

The work described in this document was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

Undercarriage and Truck Component Inspection of Railcars Using New Vision TFDS

Matthew Witte, Ph. D. and Brian Lindeman

Summary

Transportation Technology Center, Inc. (TTCI) is working with Suzhou New Vision Electronic Technology Co., Ltd. (New Vision) of China to develop and evaluate a machine vision inspection system for evaluating the components of railcar trucks and undercar components. The Trouble of Freight car Detection System (TFDS) is a machine vision system for evaluating the condition of freight car truck and underbody components. The New Vision TFDS installed at the Facility for Accelerated Service Testing (FAST) at the Transportation Technology Center (TTC) in Pueblo, Colorado, represents an adaptation of the fourth generation of TFDS devices from China.

The TFDS photographs railcars with cameras and lasers at axle level and from the underside of the car. The 2D camera images and 1D laser range data are combined to form 3D images of the railcar components. These images are compared to 3D models of the railcars to identify defects such as bent or missing components. The 3D models are derived from the historical images taken of each railcar. The system uses a comparator algorithm to distinguish changes between the current image and the reference image of that car. Differences between the images are flagged automatically. The flagged differences currently require manual review to determine if they are true defects or benign changes such as dirt or a moved lever. New Vision is working on algorithms that will automate evaluation of the defects. They are also investigating automation of inspections that benefit the most from 3D information, such as the brake rigging and air hose height.



Please contact **Brian Lindeman (719) 584-0714** with questions or concerns regarding this *Technology Digest*. E-mail: brian_lindeman@aar.com.

©2017 Transportation Technology Center, Inc. Unauthorized duplication or distribution prohibited.



INTRODUCTION

Under the Strategic Research Initiatives (SRI) Program of the Association of American Railroads (AAR), TTCI has been working with New Vision of China to evaluate and develop the TFDS at the TTC in Pueblo, Colorado. TTC provides a venue for vendors to test and develop their machine vision inspection systems in an environment representative of the North American railroads.

BACKGROUND

New Vision started TFDS inspections in 2009 in China. Original systems produced images that were displayed on monitors and evaluated by human inspectors. As camera and data collection technologies evolved, New Vision progressed the design of both the hardware and software systems. The initial system used a camera with a relatively low resolution of 780 x 580. Now, in the fourth generation, the system uses a high-speed camera array with laser range finders and is capable of providing 3D high definition images. The image processors at FAST can finish processing images before the train arrives again, which is every four minutes.

CONCEPT OF OPERATION

The New Vision TFDS is a machine vision system for inspecting truck components and underbody structures of railcars. TFDS produces 3D images by combining high resolution 2D images with 1D laser range data. The result is 3D images with true depth information. These images are compared to a 3D reference model to identify differences. The concept is that missing or damaged parts will result in image differences. The reference image is captured the first time the vehicle passes the system and is updated with each subsequent pass. Current algorithms are not autonomously capable of determining the defect state of the initial reference image. Manual review is required to assess the initial condition. All subsequent changes will be captured by the comparator algorithm.

SYSTEM SPECIFICATIONS

The system under development at TTC is an adaptation of the fourth generation of devices currently used in China. The depth resolution of the 3D imaging has a precision of +/- 5/32 inch. Differences in size of 3/4-inch by 3/4-inch by 3/4-inch are identifiable by the comparator algorithm. Train speed during inspection ranges from 5 mph to 62 mph. Ambient operating range is -40°F to 167°F.

INSTALLATION AND HARDWARE

The New Vision TFDS was installed on the High Tonnage Loop (HTL) at FAST in 2015. Figure 1 shows the track side foundations and conduits during installation. Tie spacing had to be opened to 18 inches to make room for the bottom caisson that holds the cameras between the rails.



Figure 1. Installation of 3D TFDS foundations and conduits

New Vision installed cameras on both sides of the track and between the rails. Side cameras are for imaging the truck components. Cameras between rail ties are for imaging the undercarriage. Figure 2 shows the wayside camera boxes and automatic equipment identification (AEI) reader, and Figure 3 shows the bottom caisson. New Vision is redesigning the caisson doors to prevent ballast from jamming the protective shutters.



Figure 2. TFDS rail side camera box and AEI reader

The TFDS is activated by wheel sensors attached to the track. Wakeup sensors are at a distance that gives the system enough time to activate before the train arrives at

the inspection station. Wheel sensors that trigger the cameras are visible in Figure 3. The sensors are configured so inspection speed of the train can vary from 5 mph to 70 mph.



Figure 3. TFDS bottom caisson with between-rail cameras

All of the wayside electronics are housed in a weatherproof box. The control computer, image processing computer (IPC) for image acquisition, image recognition server, remote control box, signal processing box, multiple-function power supply box, uninterrupted power supply, network device, and power supply box are located in a climate controlled bungalow nearby.

IMAGING CAPABILITY

TTCI operated test trains to test the consistency of image quality. A test train was run at various times of the day to test for glare from the sun at different angles. New Vision engineers adjusted settings to reduce sun glare and improve image consistency for the varying conditions. After New Vision updated the laser range finder, image quality appeared consistent at 5, 10, and 15 mph. Imaging capability was later verified to 45 mph with the FAST train. Although it cannot be verified on the HTL, New Vision claims capability to 70 mph.

INSPECTIONS

Images are produced for all components near axle level and for the underside of the railcar near the axles. Figures 4 through 6 show examples. Inspections are per image, with all visible components being evaluated for changes.

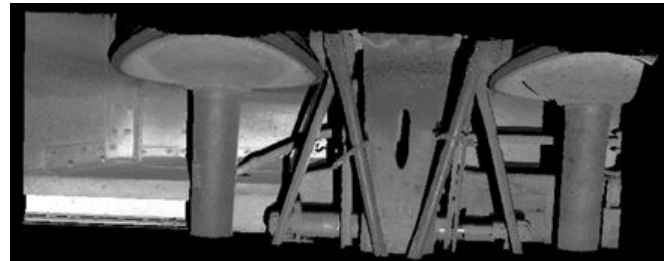


Figure 4. TFDS 3D image of underside of truck

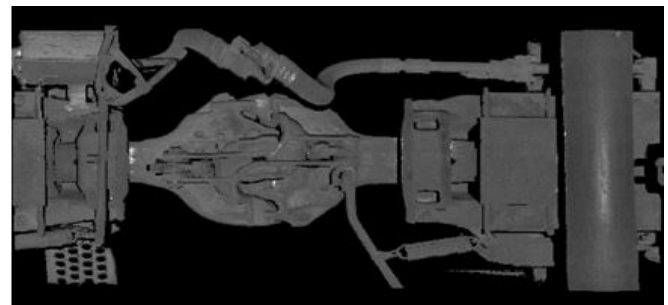


Figure 5. TFDS 3D image of underside of coupler area

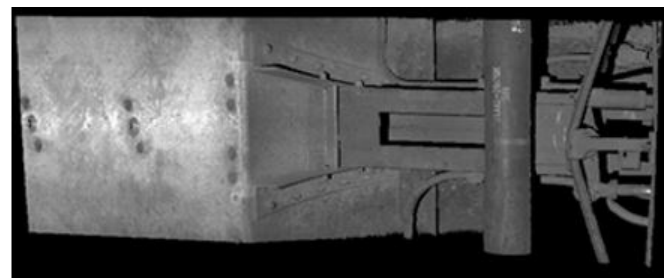


Figure 6. TFDS 3D image of underside of body

DETECTION ALGORITHMS

New Vision runs an image comparator algorithm to find differences between images. This is done on a per-car basis, when the baseline image is created the first time a car is seen. As such, the car is not autonomously inspected until its second pass of the system. Figure 7 shows the detection of small magnets attached to a railcar on the train at FAST. These magnets were sized to simulate defects and are just above the detection threshold.

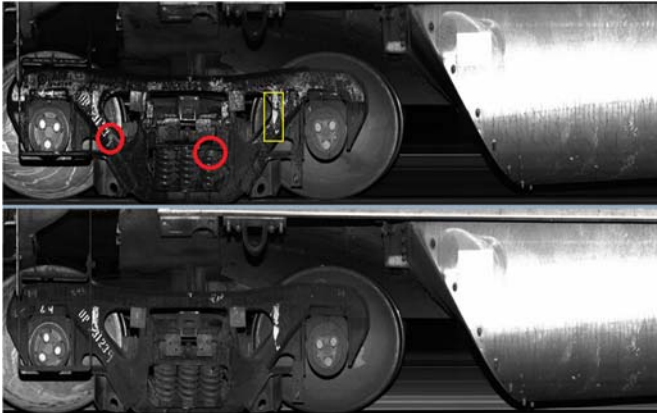


Figure 7. Detection of artificial defects (magnets)

Although the algorithm can consistently find artificial defects above the size threshold, it also detects many insignificant differences. Optical differences can cause an indication. Figure 8 shows a false detection due to lighting variations. This indication is caused by slight variation in image exposure due to lighting.

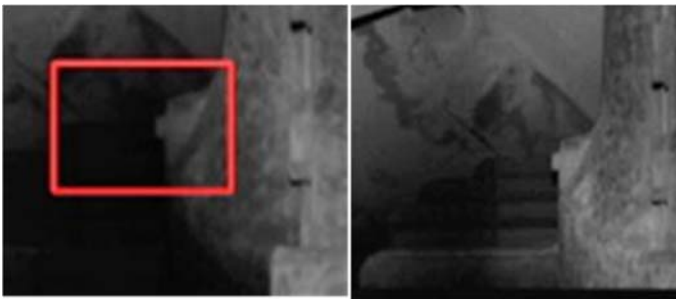


Figure 8. False detection due to lighting variation

CONCLUSION

The TFDS creates true depth 3D images by combining 2D area scan photos and 1D laser range data. Image capture has been tested up to 45 mph on the HTL. The TFDS detection scheme is based on a comparator algorithm. This algorithm compares the most recent image to the previous image of the same car. In its current state, the system is susceptible to both missed detections and false alarms. Currently, the only method to determine if the first image has a defect present is by manual review. False detections are also common. Intermittent changes in image quality (possibly due to lighting and triggering) create exposure differences that result in false indications. There is currently no intelligence for identifying the cause for image differences. Such differences could be the result of repair work done, dirt or corrosion formations, or foreign objects such as tumbleweeds.

NEXT STEPS

New Vision is reviewing vetted image data provided by TTCI. This data will provide a basis for defect identification so New Vision can create algorithms that autonomously differentiate true defects from insignificant changes. TTCI has also suggested that New Vision capitalize on the benefits of 3D machine vision for the inspection of position sensitive hardware such as brake beams and air hoses. Full automation may take over six months to complete because of the variety of hardware available in North America.

Visit our website at <http://www.ttc1.aar.com>

Disclaimer: Preliminary results in this document are disseminated by the AAR/TTCI for information purposes only and are given to, and are accepted by, the recipient at the recipient's sole risk. The AAR/TTCI makes no representations or warranties, either expressed or implied, with respect to this document or its contents. The AAR/TTCI assumes no liability to anyone for special, collateral, exemplary, indirect, incidental, consequential or any other kind of damage resulting from the use or application of this document or its content. Any attempt to apply the information contained in this document is done at the recipient's own risk.