

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

Automated Safety Appliance Inspection System Evaluation

James Robeda and Semih Kalay

Summary

Through extensive testing at the Transportation Technology Center (TTC), Pueblo, Colorado, the railroad industry has evaluated two advanced machine vision systems capable of automatic inspection of the safety appliances on coal cars using high-speed digital video cameras, lighting, and other sophisticated electronic equipment.

Results of the tests conducted so far indicate that the use of a combination of technology driven car inspection equipment and performance-based inspections may be feasible to replace the current inbound and outbound inspections performed by yard inspectors.

The systems are capable of detecting defects at rates better than 98 percent. The high defect detection rates of both systems are very encouraging. The results indicate that safety appliance defects can be reliably detected using machine vision technology. However, both systems also produce an equally high rate of false positive readings, which is certainly a cause for concern. The vendors are addressing the issue and further development and testing of the systems will continue at TTC and in several revenue service locations.

Machine vision technology has been used in the manufacturing environment for some time. The technology lends itself to performing routine inspections where repetition and inspector fatigue are issues. In recent years, this technology has found applications in the railway industry in detectors such as wheel profile measurements systems and brake shoe measurement systems. The technology can enhance the inspection process because it is objective rather than subjective, and it provides historical data that can be used for trending and preventative maintenance.

The Association of American Railroads' (AAR) Strategic Research Initiatives Program provides research support for the AAR Technology Driven Train Inspection Task Force activities as they identify essential Federal Railroad Administration rule changes and waivers that will enable cost effective application of new technologies.



INTRODUCTION

The Code of Federal Regulations (CFR) Title 49 Section 231 governs the condition of railcar safety appliances (e.g., ladders, handholds, and sill steps). Although not specifically detailed in the regulation, inspection of safety appliances is required to ensure compliance with the rules. Safety appliances are traditionally inspected by mechanical forces while they are conducting pre-departure inspections or by the train crew when they are conducting inspections required by CFR 215 Appendix D. These inspections require time and resources and can be somewhat subjective. Machine vision technology has proven effective in certain railway applications, such as wheel profile monitoring and brake shoe condition monitoring and is being developed to improve both the effectiveness and efficiency of the current manual inspection process.

In 2006, under the direction of the AAR’s SRI Technology Driven Train Inspection (TDTI), the University Illinois at Urbana-Champaign conducted a proof-of-concept demonstration verifying the feasibility of machine vision technology for this application. The successful completion of this demonstration and the increasing use of machine vision technology in the railway industry prompted further development of a prototype system. In 2007, a request for proposal was issued to develop a prototype system to assess safety appliance condition on open top hopper and high sided gondola cars with the capability to incorporate additional car types in the future. Two vendors were chosen to develop prototype systems (Figures 1 and 2) to be installed and tested at the Facility for Accelerated Service Testing (FAST), Pueblo, Colorado. Initial testing and evaluation was completed in October 2008.



Figure 1. Vendor A Installation at FAST



Figure 2. Vendor B Installation at FAST

BACKGROUND

Machine vision technology has been used in the manufacturing environment for some time. The technology lends itself to performing routine inspections where repetition and inspector fatigue are issues. In recent years, this technology has found applications in the railway industry in detectors such as wheel profile measurements systems and brake shoe measurement systems. The technology can enhance the inspection process because it is objective rather than subjective, and it provides historical data that can be used for trending and preventative maintenance.

A natural extension of the technology in the railway industry is the inspection of railcar safety appliances. However, adaptation to this application presents certain challenges. The wide variation of safety appliance location and design requires a very robust recognition algorithm as well as extensive image acquisition. Although significant, these challenges are being addressed by the two vendors selected to develop the concept under the direction and oversight of Transportation Technology Center, Inc.

The vendors approached these challenges differently. One uses streaming video with six digital cameras for each side of the track with visible spectra flood and strobe lighting. The other chose triggered images using eight cameras and infra-red strobe lighting. Each approach has certain advantages as well as disadvantages.

Streaming video requires greater storage capacity as well as the ability of the algorithm to locate the area of interest. However, streaming video captures an image of the entire railcar, which allows detection of safety appliances at locations other than in the corners.

Triggered images require less storage capacity and eliminate the need for the algorithm to locate the area of interest. However, different car types and alternate safety appliance locations require exact triggering capabilities.

Both vendors have developed algorithms that can detect deformed or missing ladders, handholds, end platforms, and brake wheels. Both systems are designed to operate 24 hours per day, 365 days per year.

Test Methodology

To evaluate each system objectively, a blind test was conducted using equipment at FAST with safety appliance defects created specifically for the test. These defects included missing, bent, and fouled safety appliances. A 50-car consist made up of coal cars was used with a limited number of test cars distributed throughout the train. Multiple passes were made in each direction at various speeds. The systems were then evaluated on both the ability to detect safety appliance defects and the rate at which false positive results were reported.

Test Results

Vendor A’s system was tested on June 30, 2008. The test consist was made up of 50 cars with 4-test cars having five known defects. The train made five passes in each direction at speeds of 15, 25, and 35 mph for a total of 30 passes. This equates to a total of 150-detection events. The system correctly identified 149 of these events for a successful detection rate of 99.3 percent. However, the system also reported high false-positive rates.

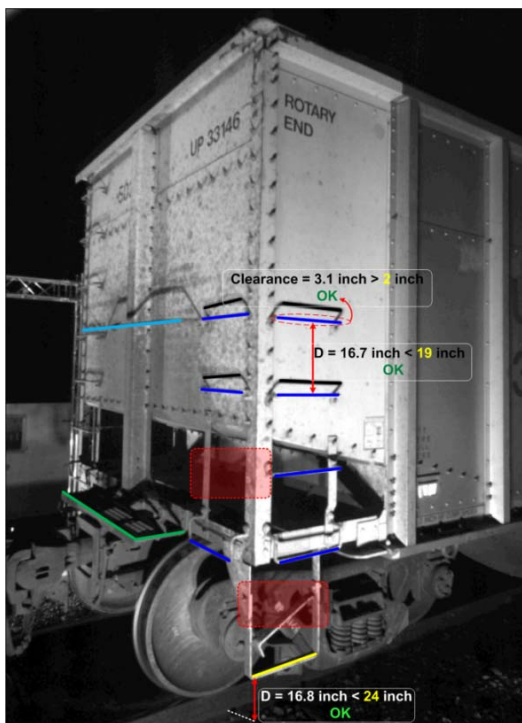


Figure 3. Vendor A Processed Image

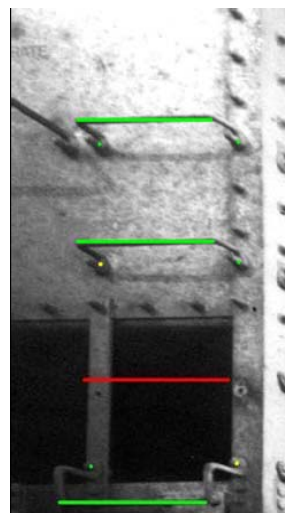
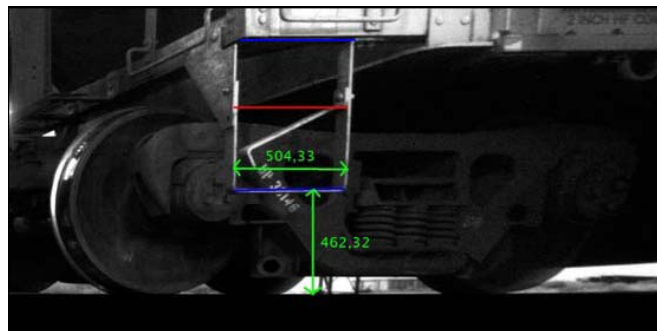


Figure 4. Vendor B Processed Images

Vendor B’s system was tested October 13, 2008. The test consist was made up of 50 cars with 5 having six known defects. The train made passes in each direction at speeds of 15, 25, and 35 mph for a total of 28 passes. This equates to a total of 168-detection events. The system correctly identified 166 of these events for a successful detection rate of 98.8 percent. However, the system also reported high false-positive rates.

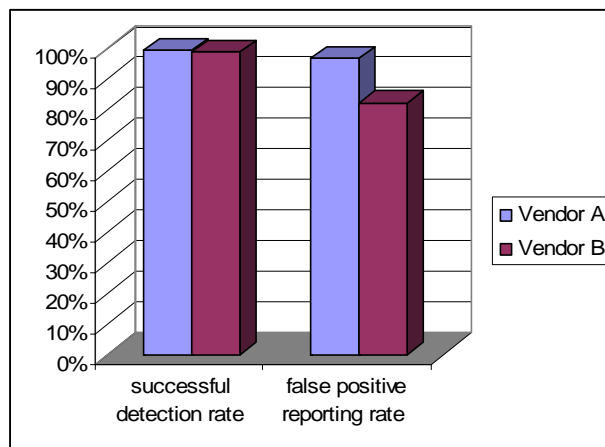


Figure 5. Test Results

CONCLUSION

The high defect detection rates of both systems are very encouraging. These results indicate that safety appliance defects can be reliably detected using machine vision technology. However, the high false-positive rates recorded by both systems are certainly a cause for concern.

The majority of the false-positive reports were triggered because the system failed to detect a safety appliance on the coal cars and reported it as missing. This occurred for handholds, ladder irons, and uncoupling levers. There were also a smaller number of false positives generated for clearance infractions, because thresholds were improperly set or reported measurements were not properly rounded.

Both vendors are currently in the process of addressing the high false-positive rates. Minor software modifications will be required to address the improper clearance reports and both vendors are currently making these changes. The missing safety appliance reports will require more effort to correct. Vendor B is attempting to address the problem using software changes only. Vendor A has added additional hardware and is also working on software enhancements to reduce the false-positive rate.

When these changes and enhancements are completed, both systems will be retested at FAST to evaluate their effectiveness and determine the future use of machine vision technology for this application.

FUTURE WORK

Development and testing will continue at FAST to address the false-positive rates. Once this issue has been successfully resolved, work will focus on algorithm and hardware expansion to include different car types. Boxcars and covered hopper cars will be addressed next with low-sided gondolas and flat, intermodal, and tank cars to follow.

In addition to the work being continued at FAST, both vendors are getting ready to install prototype systems in revenue service. These systems will be used to verify test results as well as evaluate real-world performance. These revenue service sites will also provide feedback as to overall system performance, as compared to current inspection methods.

On December 18, 2008, Vendor A's prototype was installed on a western railroad and began collecting data on safety appliances. Vendor B's prototype system will be installed on an eastern railroad in early 2009.

Work that has been completed on the Automated Safety Appliance Inspection System is also being leveraged to begin the development of additional applications of the technology to inspect the entire railcar including the structural components (e.g., center sills, side sills, and cross bearers).

Under the SRI program, in 2008, researchers at University Illinois at Urbana-Champaign demonstrated the feasibility of a underframe imaging. Further demonstration tests will be conducted in 2009 using a 12-camera system at TTC to identify the railcar structural components and to detect defects.

REFERENCES

1. U.S. Department of Transportation, Federal Railroad Administration. November 1, 2007. Office of Safety, Code of Federal Regulations Title 49. *Railroad Freight Car Safety Standards- Part 231*.

Visit our website at <http://www.ttc.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.