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MACHINE VISION DATA PRODUCTS FOR THE AUTOMATED TRACK INSPECTION PROGRAM

SUMMARY

The Federal Railroad Administration (FRA) Office of Railroad Safety's Automated Track Inspection Program (ATIP) uses machine vision inspection technology along with Track Geometry Measurement and Gage Restraint Measurement Systems to thoroughly evaluate track. Algorithms trained to detect railroad infrastructure assets (e.g., fasteners) process images collected during ATIP surveys and identify possible defects associated with those assets.

With FRA support, ENSCO, Inc. developed software utilities to automatically detect and extract high-resolution images around areas of interest, such as switches, frogs, track geometry defects, and track with reduced lateral strength. Researchers conducted the work from July 2019 to November 2020. These new data products provide additional information for FRA safety inspectors to assess track safety. The first iteration of the algorithms showed promising results that will serve as a basis for the development of an automated evaluation of switch components.

BACKGROUND

FRA's ATIP recently started using machine vision inspection technology on its manned DOTX-220 track inspection vehicle. The FRA Office of Research, Development, and Technology (RD&T) identified an opportunity to develop and integrate new information from the data collected by the DOTX-220's imaging systems.

FRA's machine vision inspection technology relies on line-scan cameras that capture images of the rail one pixel-width-line at a time. Each scan line is stitched to the previous, creating one continuous image. The machine vision systems deployed on DOTX-220 includes a Track Component Imaging System (TCIS), which collects high-resolution images of the track roadbed; a Joint Bar Imaging System (JBIS) that captures images of each rail to assess joint bars, bolts, and gaps; and a Rail Surface Imaging System (RSIS) that captures high-resolution images of the top surface of the rails. The recently installed JBIS includes a suite of algorithms that detect joint bars and look for notable safety exceptions, such as cracks and missing bolts. Example images from the systems are shown in Figure 1.

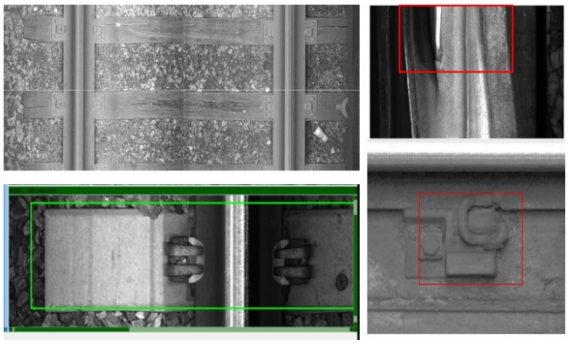

Figure 1. Example Images from FRA's DOTX 220 Machine Vision Inspection Systems

FRA also employs two area-scan imaging systems on the DOTX-220. FRA's Roadbed Driver View Imaging System (DVIS) captures a picture of the track and the surrounding wayside behind the survey vehicle at 25-foot intervals. FRA's Right-of-Way DVIS captures images looking down the track at 53-foot intervals. Examples of images from these systems are provided in Figure 2 below.

Figure 2. Example Images from FRA's Roadbed (left) and Right-of-Way DVIS (right).

OBJECTIVES

This effort aimed to develop image analysis technologies that identify and extract safety- and wayside asset-related information from TCIS, JBIS, and RSIS images.

METHODS

The effort began by creating a Data Product Plan to prioritize the image analyses. The team ranked each possible TCIS, JBIS, and RSIS data output by development effort and impact on FRA's safety assurance mission. The rankings considered recent trends in track-caused accident statistics to be a proxy for safety impact. In 2018, the condition of switch components made up 3 of the top 15 reasons for track-caused accidents [1]. As a result, FRA focused on developing frog and switch inspection products using the new image data.

The project leveraged systems already in use on the DOTX-220 to automatically extract image-based data products. The Track Geometry Measurement System (TGMS) records the location of events, such as locations of special track work, during a survey. The TGMS and the Gage Restraint Measurement System (GRMS) record the location of exceptions to predefined track geometry and track strength thresholds. Because all measurement systems on board the DOTX-220 are synchronized, the metadata produced from the track measurement systems was used to extract images and present them as tailored reports. Images extracted in the vicinity of a switch provide track inspectors with high-resolution pictures that can be used to assess the condition of switch components (e.g., switch point degradation) without being on the track. Images around track geometry or strength exceptions can also be useful to inspectors. The same logic used to extract images around switches was used to extract images near exceptions – so that the full views of the track bed and surrounding area could be analyzed by inspectors in an office environment.

The extraction routine was implemented in ENSCO's Virtual Track Walk software, which evaluates track inspection data and is run in the office or on a survey vehicle. The software automatically exports images around selected track events and exceptions in the form of JPEG images. PDF reports provide identifying information related to each exported image.

Developers also used images around switch components to train algorithms to identify switch points and frogs for use in future automated switch evaluation development.

RESULTS

The new event and exception reports can be used with current track condition reports to present a more complete picture of track conditions around these areas. Before the development of the image-based reports, inspectors received a strip chart representation of the parameter in question and metadata such as location, length, and severity. The track images add visual aids to analyze nearby track so that inspectors can see the entire track bed, a detailed view of the rails, and the surrounding area.

Figure 3 shows an example of the TCIS image extracted around a weak track location (as identified by GRMS). The yellow marks on the side of the image indicate the length of the recorded exception, and the red mark indicates the location of the peak exception value.

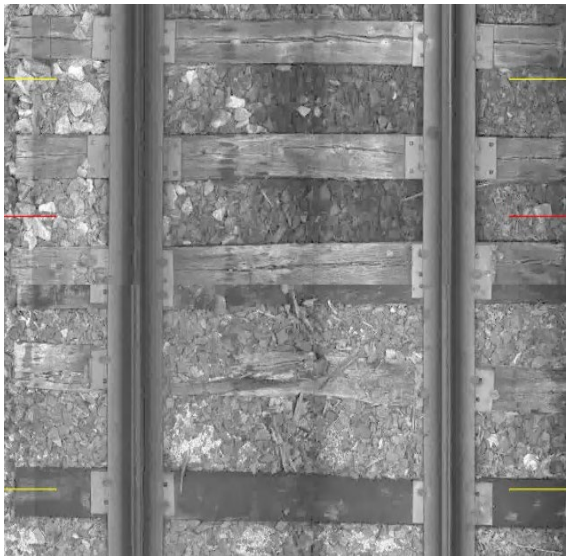

Figure 3. Example Exception Report (top) and Example TCIS Image at a GRMS Exception Location (bottom)

The geometry Image Exception Reports present data similar to other reports from FRA's ATIP fleet. The PDF report provides location and magnitude information about the individual exception as well as links to relevant extracted images. Images extracted from TCIS, the Roadbed DVIS, and ROW DVIS are automatically archived for evaluation.

A similar set of images are automatically extracted from various image data products in the vicinity of switches and other user-defined track assets. An Event Report, automatically produced for each survey, details the images extracted from the TCIS, JBIS, RSIS, and both DVIS for these areas. Figure 4 shows examples of extracted images for a switch.

Users can define the length of the image extracted from the machine vision systems by specifying the distance of the track before and after the event or exception of interest. The image-based reports and all exported imagery are available to FRA inspectors on the DOTX-220 following the surveys.

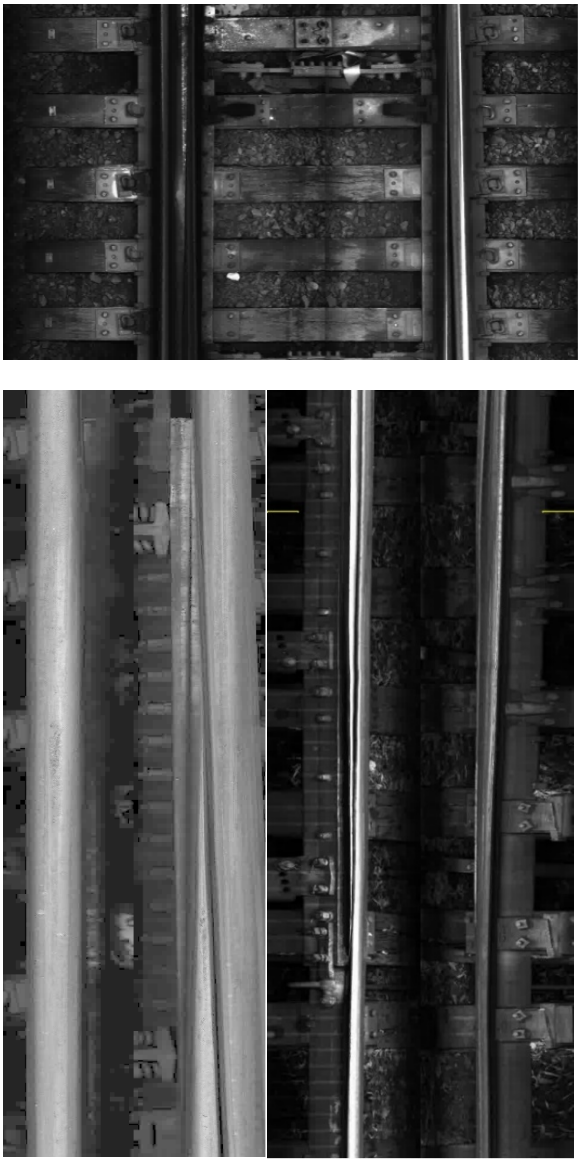

Figure 4. Extracted Images Surrounding a Switch Point from TCIS (top), RSIS (bottom-left), and JBIS (bottom-right)

CONCLUSIONS

The new machine vision data products present images associated with track events and exceptions. This imagery provides FRA track inspectors with valuable information to better evaluate the track. Reports configured to focus on switch components will allow FRA personnel to evaluate switch conditions in great detail without having to be on-track. Images extracted

around exceptions identified by TGMS and GRMS allow the user to evaluate contributing factors to track conditions.

FUTURE ACTION

This project demonstrated that algorithms can be trained to find switches and frogs. More training data is needed to further refine the framework and reduce the true and false positive rates to an acceptable level. Once the base detection algorithms are further refined, new automated algorithms for exception detection can be added to further an automated evaluation of switch components.

REFERENCES

[1] FRA, Office of Safety Analysis. 1.14 – Graphic Ten Year Accident/Incident Overview.

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