Video Track Inspector - hands on predictive maintenance on track circuits

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SUMMARY

The main root cause of unexpected occupancy of track circuits is caused by the failure of the Insulated Rail Joints. As a matter of fact over ten percent of Strukton Rail's railway infrastructure malfunctions are caused by the occupancy of track circuits when they are not supposed too. Mitigating these malfunctions is of high priority.

Siemens Mobility and Strukton Rail are jointly working on solutions in the area of predictive maintenance based on video analytics to improve the reliability of track circuits. This use case focuses on the identification, detection and prediction of defects at track circuits, to be precise; the Insulated Rail Joint. Insulated Rail Joints are bolted rail joints containing bonded insulation materials wrapped around it. Each Insulated Rail Joint contains insulation material to electrically isolate them. Insulated rail joints are essential components within the track circuit that control signalling and broken rail identification systems.

INTRODUCTION

No train can run without well-functioning infrastructure. Points, tracks, signalling, telecommunications, power supply and overhead contact wires must be one hundred percent reliable. The main purpose of maintenance is to ensure the one hundred percent availability of infrastructure components is maintained. Railway maintenance today is facing several challenges:

- Track maintenance activities are often performed with fixed intervals because the actual condition of the infrastructure is unknown;
- Wherever the condition of components is measured or by visual inspection by engineers who walk along the tracks, the specific rail section must be taken out of operation, resulting in downtime, inefficiency and costs;
- Analysis is most of the time done afterwards by visual inspection of (video) material or assessments of captured data. This is also time consuming and prone to errors due to human interference.

1 OVERVIEW OF THE SOLUTION

1.1 Cooperative approach

The collaboration of Siemens Mobility and Strukton Rail is unique; it combines data analytics and artificial intelligence knowledge from Siemens Mobility with operational maintenance knowledge of Strukton Rail. The focus of the collaboration is to achieve the best possible service for customers.

Video surveying is not new for Strukton Rail with video surveillance trains scanning the Strukton Rail maintenance contracts for decades. Strukton Rail operators at the Strukton Rail Control Centre process significant amounts of video data safeguarding the network on a daily basis, see figure 1.

Figure 1: setup of video surveying at Strukton Rail Control Centre

Strukton Rail has very detailed knowledge of the failure modes appearing on Insulated Rail Joints and their degeneration behaviour over time. Processing the video data is however a labour-intensive task. As a single source supplier and system integrator, Siemens Mobility bundles the necessary expertise to meet passenger requirements with innovations, and to allow transportation system providers to optimally deploy infrastructure and vehicles.

Siemens Mobility and Strukton Rail sat together to review how to process all this data in an automated and structured way, resulting in the first project automatically detecting and assessing the condition of the Insulated Rail Joints. Following the cycle from data generation, data analytics to data visualization and decision support, this paper will describe the solution of the Video Track Inspector in more details.

1.2 Data capturing

Individual components must be calibrated perfectly to each other to enable a highly automated analysis. A multi-line scan camera system attached to a video surveillance train provides multi-view video stream of the rails. The cameras are looking perpendicularly to train movement. Ten cameras are arranged to capture the rails from the side at different angles, see figure 2. Below 40km/h, the sample distance is also the spatial resolution of a pixel orthogonal to the track. Between 40 to 80 km/h, 1 line is skipped after every line captured (= double sample distance). Therefore the data capturing is done in service

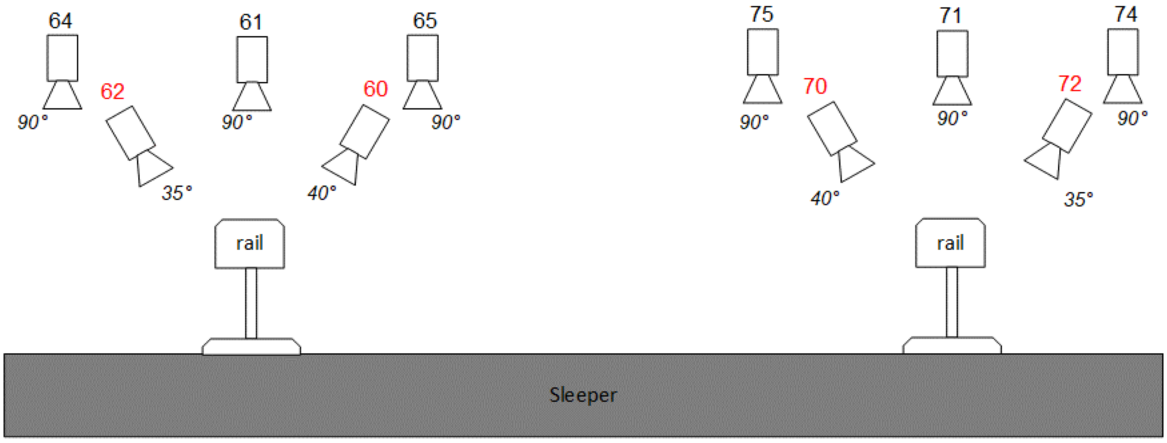

Figure 2: Schematic overview of camera setup

Each rail is observed by those 5 cameras giving a high-quality signal for artificial intelligence (AI) based analysis, which can fully exploit detailed and high-dimensional information. Currently the video material is stored on SSD-drives, that are exchanged after each run. The generated video material is then uploaded to the Siemens Mobility Application Suite Railigent, powered by MindSphere.

In future, the data generation process will be improved by the usage of in-service trains. This will enable further cost savings, additional revenues, avoidance of severe safety incidents to even more improve asset integrity. Furthermore, a wireless transfer of the material through WIFI or 5G into the cloud will be investigated, which would minimize the manual effort.

1.3 Data analytics

Key for enabling data analytics is reliable outcomes to base maintenance decisions on. Before the solution is used in daily maintenance practices a comprehensive evaluation is performed using well established metrics such as confusion matrices, capture rates and false positive rates. Approximately 20.000 joints have been manually assessed to annotate and assess defects. This initial dataset has been proven to be essential for verification and evaluation of the algorithms. The algorithms are connected to a self-learning machine interface at first to support railway engineers in decision making and hopefully in time, when there are enough annotated defects, to do the assessment stand-alone without human interference.

Six campaigns were processed using the current version of the VTI. Video material with a total length of more than 3.500 km was successfully analysed and has resulted in the identification of 18.286 insulated rail joints. All insulated rail joints were automatically inspected for defects. Domain experts in the Strukton Control Centre are now verifying the correctness of the fine-grained analysis by accepting and rejecting the automated decision. Those decisions are fed into the self-learning concept to further improve the performance of the currently deployed digital algorithms.

In essence, two Digital Algorithms are necessary to perform abnormality detection at elements on the track, such as defects at Insulated Rail Joints like missing insulation or deformation of the railhead, which in the long run lead to failures.

1.3.1 Digital Algorithm 1: Automatic detection and location of assets

The first algorithm is checking the video material for characteristics of an Insulated Rail Joint and points out the exact location. The algorithm has a very high accuracy rate of more than 97% (true positives) with a corresponding false positive rate of 6% (there is no joint, but the system reports a joint). False positives are manually rejected by engineers in the Strukton Rail Control Centre generating additional learning examples for the self-learning machine interface. The self-learning mechanism will be an essential mechanism to improve the end to end performance within the entire inspection process, the outcomes of the Digital Algorithm and/or the Control Centre assessment are also visible as an overview in the overview screen as shown in figure 3.

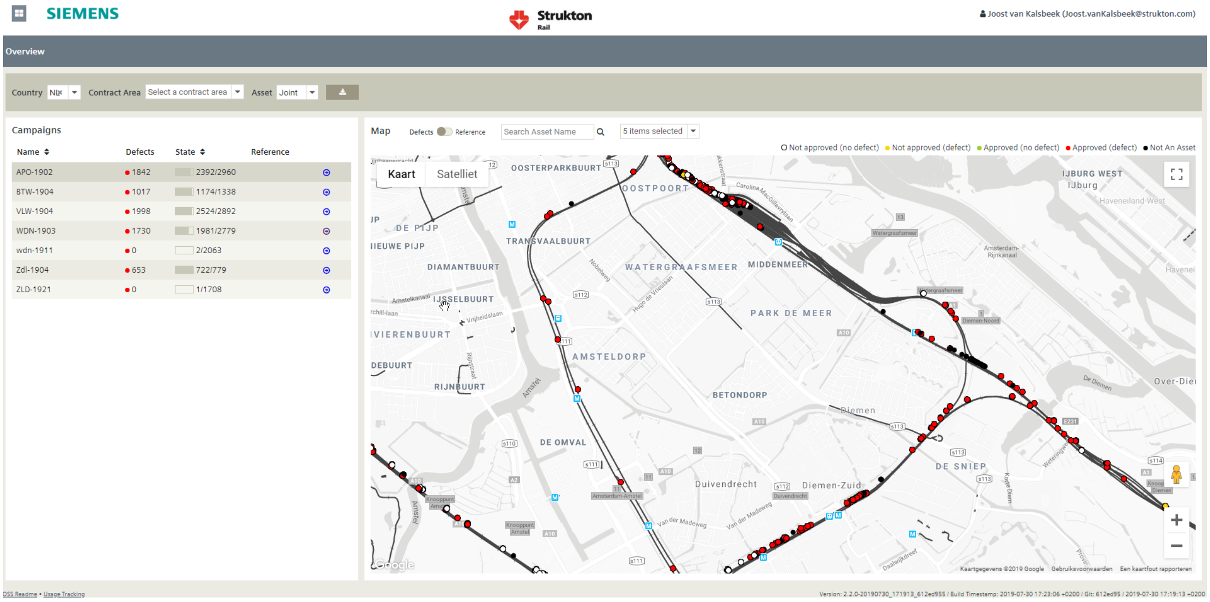

Figure 3: overview of campaigns with locations of assets found by Digital Algorithm 1

The algorithm can process pictures taken under various weather and day/night conditions. The exact localization of the assets is necessary, to enable a comparison of the joint condition over several measurement campaigns (trend analysis) by the following second algorithm.

1.3.2 Digital Algorithm 2: Automatic assessment of the railway asset condition

The second Digital Algorithm is assessing the condition of the Insulated Rail Joint, the size of the gap and deformation of railhead which is automatically assessed. If the gap in the railhead is declining, a short circuit will occur in the end. If the gap is closed by 80%, there is still some insulation between the two rails, but a maintenance task should be triggered quickly to prevent it from total closure and short circuiting. This second digital algorithm provides that assessment and, in the future, will predict a degeneration timeline. This helps operators to act before a problem fully occurs and step into predictive maintenance.

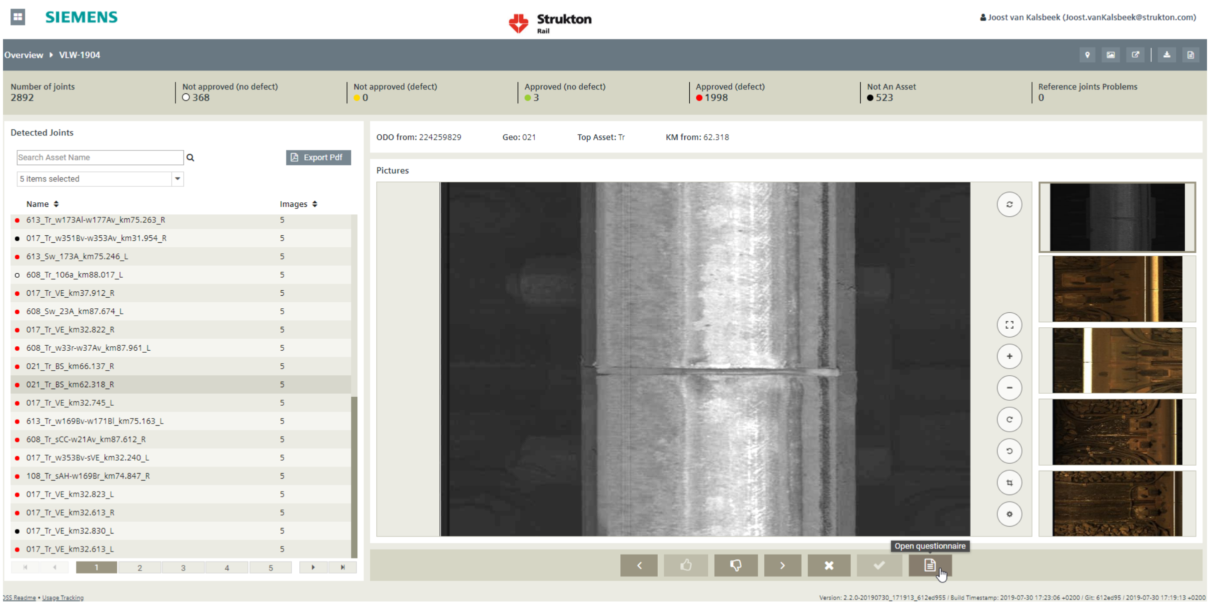

Figure 4: Digital Algorithm analysis on gap and deformation of railhead

Figure 4 displays the main assessment screen for the experts. of the Digital Algorithm 2 trained on identifying the gap and deformation of railhead. Within the tool experts of the Strukton Control Centre verify the outcomes and give their feedback in the inspection form shown in figure 5.

The deployed analysis steps are hosted within Railigent by exploiting the application suite powered by MindSphere. Major Railigent features are:

- State-of-the art: build with security and reliability in mind;
- Cloud-based & big data ready: Scalable to (almost) any amount of data allowing fast on boarding of new customers or tracks;
- Easy integration with other data from the rail world, such as vibration sensors on other trains or train control systems.

The algorithms are trained with Strukton Rail's real examples, see analysis screen in figure 4 and 5, through labelled pictures and improved by feedback data from using the tool in Strukton Rail operations (questionaire). In the data analytics phase it was especially challenging to acquire enough labelled pictures in the beginning (over a thousand pictures were needed), to have a broad enough data set for the initial setup of the algorithm.

Unfortunately, further details of the Digital Algorithm cannot be published at the moment, since they are currently under patent registration.

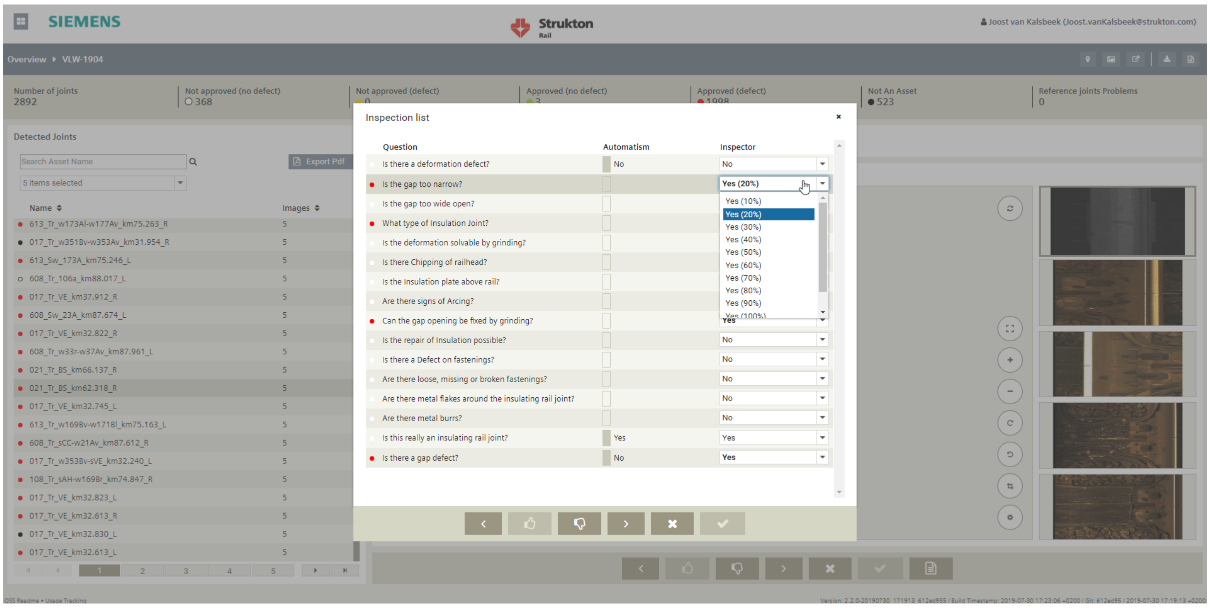

Figure 5: Video Track Inspector Insulated Rail Joint questionnaire

2 CONCLUSION

The current benefits from assessing Insulated Rail Joints with the Video Track Inspector are numerous. Each customer has its own drivers and requirements. In the Strukton Rail case, the Video Track Inspector is now successfully through the pilot phase and runs within the Strukton Rail Control Centre supporting the current maintenance process. The requirement to undertake physical inspections has been removed which will reduce ongoing inspections and maintenance costs. Most cost savings can be found in offering more uptime and a higher quality, because there is no longer a need for inspectors and engineers to go out and inspect assets. They only go out at the right moment in time to maintain the assets when it is really necessary.

The introduction of the Video Track Inspector creates the future of digitalizing railway track maintenance. The Insulated Rail Joint is just the first of many assets to be assessed. Key focus will be on safety and reliability of vulnerable assets like the guard rails and crossings in point work, rolling contact fatigue and fishplates on rails. In the coming years there will be a focus on developing a mount-on data capturing system enabling the Video Track Inspector to work for all heavy and light rail networks around the globe. This will increase flexibility towards a variety of customers and track gauges. A stream of regular incoming data is achieved by using in-service trains, which enables to set up highly detailed simulation models of the surveyed tracks. On that basis valid predictions of the future can be derived, which support the transition process from time-based maintenance strategies towards predictive maintenance.