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Fully Automated Train Scan: Automatic Truck Component Scanning System Evaluation

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Summary

As part of the Association of American Railroads' Strategic Research Initiatives Program for advancing methods to improve inspection efficiency of components, Transportation Technology Center, Inc. (TTCI) has tested and evaluated a fully automated machine vision system for inspecting railcar truck components.

The system is capable of detecting missing axle end cap bolts, broken and missing springs, and accurately measures axle spacing. The demonstration included automated broadcasting of data to the equipment health management system located at the Transportation Technology Center, Pueblo, Colorado.

The system tested and evaluated was supplied by KLD Labs Inc. (KLD). The KLD truck component inspection system uses cameras, lighting, control equipment, and advanced analysis algorithms to analyze and report on the condition of truck components. TTCI began evaluation of this system in 2013 with a single sided, unidirectional system, and in 2014 the system was updated to include:

- Bidirectional measurement capability
- Data acquisition for trains traveling up to 45 mph
- Two-sided inspection capability
- Accurate imaging and measurements independent of train speed

Performance of the KLD truck component inspection system was verified using a "hospital train," a test train with known defects and the test train (FAST train) at the Facility for Accelerated Service Testing. The FAST train was used to perform inspections and to measure false detection rates under normal operating conditions. The KLD system found two broken springs on the FAST train that developed during normal operation.

Other inspections are being developed, and the system is proposed for a revenue service test in 2015.

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INTRODUCTION

Manual inspection of train components is repetitive and monotonous. The process lacks an easily accessible database, which makes trending of defects and optimizing preventive maintenance schedules nearly impossible. Automated inspection using machine vision promises to overcome these limitations. Machine vision technologies are able to objectively inspect areas of a railcar that are not easily visible to a manual inspector.

TTCI tested and evaluated the truck component inspection system produced by KLD Labs, Huntington Station, New York. The system was installed at the Facility for Accelerated Service Testing (FAST) on the High Tonnage Loop (HTL) and has the capability of performing bidirectional inspections on both sides of the FAST train under normal operating speeds up to 45 mph.

OBJECTIVES

The machine vision development project has been underway for several years. Initial efforts focused on producing consistently high quality images. Considerably longer development times were needed to develop the automated inspection algorithms based on these images. A final step involves efficiently reporting and archiving results. The effort in 2014 included testing the KLD system all the way through the final step of automated reporting of results to the equipment health management system (EHMS) located at the Transportation Technology Center (TTC).

INSPECTION SYSTEM

The primary components of the KLD truck component inspection system are cameras and lights arranged to image truck components at approximately the axle height level. Figure 1 shows the cameras and lighting modules.

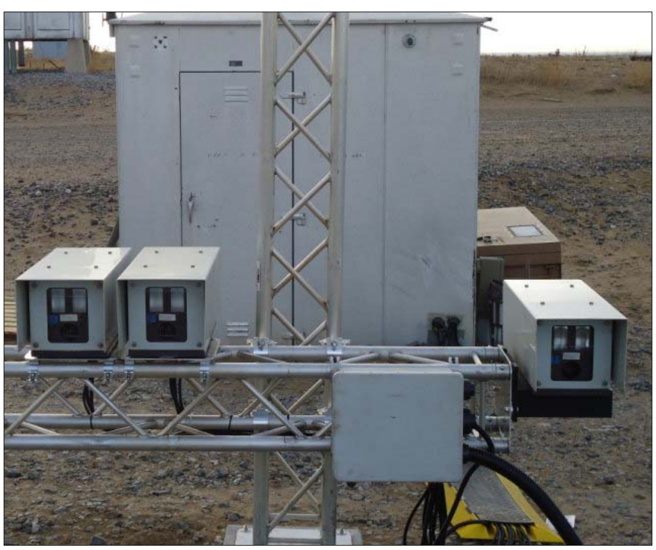

Figure 1. KLD Camera and Lighting Modules

Figure 2 shows the FAST train being inspected during a test pass. The system is completed by track-mounted train sensors and other control equipment.

The central computer with processor and database storage is kept in a wayside bungalow, which is visible in the background of Figure 1.

Figure 2. KLD Truck Inspection System examining the FAST Train

TESTING

The FAST train runs nightly on the HTL. The HTL provides a unique opportunity to test machine vision systems in conjunction with heavy axle load traffic or with dedicated test trains containing known defects. TTCI scheduled both traffic types so that detection capability and false alarm rates could be evaluated. Results from this testing are summarized below.

Missing Bearing End Cap Bolt Detection

The bearing end cap inspection is meant to confirm the integrity of the bearing end cap fasteners by reporting missing or damaged bolts. During this phase of testing, a hospital consist was used to introduce known defects to the system. A total of 1,404 axle end caps were evaluated by the system during this phase. The system successfully identified the missing bolt 17 times with no false positives. The system, however, failed to identify the missing bolt 12 times. In 11 of these 12 times, the ladder or its shadow obscured the view of the detection (see Figure 3). In the twelth case, however, the bolt was not obscured by the ladder or its shadow. KLD is studying the cause for this missed detection.

After the algorithm was deployed and active, it was tested for false detections on the FAST train. After 67 passes, involving 58,230 axle end cap inspections, the algorithm identified a total of 88 missing bolts. Upon manual inspection, however, no missing end bolts were identified. This means that the false positive detection rate is 0.15 percent. Closer examination of the images of the failure cases revealed that false positive detections were related to two causes: ladder shadowing and an alternative fastener type. Figure 4 shows bolts partially obscured by ladder shadowing.

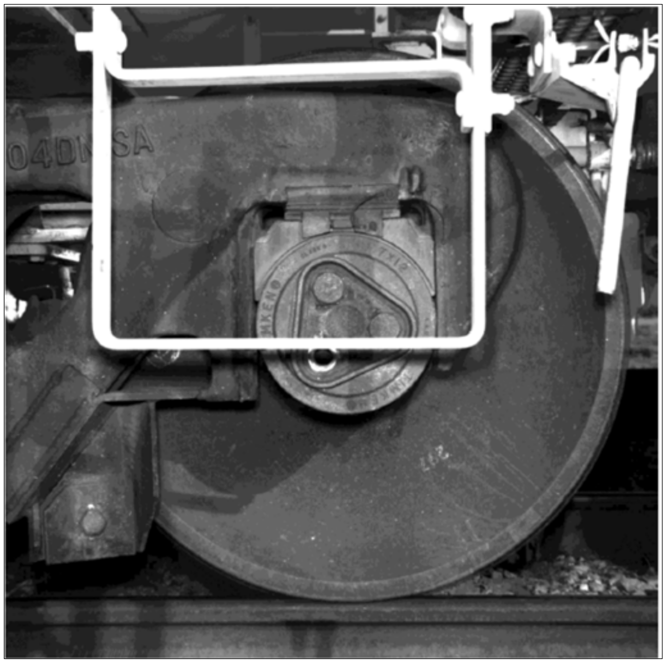

Figure 3. Missing Bolt Obscured by Ladder or Shadow

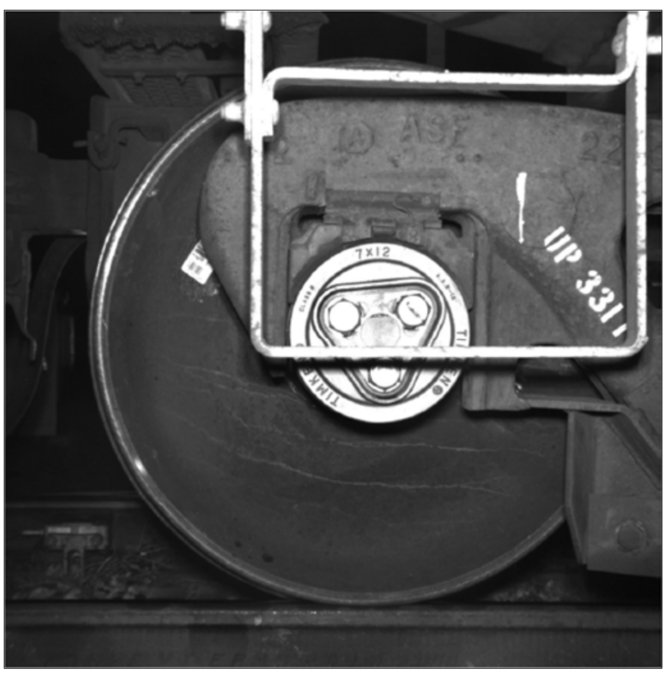

Figure 4. Bolt Partially Blocked by Ladder Shadowing

Figure 5 shows the alternative fastener head style that caused some false detections.

KLD finds missing fasteners by identifying the round hole where the bolt head should be found. The nonstandard fasteners on this particular test car fooled the algorithm, causing the false alarm.

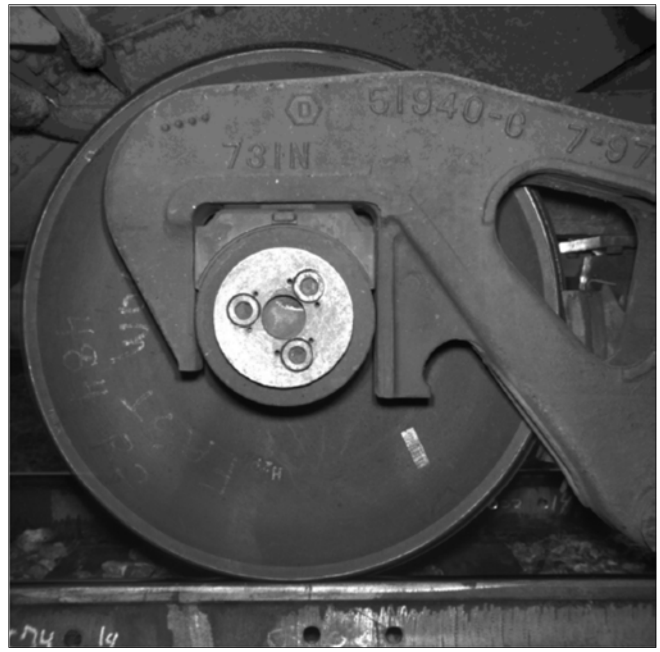

Figure 5. Different Fastening System

Broken or Missing Spring Detection

The broken spring detection algorithm was developed using the hospital consist. The system analyzed 29 passes of the test consist containing one broken spring. A total of 696 spring nests were evaluated. The algorithm identified the broken spring all 29 times, but falsely identified good springs as broken 21 times, giving a false positive rate of 3.1 percent. All cases of false positive detection occurred on an overly compressed spring. Figure 6 shows an example image for this case where the left spring is wrongly identified as broken.

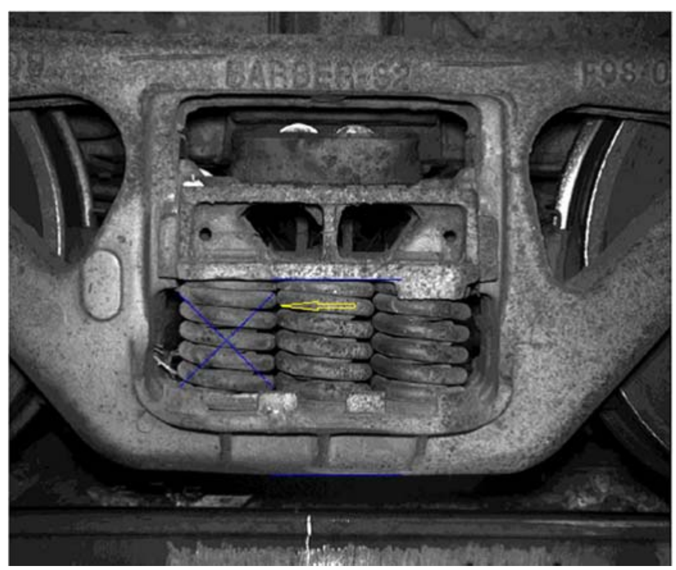

Figure 6. Over Compressed Spring Wrongly Identified as Broken

The KLD spring diagnostic identifies broken springs by looking for unevenly spaced coils. The premise is that mating coils will touch if a spring has a broken coil. This testing revealed that over-compressed springs can exhibit uneven coil spacing even if they are not broken. KLD is developing a spring compression measurement algorithm and should be able to eliminate the false positive event by combining information from these two inspections.

In the same 29 passes, the system was introduced to a missing spring in a different area of the train. The system successfully identified the missing spring 24 times and failed to do so a total of 5 times. This yields a false negative rate of 17.2 percent. There were no false positives for the missing spring measurement. At the time of testing, the Data Quality Index (DQI) calculation used in the algorithm detection was lower than what the system is currently running. Lowering this DQI calculation allows for more defects to be detected but may increase false positive percentage by analyzing lower quality images.

On subsequent FAST train testing, the broken spring algorithm identified two broken springs on the train that developed during normal operation.

Axle Spacing

As well as condition inspection, machine vision introduces the ability to make measurements that are not possible during static inspection. One such measurement is axle spacing on a moving railcar. KLD performed this measurement on the FAST train using its proprietary algorithms. The FAST train test is unique because it provides repeated measurements of the same cars. For 20 passes of the train, one specific leading axle had a standard deviation that was larger than the others. The axle spacing side to side difference for this truck varied up to the maximum of 17.85 millimeters (0.7 inch). The images of this truck were analyzed manually for confirmation of the data. Figure 7 shows the journal bearing shifted to the forward limit. Subsequent passes confirmed this same axle at the rearward limit. This particular car did not stand out in data collected by truck performance detectors located at FAST. Investigations are still underway to determine the cause of this behavior.

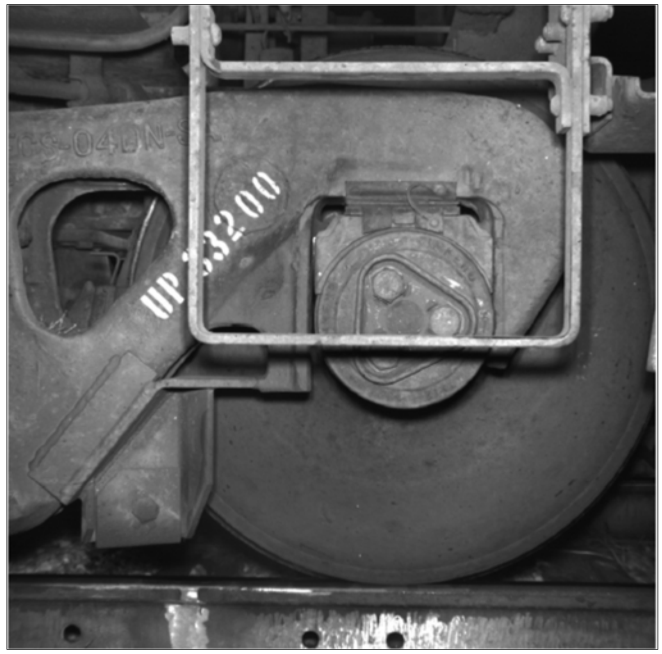

Figure 7. Axle Shifted to Forward Limit

CONCLUSIONS AND CONTINUED EFFORTS

KLD has substantially demonstrated the capabilities of its truck component inspection system at TTC. The system is capable of detecting missing axle end cap bolt, broken and missing springs, and accurately measures axle spacing. The demonstration included automated broadcasting of data to the EHMS database.

KLD is continuing to develop the truck component inspection system. In the future, KLD will move into revenue service testing for demonstration and be provided with the opportunity to gather more data on more components on a Class I rail fleet.