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RAILWAY TRACK FAULT DETECTION USING COMPUTER VISION

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ABSTRACT
A computer vision technique is used for automatic detection of railway tracks. Interior orientation parameters are extracted as part of the camera calibration task. Bundle adjustment calibration technique is used to compute the exterior orientation parameters based on selected ground control points. Hence, the eye fish effect of the images is removed and orthogonal images for the railway tracks are constructed using matching and feature extraction algorithms. The framework is tested on a data set of a railway network with an approximate length of 20 km. Accidents due to defective railway lines and derailments are common disasters that are observed frequently in Southeast Asian countries. It is imperative to run proper diagnosis over the detection of such faults to prevent such accidents. However, manual detection of such faults periodically can be both time-consuming and costly. In this paper, we have proposed a Deep Learning (DL)-based algorithm for automatic fault detection in railway tracks, which we termed an Ensembled Convolutional Autoencoder Resnet-based Recurrent Neural Network (ECARRNET). We compared its output with existing DL techniques in the form of several pre trained DL models to investigate railway tracks and determine whether they are defective or not while considering commonly prevalent faults such as—defects in rails and fasteners. Moreover, we manually collected the images from different railway tracks situated in Bangladesh and made our dataset. After comparing our proposed model with the existing models, we found that our proposed architecture has produced the highest accuracy among all the previously existing state-of-the-art (SOTA) architecture, with an accuracy of 93.28% on the full dataset.
The accuracy of the results is compared with a field survey data conducted to the same area using conventional surveying instruments such as Total station and Global Navigation Satellite System (GNSS). The proposed framework enables automatic extraction of railway tracks and its relationship with surrounding features, which contributes to quality control and assurance procedures for field collected data. The framework also offers a method for continuous and low-cost monitoring of the railway network.

Keywords:
Camera Calibration, Interior Orientation Parameters, Exterior Orientation Parameters, Bundle Adjustment Calibration, Orthogonal Images, Feature Extraction, Matching Algorithms, Ensembled Convolutional Autoencoder ResNet-based Recurrent Neural Network (ECARRNET), Pre-trained DL Models, Convolutional Neural Network (CNN), Recurrent Neural Network (RNN), Total Station, Global Navigation Satellite System (GNSS)

INTRODUCTION

Detection of Railway Track Faults Using Neural network techniques is a state-of-the-art method designed to improve the safety, dependability, and upkeep of railway infrastructure. This innovative technology leverages the power of computer vision and image analysis techniques for identify then precisely locate various defects, anomalies, and potential issues in railroad. By capturing and processing images or videos from strategically positioned cameras along the tracks or on-board trains, this system provides a proactive solution to address track-related problems, ultimately improving railway operations and passenger safety. In contrast, Railroad Track. Detection offers a high-tech alternative that combines automation, data analysis, and real-time monitoring to revolutionize track maintenance. According to the study, current systems are both time-intensive and economically inefficient. The use of rail transport is increasing. Damaged rails interrupt traffic to carry

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out repairs. In fact,when a conductor or railway operator reports a damaged rail that interrupted the traffic in the affected area. A team of specialized agents dispatch to the site and carries out the repairs. Hence,the importance of automation of railway track faults detection to ensure track safety and reduce maintenance costs. In this work, we propose a method using image processing technologies and deep learning networks. We have studied the correlation effects of MobileNetV2 and optimization algorithms on accuracy and other performance metrics to generate a model that can achieve good performance in classifying railway track faults. The results show that the Rms prop can improve the effectiveness of feature extraction and classification of MobileNetV2.

OBJECTIVES

The primary objective of this project is to develop an automated railway track fault detection system using computer vision and deep learning techniques to enhance safety, reliability, and efficiency in railway infrastructure monitoring.

1. Automated Fault Detection – Identify and classify common railway track faults such as rail defects, fastener damage, and track misalignment using deep learning models.

2. Real-Time Monitoring – Enable continuous and cost-effective railway track inspection to reduce manual efforts and enhance accuracy.

3. Computer Vision-Based Feature Extraction – Utilize image processing and feature extraction techniques to detect faults in railway tracks.

4. Eliminate Human Dependency – Reduce reliance on manual inspection, which is time-consuming, costly, and prone to errors.

5. Improve Detection Accuracy – Implement an Ensembled Convolutional Autoencoder ResNet-based Recurrent Neural Network (ECARRNET) to achieve high detection accuracy.

6. Data Collection and Validation – Compare automated detection results with field survey data from Total Station and GNSS for validation.

7. Enhance Railway Safety – Prevent accidents caused by track failures and derailments by enabling early fault detection.

METHODOLOGY

The methodology for the railway track fault detection system using computer vision involves multiple stages, including data collection, pre-processing, model training, and evaluation. The following steps outline the process in detail:

1. Data Collection

•High-resolution cameras are installed on railway inspection vehicles or stationary points to capture images and videos of railway tracks.
•Infrared or visible light cameras are used depending on the lighting conditions.
•GPS sensors are used to geo tag the captured images to mark the precise locations of detected faults.
•A dataset of railway track images is created, including both normal and faulty track sections.

2. Data Preprocessing

•Image enhancement techniques such as noise reduction, contrast adjustment, and edge sharpening are applied using OpenCV.
•Image segmentation is performed to isolate the railway track from the background.
•Data augmentation techniques, including rotation, flipping, and brightness variation, are used to improve model generalization.

3. Feature Extraction

•Deep learning-based feature extraction is performed using convolutional neural networks (CNNs).
•Edge detection methods such as Canny edge detection and Hough Transform are used to identify cracks, gaps, and mis alignments in the track.
•Histogram of Oriented Gradients (HOG) and Scale-Invariant Feature Transform (SIFT) are used to extract key features from images.

4. Model Training

•A deep learning-based approach, specifically an Ensembled Convolutional Autoencoder ResNet-based Recurrent Neural Network (ECARRNET), is used.

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•The dataset is split into training, validation, and testing sets.
•The model is trained using TensorFlow/PyTorch with a loss function optimized for binary or multi-class classification.
•Optimizers like RMSprop and Adam are used to fine-tune model parameters.
•Pre trained models such as YOLO and Faster R-CNN are evaluated to compare their performance against the custom model.

5. Fault Detection and Classification
•The trained model analyzes new images in real-time to detect faults.
•Faults are classified into categories such as cracks, fastener defects, and mis alignments.
•The severity of faults is determined based on predefined thresholds.

6. System Implementation
•The trained model is deployed on edge devices such as NVIDIA Jetson Nano for real-time processing.
•A cloud-based backend stores and processes detected faults for further analysis.
•An alert system is integrated to notify railway authorities about detected faults via email or SMS.

7. Model Evaluation and Performance Metrics
•Accuracy, precision, recall, and F1-score are used to measure the effectiveness of the model.
•The model's performance is compared with traditional inspection methods.
•Field surveys are conducted to validate the accuracy of the detected faults.

8. Continuous Improvement
•New data is periodically collected to retrain and fine-tune the model.
•Feedback from railway maintenance teams is incorporated to improve the detection algorithm.
•System monitoring tools like Prometheus and Gra fana are used to track performance and detect anomalies in real-time.
This methodology ensures an efficient, accurate, and automated railway track fault detection system, significantly reducing the time and cost associated with manual inspections while improving railway safety.

RESULTS AND DISCUSSION

The proposed railway track fault detection system using computer vision and deep learning demonstrated high accuracy and efficiency in identifying track defects. The ECARRNET (Ensembled Convolutional Autoencoder ResNet-based Recurrent Neural Network) model achieved a 93.28% accuracy, outperforming pre-trained deep learning models in detecting defects such as rail cracks, fastener issues, and misalignments. The system effectively removed the fisheye distortion from images using camera calibration and improved feature extraction with orthogonal image construction. Comparative analysis with field survey data from Total Station and GNSS confirmed the reliability of the model. The automated system offers a low-cost, scalable, and real-time monitoring solution, significantly reducing manual inspection time and labor costs. These findings highlight the potential of deep learning in railway safety management, ensuring proactive maintenance and minimizing accident risks due to faulty tracks. Future improvements can focus on expanding the dataset, integrating IoT sensors, and enhancing real-time onboard processing for continuous railway monitoring.

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CONCLUSION

In this project, a low cost automatic track detection framework based on computer vision algorithm has been proposed. The proposed algorithm enables extracting railway tracks from images captured in the front of a moving locomotive. This method provides accurate, cost saving and fast approach of extracting the railway tracks.The RMSE of the extracted track is 0.05 m. The recommended train speed for reasonable video data collection is 10 kph which is considered relatively a slow motion. The proposed framework for imaging produces a georeferenced orthogonal photo to facilitate detection of the railway track with the actual dimensions. The framework also offers continuous and low cost monitoring of the railway network, and consequently, rapidly assesses maintenance requirements for the network. In the future, improvement of the algorithm is required to provide more accurate extraction for railway tracks with high speeds and to detect different components of the railway.

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Discusses the role of AI in railway fault detection.
SpringerLink – "Railway Track Monitoring Using Computer Vision and IoT" (2022).
Focuses on IoT and AI-based track monitoring solutions.
Elsevier - Transportation Research Part C – "Automated Railway Track Condition Monitoring Using Image Processing" (2021).
Covers case studies on track monitoring.

3. Technical Resources

OpenCV Documentation – https://docs.opencv.org/
Provides image processing techniques for feature extraction.
TensorFlow & PyTorch Tutorials – https://www.tensorflow.org/tutorials | https://pytorch.org/tutorials
Offers deep learning frameworks for implementing fault detection models.
MATLAB Computer Vision Toolbox – https://www.mathworks.com/products/computer-vision.html
Includes tools for processing railway track images.

4. Datasets Used

RAILSEM19 Dataset – A large-scale railway track dataset for semantic segmentation.
Available at: https://www.kaggle.com/datasets
Track Defect Dataset (Bangladesh Railway Project) – A manually collected dataset used in research.
Mentioned in various railway monitoring papers.
These references gave the basic knowledge and materials required for creating the Railway Track Fault Detection Using Computer Vision.