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# Accelerating Machine Vision Inspection Algorithm Development

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## Summary

Transportation Technology Center, Inc. (TTCI) has developed a viewing portal for reviewing machine vision inspection images. The manual reviewer interface is being developed to work on multiple machine vision systems. It seeks to answer the first question of algorithm developers: what does the defect look like? This web-based manual viewer provides a convenient portal to easily capture the intelligence of a human inspector. Markups and comments generated by the inspector are automatically recorded in a database of reviewed images. This database is made available to algorithm developers who in turn can use it to create robust detection algorithms for the variety of cars and components available in revenue service. The end effect is to accelerate the development of automated detection systems. This *Technology Digest* summarizes the development of the manual reviewer interface.

Railcar inspection has traditionally been a visual process. Railcars and components are typically inspected visually at rail yards when trains arrive and/or depart. Now, using machine vision technologies, train inspection is evolving to include automated imaging and in-motion evaluation. Machine vision inspection of railcars while in a moving train promises to improve inspection efficiency and safety. It increases the inspection rate, reduces exposure of humans to rail yard hazards, “looks” at the underside of equipment, and increases the rate at which potentially failing components are identified. Additionally, it provides a history of each inspection, which allows for trending of component condition and proactive maintenance rather than reactive repair.

In collaboration with the Federal Railroad Administration (FRA), the Association of American Railroads’ (AAR) Strategic Research Initiatives (SRI) Program has sponsored TTCI in the development of a manual data reviewer interface for machine vision inspection systems. As part of the SRI Program, TTCI has provided a venue for machine vision developers to test and develop their inspection systems in a realistic environment. Several of the machine vision systems developed at TTCI have been deployed in revenue service. A common issue during deployment is that automated detection algorithms that work well during testing are overwhelmed by the variety of cars and components encountered in revenue service. The manual reviewer makes data available to create robust detection algorithms earlier in the design cycle.

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**INTRODUCTION**

As part of AAR SRI research efforts aimed at developing machine vision systems for advancing autonomous rail vehicle component inspection, a manual reviewer prototype for viewing machine vision image data is being developed. This reviewer provides a portal for inspection experts to review component images and to record the condition information they observe. As users evaluate car component images, vetted defect information is captured in a database. This vetted information will be available to system developers who can use it to optimize inspection algorithms based on data from a large sample of cars.

**BACKGROUND**

With recent developments in imaging hardware and data storage systems, the present challenge for machine vision providers is reliable automation of defect identification. It is not feasible to develop automated algorithms without proper knowledge of what constitutes a defect. In the manufacturing environment, where machine vision inspection is well established, the acceptable state of components can be clearly distinguished from the defective state because conditions are controlled and component configurations are well defined. In the railroad environment, environmental factors are not controlled and the hardware being inspected changes continually. Railcar type, manufacturer, configuration, and wear state all contribute to a general state of the car. Baseline acceptable condition is not constant in the railroad environment. Likewise, failure modes and mechanisms can vary. Car loading state, component wear, and environmental factors all influence the component evaluation algorithms. In addition, component defects occur in various modes. They can be abrupt failure, such as a broken spring, or progressive wear, such as excessive wedge rise.

Automated railcar inspection systems have been under development for several years. Previous FRA testing to demonstrate automated inspection of safety appliances revealed that normal variations in railcar components (manufacturer, model, type, etc.) can easily confound image analysis algorithms. Machine vision systems must be programmed to recognize defects and out-of-specification conditions. In general, the commercial vendors that code up the inspection algorithms for evaluating component condition are not themselves rail equipment inspection experts. Consequently, inspection automation is an inefficient process of trial and error. A way to address this shortcoming is to better answer the first question of every algorithm developer: what does the defect look like? The primary purpose of this work is to provide an efficient means to answer this question. Hence, a manual reviewer interface is being developed that can work with multiple systems.

**METHODS**

To develop the features of the viewer, data from the KLD truck component inspection system at TTC was used. Figure 1 shows this KLD system located in Section 1 of the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST).

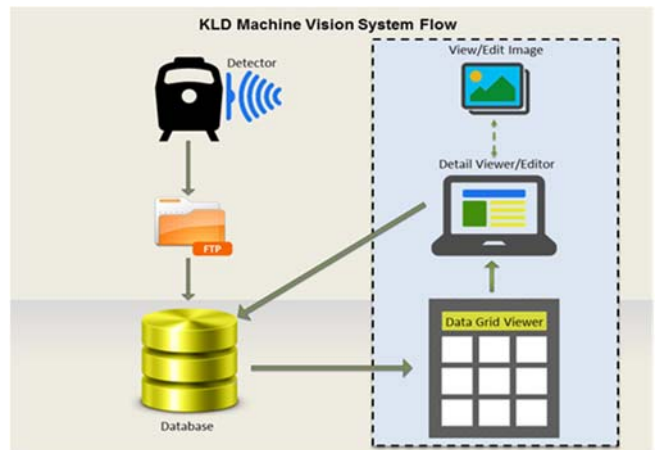


**Figure 1. KLD Truck Component Inspection System**

This is the first phase of a two-phase project. In this phase, TTCI designed and tested a manual reviewer using data from the machine vision systems under test at TTC. This established functionality of the manual reviewer and provided an opportunity to confirm intended operation. In the second phase, the manual reviewer will be installed on a railroad at a revenue service location to allow populating the database with revenue service images.

**SYSTEM CONFIGURATION**

A team from TTCI's Software Services department developed the viewer software design configuration. The viewer consists of a database that contains machine vision images alongside a web-based end-user interface. Figure 2 diagrams the system data flow.



**Figure 2. Manual Viewer Data Flow**

The end-user interface portal is platform independent; it can be accessed through any internet browser with appropriate login credentials. Access privileges vary depending on who accesses the data. Filters and security privileges are adjustable for the various users.

### DESIGN CONSIDERATIONS

The first and primary use of this viewer is for an expert reviewer to be able to look at all image data from a given passing train and use it to determine the condition of the inspected components (bearing end cap bolts, broken spring, missing spring) and any other observable details that might be visible (e.g., bearing adapter condition, wedge presence, wedge rise, side frame condition, and number of casting buttons on each side frame). This function would most likely be performed on a “per train” basis, where every image, in sequence, from a given camera, would be viewed in rapid succession. The human eye can catch differences quickly, so rapid fire (multiple frames per second) is essential for this mode of review. An expert reviewer can parse the data differently for a given train. For a given run, the human reviewer may compare images side to side, or look at every front wheel on the lead end in succession, or look at only the images that the system automatically identified as defective. Each of these sorting methods may require a different query, so technological considerations will limit each of the choices. The design accounts for these limitations as appropriate.

The expert reviewer needs the ability to edit data within the database. Based upon his/her observations, marks will be left within the data in the form of hand drawings, typed comments, spoken audio, or other input mode. The objective is to capture the human intelligence as easily as possible for later extraction by the algorithm developer. This annotation data is automatically saved along with original image data. In addition, the database keeps track of the images that have and have not been viewed. Positive identification of no defects is equally or more important than identifying defects. This information is critical to defining the acceptable condition.

### VIEWER DEVELOPMENT

To conceptualize and develop the manual reviewer, data as generated by the KLD MV system at TTC was used. The system consists of six cameras, three on each side of the track, that capture images of truck components such as axle ends, spring nests, and side frames. During the FAST train nightly operations, the KLD system automatically images truck components, analyzes them for defects, and stores the result locally. For each observed train, summary ASCII reports describing component condition are generated by the KLD system.

At the request of TTCI, KLD now sends select images and reports to the manual reviewer database system. This is accomplished via File Transfer Protocol (FTP). The FTP transfer can be programmed to occur automatically after each passing train or it can be configured to select only certain files, for instance only trains with reported defects. This allows control of the database size. Once the data is in the database, human users have instantaneous access to the data through the manual reviewer interface. Exception records are queried through built-in filters; images retrieved, annotated and saved. Vetted defect reports can then be created and emailed to select recipients, including persons involved in developing the manual reviewer.

### VIEWER OPERATION

By design, as shown in Figure 3, the reviewer will click on the View Details checkbox in the left column of the grid. A detail screen with the image corresponding to the alarm is then displayed. This example shows the detail screen for a missing axle end cap bolt.

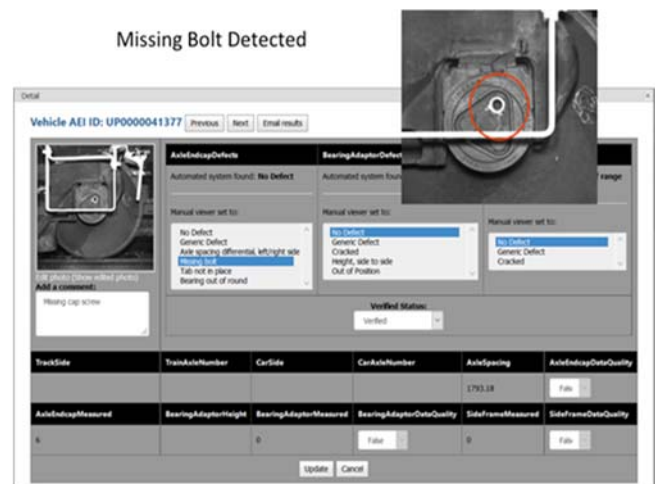


Figure 3. Markup of a Missing Axle End Cap Bolt

The reviewer can easily sequence (forwards and backwards) through a series of defects without leaving the detail screen simply by clicking on ‘next’ and ‘previous’ icons, located at the top center of the detail screen. If, upon examination of the image, the reviewer finds that the algorithm has incorrectly identified a defect, the defect indication status can be changed by clicking to highlight another defect condition status. Then the location of concern on the image can be highlighted by hovering over the image, and then marking up the image (e.g., drawing a red circle around the item of concern). The reviewer can then click the ‘verified’ selection and ‘update’ to save the record and an edited version of the image into the database. Finally, the reviewer can create vetted defect reports and send them to select recipients. Figure 4 shows an example email report.

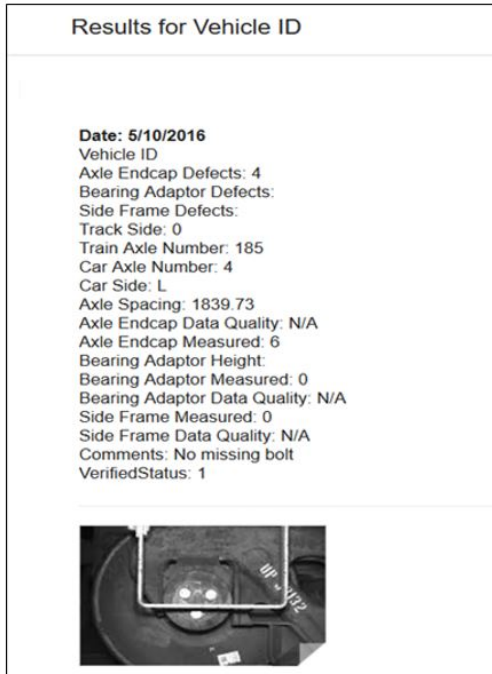


Figure 4. Typical Email Report with Vetted Defect Information

**EXAMPLE RESULTS**

When an expert user logs in to the KLD portal, the FAST train lap reports are displayed chronologically, with most recent first. Figure 5 shows the first portal webpage displaying the most recent records FTP'd from the KLD system. A number of filters are available on top for data sorting and analysis. Filters such as date & time, vehicle ID numbers, car sides, and defect types allow for specific sorting and targeted data analysis.

Figure 5. Manual Viewer Data Records

The functionality of the reviewer database system is enhanced by imbedding component condition images when a defect has been “called out” by one of the automation algorithms. This allows the expert reviewer to determine whether the defect condition alerted by the system is valid. Figure 6 shows an example of an image that was consistently identified by the system.

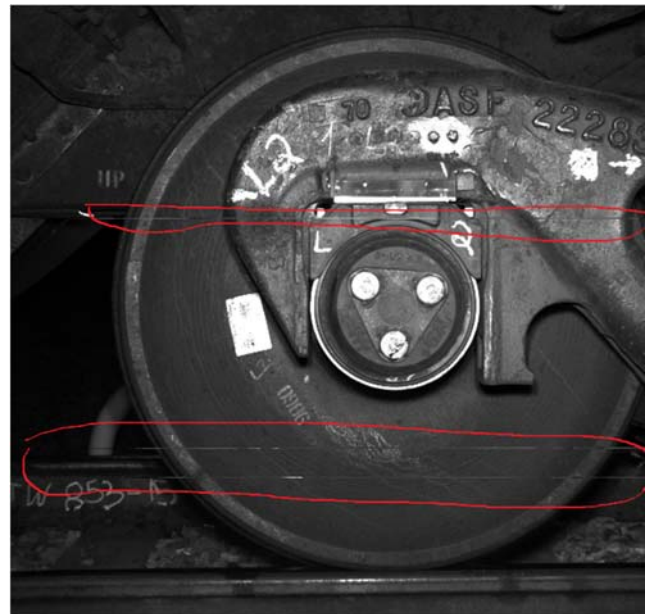


Figure 6. Image with Noise (lines) caused a False Alarm

This image has noise in the form of lines. These lines are an artifact of an imaging error caused by a faulty sensor. The expert reviewer discovered the lines and alerted KLD, who in turn diagnosed the issue and effected a repair.

**NEXT STEPS**

This report summarizes the manual reviewer development thus far. It has been used with the KLD Labs truck component inspection system located at TTC. The next step is to install an identical KLD inspection system in revenue service and to apply the viewer to this new system. TTCI is also generalizing the interface to work with other machine vision inspection systems.

**ACKNOWLEDGEMENTS**

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