention their role in shaping the future of rail travel.Railway systems around the world operate in a variety of environments where the railway track is threatened by temporal, spatial, and weather factors.

The objective is to create a system that can assess the given inputs and provide a clear indication of whether the track is faulty or not. The goal of this research is to develop a dependable system that can examine audio signals from tracks and determine whether or not a track has been cracked.One of Pakistan's main means of transportation is the railway system, which has recently seen a number of rail accidents. In light of this, railway tracks represent the single most significant contributing cause to derailments, necessitating the use of an efficient and reliable track fault detection system.

Machine-learning- and deep-learning-based systems have achieved good results in a variety of applications due to recent advancements in these techniques. As railway derailment directly affects human life and the economy, this motivated us to design a system to improve the performance of railway track detection using a machine-learning-based approach. Image-processing-based approaches are utilized predominantly, along with other sensors, for railway track detection.

However, approaches that require dedicated sensors are expensive and methods involving image processing require higher computational processing capabilities. Instead, we suggest an easy-to-use yet effective technique that makes use of acoustic signals. The dataset is fully detailed; data was collected from railway tracks using a customized railway.Experiments were undertaken using seven well-known machine learning models including Logistic Regression (LR), Support Vector Machine (SVM), Adaboost Classifier (ADA), Gradient Boosting Machine (GBM), Extra Trees Classifier (ETC) and K-Nearest Neighbor (KNN).

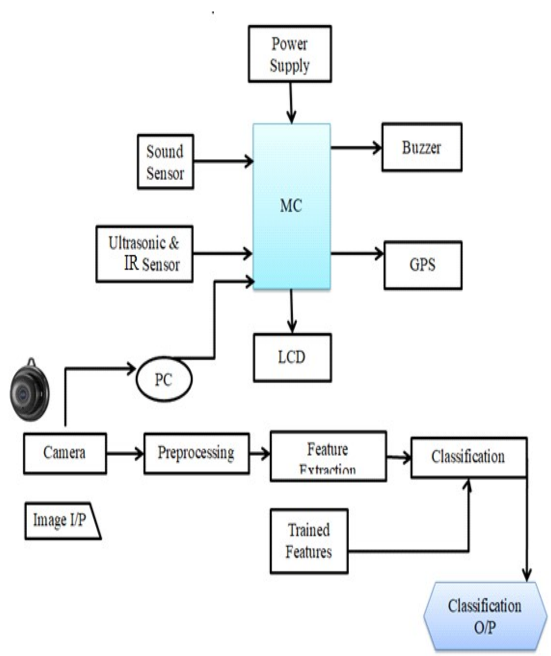
The main objective of this project are:

- To improve the railway safety by early detection of track faults like cracks, and misalignments to reduce the risk of accidents and ensure passenger and cargo safety.
- To reduce expensive service disruptions caused by track faults by identifying and addressing issues before they lead to significant operational interruptions.
- To implement predictive maintenance strategies by analyzing past data, leading to efficient resource allocation and cost reduction in track maintenance activities.
- To establish a continuous, real-time monitoring system using IoT sensors to provide instant data on track conditions, enabling immediate responses to emerging faults.

II.PROPOSED SYSTEM

1. AIM OF THE PROJECT

- The project aims to develop a system that can identify various types of faults as soon as they occur.
- Implement Internet of Things (IoT) sensors beside railroad tracks to continuously check for issues, cracks, and misalignment.
- Image data can be analyzed to detect visual anomalies or track defects that may not be detected by sensor data alone.
- Image processing algorithms CNN can be used for fault detection, classification, and tracking.



- PROPOSED BLOCK DIAGRAM

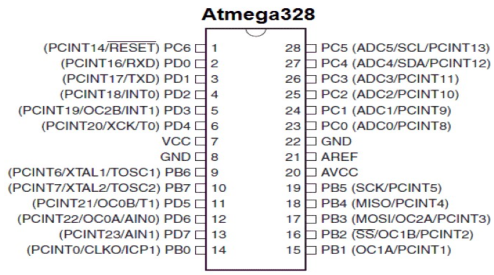
This system involves the design of fault finding in railway tracks.This system makes use of a controller to interface Internet of Things (IoT) sensors, including sound, infrared, and ultrasonic sensors, for vehicle-based detection. The microcontroller receives a signal from the sensing device once it has detected voltage differences from the ultrasonic sensor.The microcontroller checks the voltage variations between measured value and threshold value and controls the devices.

Preprocessing is used to improve the quality of the image and to make it easier for the feature extraction and classification algorithms. Taking relevant features out of an image is a process known as feature extraction.These features will be used by the classification algorithm to classify the image. Classification is the process of assigning an image to a specific class. The class may indicate the presence or absence of a fault, or it may indicate the type of fault.

Image processing techniques is used to improve the quality of the images, to segment the images into different regions, or to extract specific features from the images. The trained features can be used to classify new railway track images into different categories, such as "normal" or "faulty". This project uses regulated 5V Power supply. The system can be operated at tunnels also, without interruption. Sound sensors are used for fault detection. The Convolutional Neural Networks and image Classification methods is used to identify the railway track fault.

2.HARDWARE REQUIREMENTS

2.1.1.Atmega 328 Microcontroller



(b) Pin Diagram for Atmega 328 Microcontroller

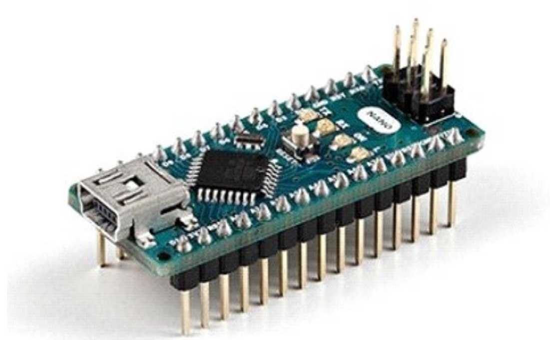
The ATmega 328 microcontroller is used to control the system and to process the results of the fault detection algorithm. The microcontroller is connected to the camera and to a display device. The microcontroller is programmed to capture images from the camera, to preprocess the images, to extract features from the images, to classify the features using the fault detection algorithm, and to display the results on the display device.

The Atmega328 microcontroller uses a machine learning algorithm to classify the extracted features to detect the presence of faults in the railway track.If a fault is detected, the Atmega328 microcontroller can generate an alarm, send a notification to a remote server, or activate a safety system.

(c) Atmega 328 Microcontroller

2.1.2.Adruino Nano

This board has many functions and features like an Arduino Duemilanove board. Still, the packaging for this Nano board is unique. The absence of a DC socket allows power to be supplied via a tiny USB port instead of being directly connected to pins such as VCC and GND. There is a tiny USB connector on this board that allows you to supply 6 to 20 volts to it.



(d) Arduino Nano

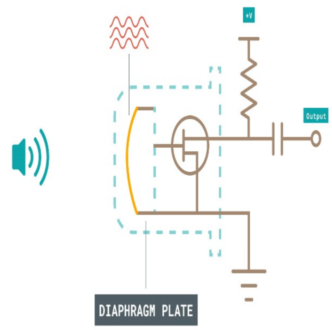
2.1.3.GPS

Location tracking: The GPS module can be used to track the location of the moving platform that the camera is mounted on. This information can then be used to geotag the captured images, which can be useful for identifying the location of faults in the railway track.

Fault notification: The GPS module can be used to pinpoint the location of a defect once it has been identified. This information can then be used to notify the operator or take other corrective actions

2.1.4 SOUND SENSOR

The **Grove Sound Sensor** module is a great instrument for measuring noise in your surroundings. It functions by vibrating in response to sound waves, which bend a plate inside the sensor and result in a change in voltage that can be measured. Larger vibrations means higher values.



(e) Circuit of Sound sensor

Fault detection: Sound sensors can be used to detect certain types of faults in the railway track, such as cracks and broken rails. When a train passes over a faulty section of track, it will produce a different sound than when it passes over a healthy section of track. These differences in sound can be detected by sound sensors and used to identify the location of faults in the railway track.

Fault notification: In the event that an image capture fails to reveal a railway track fault, sound sensors can be employed to alert the operator of the problem. For example, a fault may be hidden by vegetation or debris. In such cases, the sound sensors can still detect the fault and notify the operator.

2.1.5 LCD

Liquid Crystal Displays (LCDs) are widely used in electronics for displaying information, and when paired with an Arduino microcontroller, they become an essential component for creating user interfaces and displaying data in various projects.

(f) LCD Display

The detected faults are displayed on an LCD screen to the Railway Track Foreman or other railway personnel. The LCD screen is typically mounted in the train's cab or at a railway station. The LCD screen displays the location of the fault, the type of fault, and the severity of the fault. LCD displays can be used to display a variety of information, such as the location of the fault, the type of fault, and the severity of the fault.

2.1.6 Micro camera

A micro camera, also known as a miniature camera or mini-camera, is a compact and highly portable imaging device designed to capture still images or video footage in a small form factor.

These tiny cameras can record visual data for a range of purposes since they have lenses, image sensors, and frequently on-board computing power.

(g) Micro camera

High-resolution photos of railroad tracks can be taken with micro cameras, which can increase the precision of defect identification.This can be used to detect cracks, misalignments, and other defects in the track. This can reduce the risk of accidents and injuries.

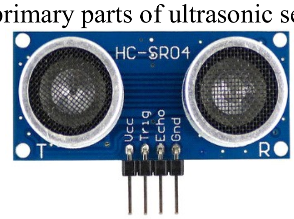
2.1.7 Buzzer

The buzzer is connected to the output pin of a microcontroller, such as an Arduino. The microcontroller is programmed to monitor the output of the machine learning algorithm that is used to detect faults in the railway track. If the machine learning algorithm detects a fault, the microcontroller sends a signal to the buzzer to activate it.

2.1.8 Ultrasonic Sensor

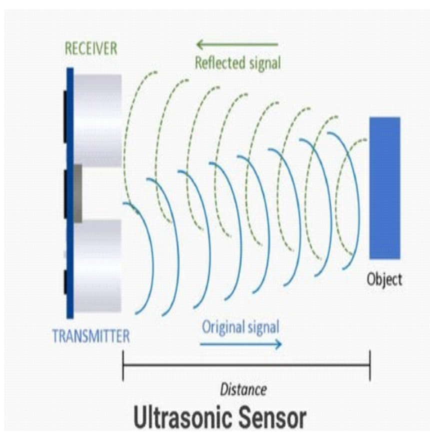
An electronic device known as an ultrasonic sensor uses ultrasonic sound waves to measure an object's distance and then transforms the sound waves' reflection into an electrical signal. The speed of audible sound—that is, sound that people can hear—is slower than that of ultrasonic waves.

The transmitter, which uses piezoelectric crystals to produce sound, and the receiver, which detects sound after it has traveled to and from the target, are the two primary parts of ultrasonic sensors.



(h) Ultrasonic Sensor

The sensor tracks the time elapsed from the transmitter's sound emission to the sensor's contact with the receiver to determine the distance between the object and the sensor.



(i) Working Principle of Ultrasonic Sensor

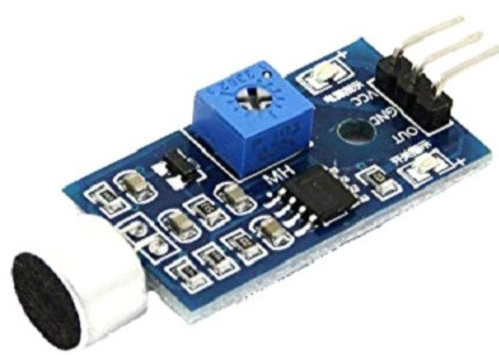
Crack detection: The ultrasonic sensor can be used to detect cracks in the railway track. The sensor emits a pulse of sound and then listens for the reflected sound. If the reflected sound is weak or distorted, it indicates that there is a crack in the track.

Object detection: Objects on the railroad track, such as fallen trees, boulders, and derailing trains, can be found using the ultrasonic sensor. Utilizing this information will increase train travel safety and help avoid accidents.
The ultrasonic sensor can add significant value to a railway track fault detection system using image processing by allowing for the detection of cracks and other faults that may not be visible in images.

2.1.8 Sound Sensor

The sound sensor is one type of module used to notice the sound. Generally, this module is used to detect the intensity of sound. This module's primary uses are in monitoring, security, and switching. This sensor's accuracy can be adjusted for user convenience.

This sensor uses an amplifier, peak detector, buffer, and microphone as input. This sensor processes an o/p voltage signal to a microcontroller and detects sound.After that, it executes required processing.



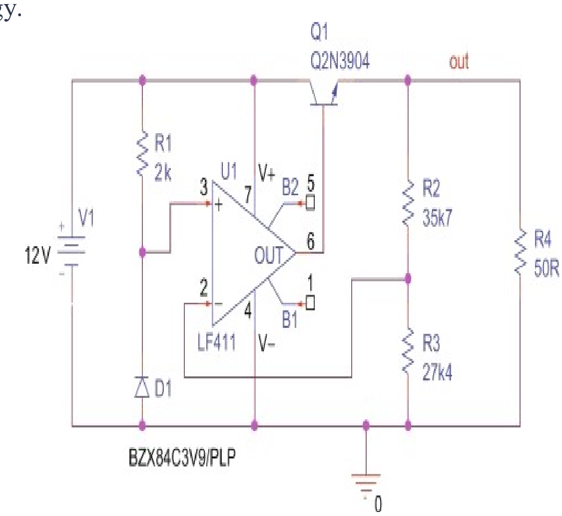
(j) Sound Sensor

This sensor operates on an analogy with human hearing. The diaphragm in the human eye converts vibrations into signals and is responsible for this process. On the other hand, this sensor uses a microphone, and its primary job is to convert voltage into current by using vibrations.

It typically consists of a diaphragm made of magnets wound around metal wire. Magnets inside the sensor vibrate in response to sound waves striking the diaphragm, and concurrently, current can be induced from the coils.

2.1.9 Power Supply

A power supply is a component that supplies power to at least one electric load. Typically, it converts one type of electrical power to another, but it may also convert a different form of energy – such as solar, mechanical, or chemical – into electrical energy.



(k) Circuit of Power Supply

3.SOFTWARE REQUIREMENTS

3.1.1 Python

This project makes use of the Python IDE 3.7. It comes with several image processing libraries. This makes it simple to create systems for detecting defects in railway tracks by extracting features from photos and classifying them.Python IDE 3.7 includes a number of libraries for developing graphical user interfaces (GUIs). This makes it easy to develop railway track fault detection systems that can be used by users with no prior experience with programming.

Tensor Flow

Tensor Flow is an end-to-end open-source platform for machine learning. It has a comprehensive,flexible ecosystem of tools, libraries, and community resources that lets researchers push the state- of-the-art in ML, and gives developers the ability to easily build and deploy ML-poweredapplications.

Tensor Flow provides a collection of workflows with intuitive, high-level APIs for both beginners and experts to create machine learning models in numerous languages. Developers have the optionto deploy models on a number of platforms such as on servers, in the cloud devices, in browsers, and on many other JavaScript platforms.

Pandas

Pandas allows various datamanipulation operations such as merging, reshaping, selecting, as well as data cleaning, and data wrangling features. The development of pandas introduced into Python many comparable features of working with Data frames that were established in the R programming language. The panda's library is built upon another library NumPy, which is oriented to efficiently working with arrays instead of the features of working on Data frames.

3.1.2 Embedded C

Embedded C is most popular programming language in software field for developing electronic gadgets. Each processor used in electronic system is associated with embedded software. Programming in embedded C begins with a collection of functions, each of which consists of a collection of statements used to carry out certain tasks.

The panda's library is built upon another library NumPy, which is oriented to efficiently working with arrays instead of the features of working on Data frames. Embedded C programming plays a key role in performing specific function by the processor. The controlling of these embedded devices can be done with thehelp of an embedded C program.

The Embedded C IDE: 1.8.9 version supports a wide range of hardware platforms, including ARM Cortex-M processors, which are commonly used in railway track fault detection systems. It includes a variety of code generation tools that can be used to generate code for railway track fault detection systems, such as code for image processing and machine learning algorithms. The Embedded C IDE: 1.8.9 version can be used to develop software for the microprocessor that is used to process the captured images and detect faults. It can be used to develop software for the GPS module that is used to track the location of the railway track fault detection system.

5. METHODOLOGY

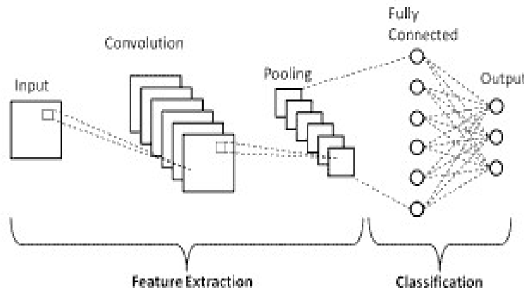
5.1 Working Principle

The system involves when any fault occur in the railway track like breakage of line at any point then vibrating will detect the gape and give us a signal about the fault. Fault can be observe with help of alarm and seen on the railway web dash when object came in front of the train then ultrasonic sensor will detect the image of object and give us a signal about the object in terms of alarm and can seen on the railway software. In the given diagram suppose that Infra-Red (IR) and ultrasonic sensor.

Ultrasonic sensors emit short, high-frequency inaudiable sound waves at regular intervals. These waves propagate in the air at the velocity of sound. When they incident on an object, then they are reflected back as echo signals to the ultrasonic receiver, which itself computes the time delay to the target based on the time-span between emitting the signal and receiving the echo signal. Similar to this, the infrared device sends out a radiation pattern and then detects it by comparing the generated radiation pattern to the threshold pattern in the specified microcontroller circuit.

Convolutional Neural Network (CNN)

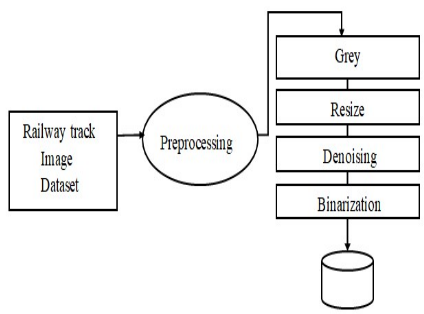
Convolutional neural networks, often known as ConvNets or CNNs, are deep learning network architectures that get their knowledge directly from data. CNNs are especially helpful in identifying patterns in photos so they can identify classes, categories, and items.They can also be quite effective for classifying audio, time-series, and signal data. So, this CNN algorithm used for railway track fault identification. The Deep learning model is being used trained using data on railroad track faults.



- **Convolutional Neural Network**

Modules Description
Railway Web Dashboard

For those in charge of managing trains and train tracks, a railway online dashboard functions similarly to a specialised website. They can view critical information regarding the trains and tracks on a single screen. This data may include the location of the trains, any track issues, and whether or not everything is operating as it should. They may also monitor safety concerns and when maintenance is needed for the trains with the use of the dashboard.

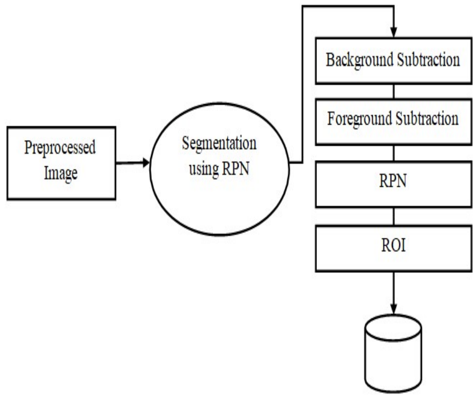


- **Process of Pre-processing**

It's like a control center that makes it easier for people to make sure the trains run on time and that everyone stays safe while traveling on them.The system enables the railway officers to have a real time view of his fields from any place via internet and even provides manual buzzercontrols if the need arises to use them.This system is totally harmless and doesn'tinjure railway tracks in any way. It also doesn't cause any harm to manual. Also, this system has a verylow power requirement thus reducing the hazards of electric shocks.

Railway Track Recognition

Teaching a computer to recognize and comprehend train tracks in the same way that people do is known as railway track recognition. It entails utilizing cameras and technology to enable a computer to "see" and recognize train tracks independently.This can be important because it allows us to keep the tracks in good condition and make sure they're safe for trains to travel on. The computer can spot any problems or damage on the tracks, like cracks or things that don't belong there, and then people can fix those issues to keep the trains running smoothly and safely.



Railway Track Classification

Railway track classification is a bit like sorting things into different categories, but it's for train tracks. Imagine you have a box of toys, and you want to put all the cars in one pile, all the dolls in another, and so on. Railway track classification does something similar, but with train tracks. It uses technology to look at the tracks and figure out what type they are, like if they're for slow trains or fast ones, if they need repairs, or if they're just fine.
This helps people who take care of the tracks know what to do with each one. It's like sorting train tracks into groups to make sure they're in the right condition for the trains that will use them.CNN algorithms were implemented to automatically detect and reject improper Rail track images during the classification process. This will ensure proper training and therefore the best possible performance.

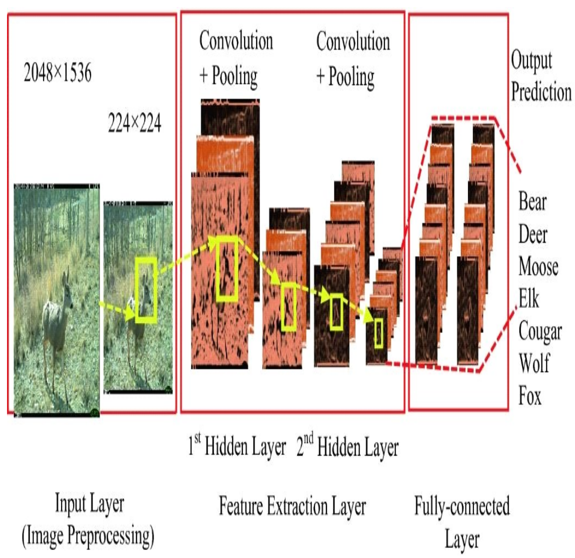


Fig 3.18 Railway Track Classification

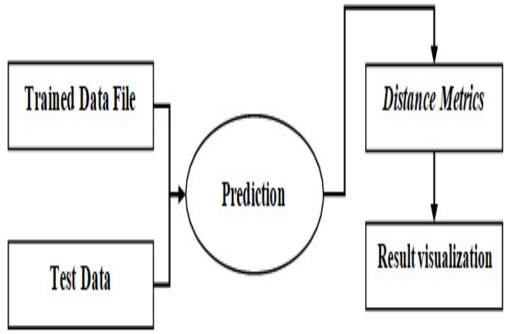
Railway Track Fault Identification

Railway track fault identification is like a special detective for train tracks. Its job is to look closely at the tracks and find any problems or faults, like cracks, loose parts, or things that shouldn't be there, such as debris or obstacles. When it finds something wrong, it sends a message to the people in charge so they can fix it. This way, the train tracks stay safe and in good shape for the trains to run on smoothly. The defect detection module receives the rail track image once it has been captured by the camera.

This module identifies the areas of an image that are probably inhabited by people. A railway track image is fed into the feature extraction module to identify the primary features that will be used for classification following the track fault detection process utilizing the Region Proposal Network (RPN).The module composes a very short feature vector that is well enough to represent the railway track image.

Prediction

The matching procedure is carried out in this module using test railway track images and trained classed results with railway track dataset classified files.Hamming Distance is used to calculate the difference according to the result, the prediction accuracy will be displayed. Here, it is done with CNN with the help of a pattern classifier, the extracted features of track image are compared with the ones stored in the railway track database. The rail track image is then classified as track fault type. If the fault is found corresponding alert module is notified.



(E) Prediction Process

Monitoring and Visualizing

The system can detect the railway track in the field, in addition the railway officers can access the view of their fields. Type of track fault and also the count can be given. The railway track fault recognition module will share the data over the cloud regularly through a Wi-Fi connection. The cloud setup will consist of a private cloud instance running on a machine. The data shared will be used to analyse the patterns and responses of railway. The officers can visualize the errors if any, resolve them, and achieve better results.

Notification

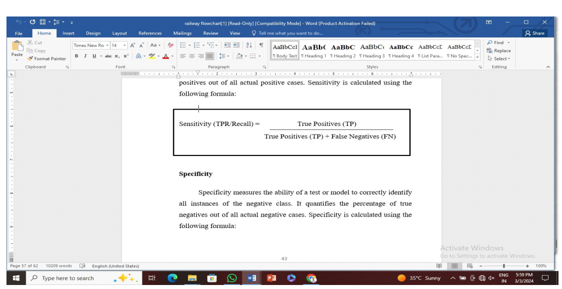
During this phase, the customer receives a notification via email and SMS on the detected motion, along with an image that was taken.The email is sent to registered email id and SMS is sent to the Telegram account of the user to the registered number.

Performance Analysis

In this module we able to find the performance of our system using Sensitivity, Specificity and Accuracy of Data in the datasets are divided into two classes ; not railway fault (the negative class) and rail track fault type (the positive class). Sensitivity, specificity, and accuracy are calculated using the True positive (TP), true negative (TN), false negative (FN), and false positive (FP). he quantity of positive cases that are labeled as positive is known as TP. The fraction of negative situations that are categorized as positive is known as FP. The quantity of negative cases categorized as such is denoted by TN, while the quantity of positive cases classified as negative is shown by FN.

Sensitivity

A test's or model's sensitivity is its capacity to accurately identify every case of the positive class. It is often referred to as recall or the true positive rate (TPR). Said another way, it measures the proportion of real positive cases among all true positive cases. Sensitivity is calculated using the following formula:



positives out of all actual positive cases. Sensitivity is calculated using the following formula:

$$\text{Sensitivity (TPR/Recall)} = \frac{\text{True Positives (TP)}}{\text{True Positives (TP)} + \text{False Negatives (FN)}}$$

Specificity

Specificity measures the ability of a test or model to correctly identify all instances of the negative class. It quantifies the percentage of true negatives out of all actual negative cases. Specificity is calculated using the following formula:

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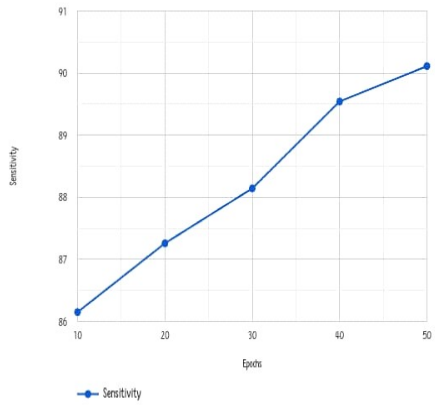
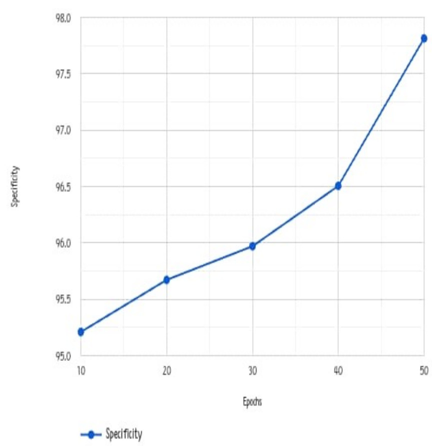


Specificity

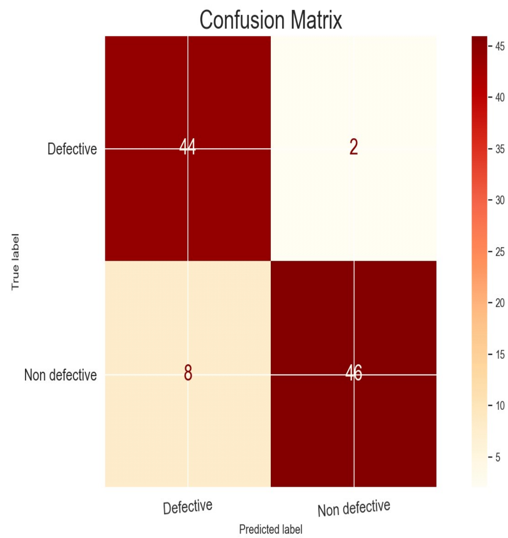
Specificity measures the ability of a test or model to correctly identify all instances of the negative class. It quantifies the percentage of true negatives out of all actual negative cases. Specificity is calculated using the following formula:

$$\text{Specificity (True Negative Rate)} = \frac{\text{True Negatives (TN)}}{\text{False Positives (FP)} + \text{True Negatives (TN)}}$$



Accuracy

Accuracy is a measure that tells whether a model/algorithm is being trained correctly and how it performs. In the context of this thesis, accuracy tells how well it is performing in detecting humansin underwater environment. Accuracy is calculated using the following formula.


Confusion Matrix
Defective
Non defective
True label
44
2
8
46
Defective
Non defective
Predicted label
45
40
35
30
25
20
15
10
5

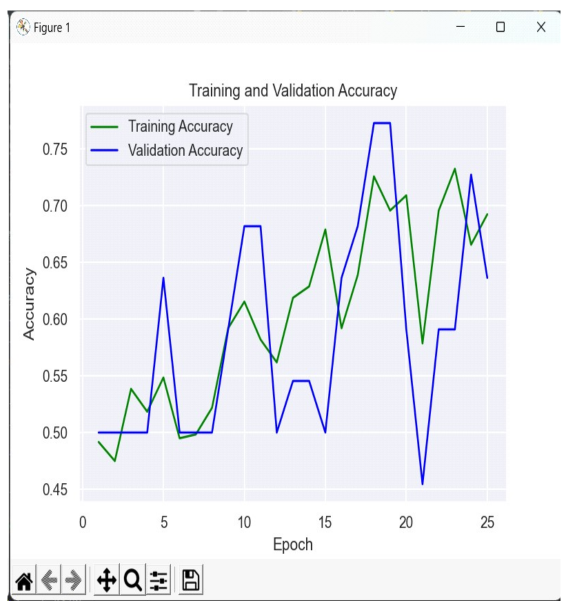
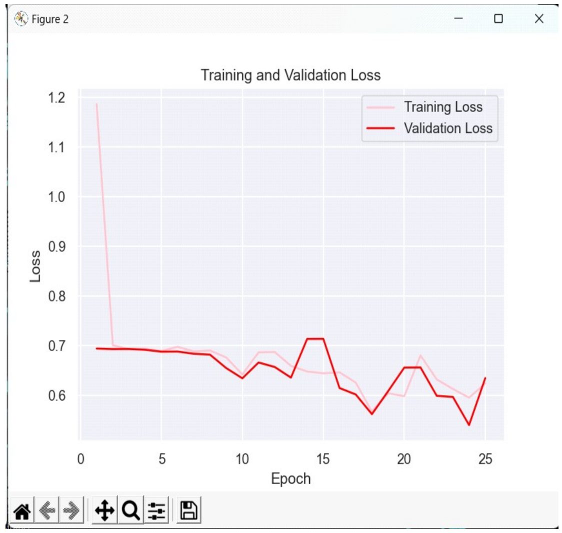
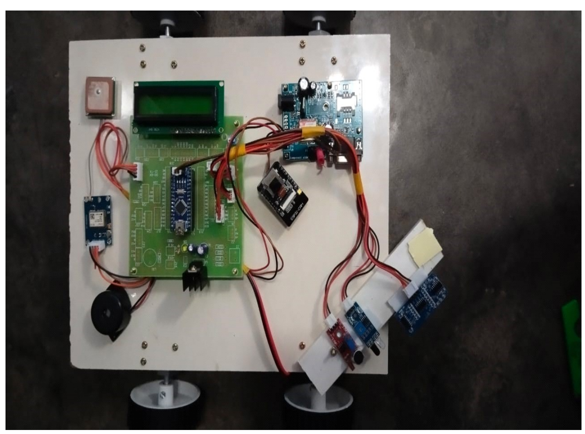


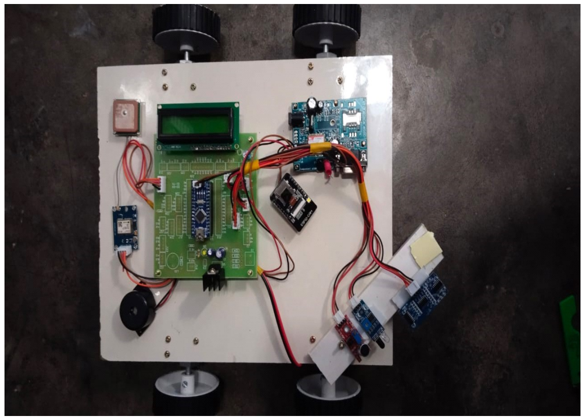
Figure 1
Training and Validation Accuracy
Training Accuracy
Validation Accuracy
Accuracy
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0
5
10
15
20
25
Epoch



6. RESULT

The results obtained can be interpreted in two ways, the first one evaluates the impact of the optimization algorithm on the classification of the railway track fault, but also the performance evaluated on datasets whose size is reduced, thus joins the standard problems to which data scientists use different data's.That said, the contribution is crucial to enhancing the circumstances for identifying faults in railroad tracks and optimizing the detector, which is built on a better IoT and DL basis for the CNN model—Mobile Net. In this way, the model predictor's parameter count has a significant applicability in mobile terminals, which is ideal for this use case. In addition, the integration of new CNN optimization techniques will serve to improve the performance but also the sensitivity of the model with a view to integrating new classes and predictors and thereby allowing tools for more efficient and evolving in different context of railway maintenance.





7.CONCLUSION

In this paper, an intelligent system detector allowing to classify defective and non-defective track fault was proposed and evaluated; based on CNN to generate a CNN model that can achieve good performance in classifying railway track fault. The results show that they can improve the effectiveness of feature extraction and classification. The model constructed based on the best-suited algorithm have boosted the results and achieved best accuracy. The proposed IOT and DL achieves great performance in track fault classification and mobile deployment open very interesting perspectives in term of applications. In fact, we will integrate this work into an inspection tool equipped with a decision support module, to facilitate the synthesis of information and the creation of the inspection report. The primary benefit of this proposed project is that it provides information to the locomotive pilot regarding line breaks as well as information to the railway control room. As is well known, the fog in the winter causes a great deal of accidents. We are done with an accuracy of 0.90. Therefore, the aim of this project is to eliminate any denials from railroads.

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