Abstract Title: Image Analytics for Efficient Overhead Line Monitoring

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Background / Context

The Overhead Line Pantograph Monitoring System (OPMS) is for monitoring electric arcs formed between the pantograph-catenary interface. The OPMS includes a set of two train top cameras, one on the left of the pantograph and the other on the right, with built-in mechanism to pick up occurrences of electric arc at the pantograph-catenary interface. These arcs can only be detected during normal operation of passenger trains, and they could be precursors for defects in the catenary-pantograph interface. The footages of electric arcs with the corresponding train location information are then sent out to a web portal for review by maintainers.

In East Rail Line (EAL), one pantograph of a passenger train is installed with the OPMS cameras. As the passenger train runs its trips daily, the OPMS cameras pick up footages of electric arcs and send to the web portal. The OPMS can send out up to 700 alarms daily, which would be impossible to process all alarms every day. An initiative had begun in 2024 to help users process these alarms by classifying the severity of the alarms with object detection model and implement machine learning operations in the workflow to enable continuous improvement of the model. The model has successfully reduced the number of alarms to be processed, for example alarms without visible arc, by 50%.

Objectives

The objective of this paper is to present MTR's innovative approach to pre-processing alarms generated by the Overhead Line Pantograph Monitoring System (OPMS). By integrating an additional layer of AI, specifically an object detection model, on top of the proprietary system's results, the efficiency of reviewing OPMS alarms is significantly enhanced.

Methods / Approach

Alarms from the OPMS contain short video snippets (around 5 seconds each) of the electric arc captured. Image snapshots were extracted from the videos for object detection. The object detection model would process these images and detect the presence of different types of arcs (Figure 1).

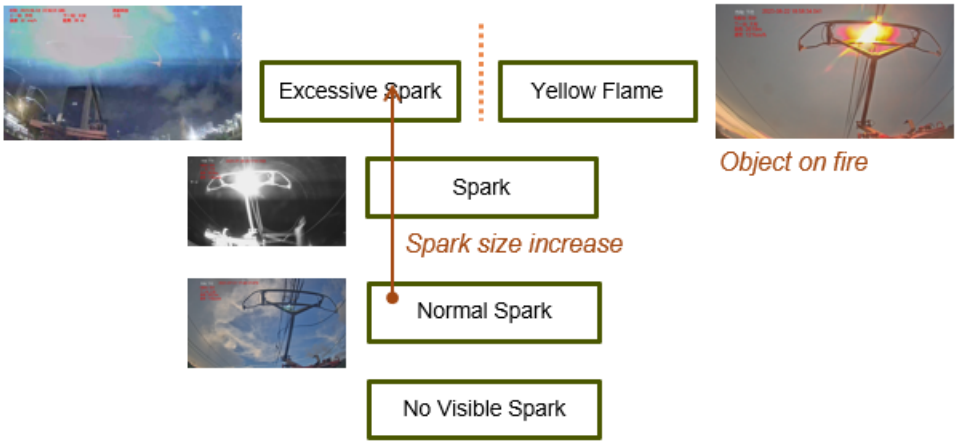

Figure 1Different types of electric arcs

Transfer learning of YOLOv5 was used to train our patented electric arc detection model. Around 1,000 photos of each severity of electric arcs were labeled and fed into the pre-trained YOLOv5 model. Only the backbone of the YOLOv5 model was frozen during the training to adapt the model to these new classes of electric arcs. After fine-tuning, our specific object detection model for electric arcs detection was able to classify these electric arcs with over 90% of accuracy. The model is then deployed to an inference endpoint to process alarms from OPMS system.

Users can review the alarms on a web portal. The web portal also provides visualization of the alarm counts and severity across time and in different sections of the overhead line. Users can use these visualizations to analyze the trends of electric arc occurrences.

Continuous ingestion of new data and re-training is enabled for the object detection model. After verifying the alarms, the verified data can be fed into the object detection model for retraining. Users can verify the alarm, re-train the model and deploy the model on the web portal. The integration of operations and machine learning enables the object detection model to continuously improve as more data are available and can adapt to future changes.

Results / Findings

From January to July 2025, our system, utilizing the patented electric arc detection model, processed over 66,000 alarms generated by the Overhead Line Pantograph Monitoring System (OPMS). The object detection model successfully filtered out more than 34,000 alarms that did not show visible electric arcs, effectively reducing the number of alarms requiring review by at least 50%.

Conclusions

This paper demonstrates the transformative potential of integrating advanced AI models with existing monitoring systems. By fine-tuning publicly available object detection models, we have significantly enhanced the efficiency of the Overhead Line Pantograph Monitoring System (OPMS). Our approach not only reduces the workload on maintenance teams by filtering out non-critical alarms but also

ensures continuous improvement through machine learning operations. This methodology can be applied to other visual detection systems, offering a scalable solution for pre-processing and improving usability without major system upgrades. This project highlights the potential benefits of leveraging AI to optimize infrastructure maintenance and suggests that similar approaches could be valuable in other contexts.