Segmentation of Overlapping Ballast Coverage on Wooden Railway Sleepers Using Transfer Learning Technique

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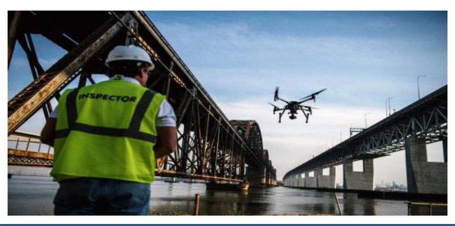
INTRODUCTION

Rail track inspection is a critical aspect of railway operations, primarily ensuring safety and preventing accidents. The inspections shall be sufficiently frequent with minimal interruptions to operations.

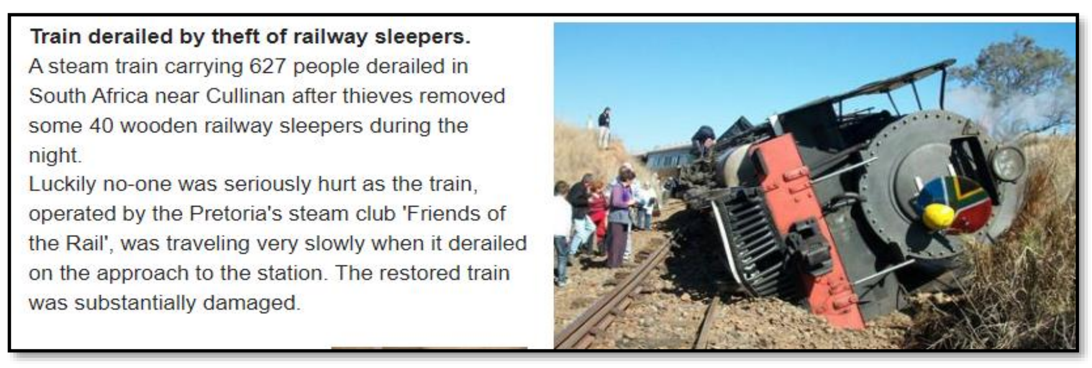
Significance of Image-Based Solutions

- Drones serve as an efficient tool for capturing images, enhancing the process of inspection automation and significantly reducing human effort.
- One Image can cover wide area on ground, handling many track elements.
- Image analysis can be done online or offline depending on criticality of inspection.
- Multiple types of components can be inspected from the drone image.
- Image-based inspection is a swift, non-invasive method that allows for frequent inspections.
- Advanced analysis algorithms such as Defect Predictions and Trend Analysis can be seamlessly integrated into the inspection process.



Sleeper/ Crosstie Inspection as Typical Example

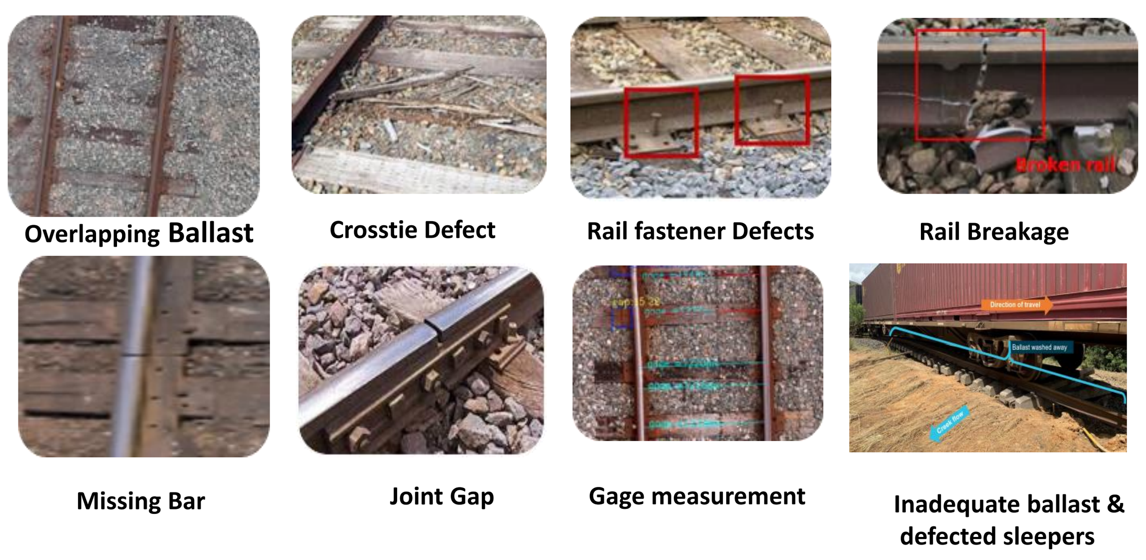
Sleepers and Crossties are crucial for railway tracks, providing support to the rails and maintaining the desired cross level between them with the aid of ballast. Crossties absorb some of the shocks and vibrations caused by passing trains, reducing wear and tear on other track components. Regular inspection and maintenance of crossties can extend the lifespan of the entire track structure.



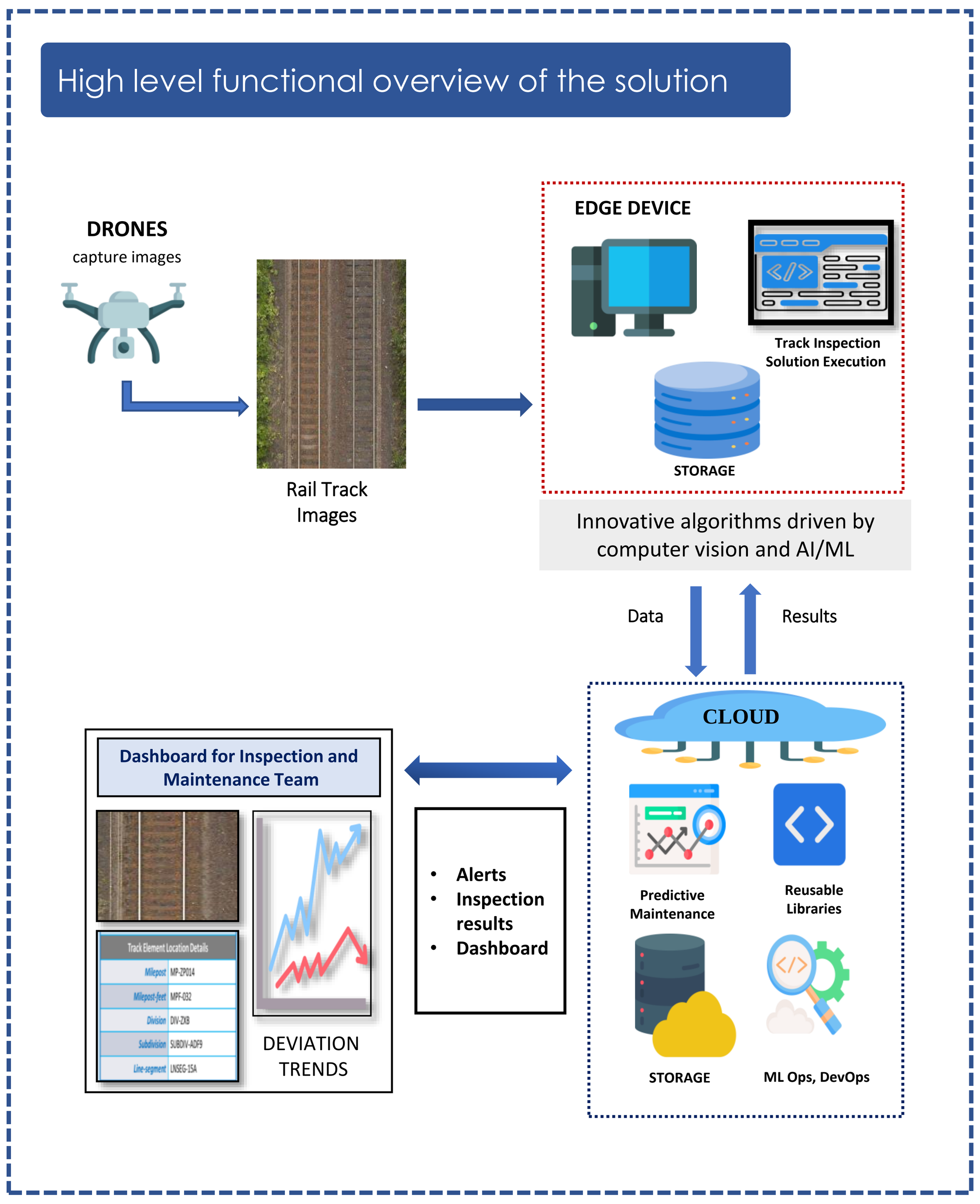
Train derailed by theft of railway sleepers.
A steam train carrying 627 people derailed in South Africa near Cullinan after thieves removed some 40 wooden railway sleepers during the night.
Luckily no-one was seriously hurt as the train, operated by the Pretoria's steam club 'Friends of the Rail', was traveling very slowly when it derailed on the approach to the station. The restored train was substantially damaged.

Real life incident of derailment due to missing sleepers
Source : South Africa's Rail Safety Regulator Investigates Cullinan Train Derailment : Shout-Africa

Along with inspection of sleepers, image analysis can help inspections of other crucial components as shown below.



SYSTEM OVERVIEW



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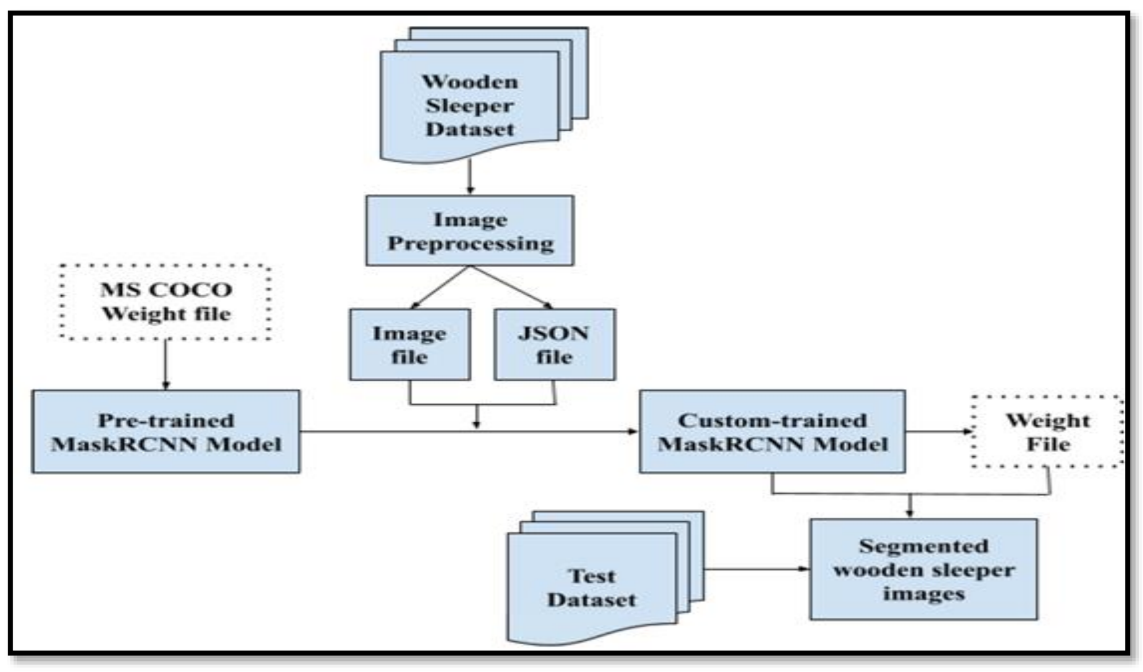
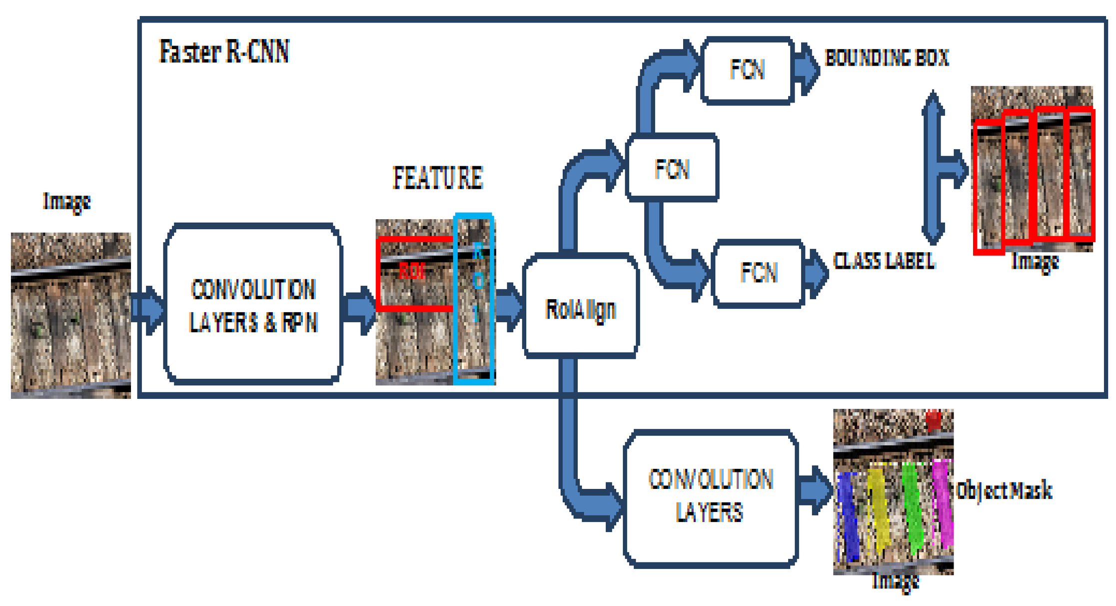
The flow chart of sleeper segmentation solution is shown below. Intelligent Algorithms are designed and developed for inspecting crossties/sleepers and analyzing overlapping ballast. The solution uses an application of texture-based segmentation using Mask RCNN.



Flow Chart of sleeper segmentation solution



Internal Architecture of Mask RCNN

DATASET PREPARATION

AI/ML algorithms need to be trained with images of elements with all possible defects, those need not be available from the rail field or it may not be practical to generate such defects. Datasets are prepared as below:

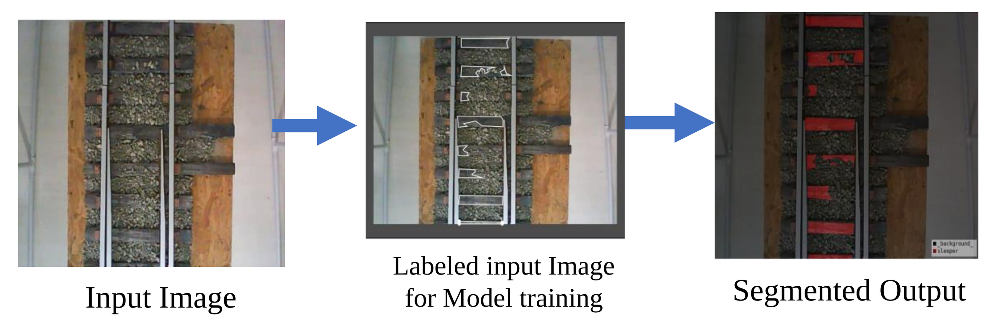
- Developed from a custom-built test track, utilizing a camera to capture oblique images from top view.
- Model Setup: The pre-trained Mask R-CNN instance segmentation model is initialized using weights from the MS COCO dataset. Model is fine tuned with the custom dataset prepared.

RESULTS

The evaluation of the sleeper instance segmentation model using Mask R-CNN is done on the COCO evaluation method, performance is measured on the metric of the average precision score and the prediction time. The average precision score is defined over the intersection over union (IoU). The result of the Instance segmentation and the respective test image is shown below. The proposed solution have a mAP score of 68.568 which is significantly improvised from the reference work of Singh et.al[1].

Result analysis

	Parameter	Value
Proposed Solution of Tata Elxsi	Mean average precision (mAP)	68.56879608855645
	Mean average Recall (mAR)	41.48405423728003
	F1 Score	51.69355718640357
Singh et.al [1]	Mean average precision (mAP)	48.759



CONCLUSION

The Rail track inspection is an integral component of railway operations, serving primarily to uphold safety standards and avert potential accidents.

Tata Elxsi developed an automated, non-invasive, high fidelity railroad solution that utilizes a cascaded AI architecture and advanced image processing techniques.

State-of-the-art Mask R-CNN model, texture based segmentation, specifically trained on a custom dataset, is employed for sleeper inspection. In cases were the sleepers are fully concealed or having non detectable textures, detections of other track elements like tie-plates, fasteners , etc. would be required to locate them.

The solution framework proposed by Tata Elxsi supports continuous learning, continuous integration and continuous deployment. The framework enables augmentation by solution pipelines and databases for improved performance. The solution can be deployed both on edge machine as well as cloud platform in which the solution will be triggered with live streaming from drones.

REFERENCES

- A. K. Singh, A. K. Dwivedi, M. Sumanth and D. Singh, "An Efficient Approach for Instance Segmentation of Railway Track Sleepers in Low Altitude UAV Images Using Mask R-CNN," IGARSS 2022 - 2022 IEEE International Geoscience and Remote Sensing Symposium, Kuala Lumpur, Malaysia, 2022, pp. 4895-4898, doi: 10.1109/IGARSS46834.2022.9883474.
- P. Bojarczak and W. Nowakowski, “Application of deep learning networks to segmentation of surface of railway tracks,” Sensors, vol. 21, no. 12, 2021. [Online]. Available: https://www.mdpi.com/ 1424-8220/21/12/4065
- K. He, G. Gkioxari, P. Dollár, and R. Girshick, “Mask r-cnn,” 2017. [Online]. Available: https://arxiv.org/abs/1703.06870.

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