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# THE FEDERAL RAILROAD ADMINISTRATION'S LIDAR-BASED AUTOMATED GRADE CROSSING SURVEY SYSTEM

## SUMMARY

As part of the Federal Railroad Administration's (FRA's) mission to improve public safety, FRA is focused on reducing train-on-vehicle collisions at grade crossings and resulting fatalities. A full-size track inspection vehicle with an automated detection system can help achieve this goal by surveying grade crossings in terms of the grade crossing's profile, its track-road angle, and its sight lines, as well as the presence and proper operation of the crossing's gates.

Figure 1. LiDAR-Based Scanning System for Grade Crossing Assessment Installed on FRA's DOTX 218

In order to realize this vision, FRA's Office of Research, Development and Technology (RD&T) has developed and deployed a LiDAR-based system on its DOTX 218 research vehicle (see Figure 1) that creates accurate, high-density point clouds of track and surrounding area in and around grade crossings at survey speeds of up to 55 mph.

This research results paper presents highlights of the FRA's development program and provides an overview of initial deployment and use of the resulting technology.

## BACKGROUND

FRA has targeted the reduction of hang-up incidents at grade crossings. Hang-ups can occur when a low-clearance commercial motor vehicle encounters a high profile (or "humped") grade crossing and becomes stuck in the railroad right-of-way (ROW). If this situation occurs, trains can collide with the vehicle because they usually cannot stop in time.

Guidelines from the American Association of State Highway and Transportation Officials (AASHTO) require that a grade crossing's change in elevation should *"be [no] more than 3 [inches] higher or lower from the top of the nearest rail at a point 30 [feet] from the rails" (1)*. The Federal Highway Association's *Railroad-Highway Grade Crossing Handbook* states that several states employ alternative standards for crossing profiles *(2)*. While the original configuration of crossings can meet one or more guidelines, the profile of a grade crossing can be altered by railroad or roadway maintenance. Note that private crossings are subject to private contractual agreements, and this makes it difficult at best to assure the safe configuration of the crossing.

To address these concerns, FRA developed a LiDAR-based system that creates accurate, high-density point clouds of grade crossings. The system, designated as the Automated Rail-based ROW Surveyor (ARROWS), employed a single LiDAR sensor on a hi-rail vehicle (Figure 2) to survey grade crossing elevation profiles *(3)*.

Following successful demonstration of the use of the LiDAR sensors on a hi-rail platform, FRA planned to deploy this type of technology on its full-sized survey vehicles to allow for grade crossing assessment throughout the country.

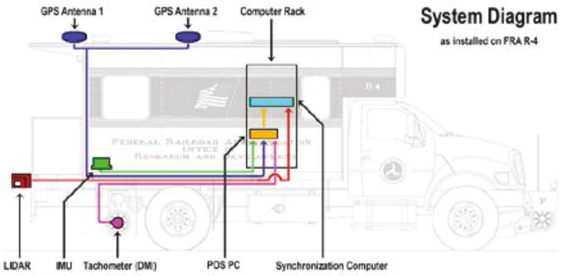

Figure 2. System Diagram of ARROWS as Installed on FRA's R-4 Hi-Rail Research Platform

## OBJECTIVES

The goal was to install and commission a LiDAR-based scanning system similar to the system that is deployed on FRA's R-4 hi-rail vehicle that could provide routine assessments of grade crossings throughout the U.S. rail network.

## METHODS

FRA's LiDAR-based surveying system was installed on FRA's DOTX 218 Gage Restraint Measurement System vehicle (Figure 1). The surveying system has five major subsystems: a measurement beam, mounted on the rear-end of DOTX 218, that supports both LiDAR sensors and an inertial measurement unit (IMU); a high-resolution axle-mounted encoder, which provides accurate distance measurements; a GPS antenna and receiver, which tags survey data with geo-location information; a ROW camera that capturing imagery; and an operator's station for data storage and system operation (Figure 3).

The team determined the number of LiDAR sensors, as well as their locations and orientations, by performing a parametric study that employed three-dimensional simulations. The survey system was built and developed by researchers at the Autonomy, Perception, Robotics, Interfaces, and Learning (APRIL) Robotics Laboratory at the University of Michigan and ENSCO, Inc.

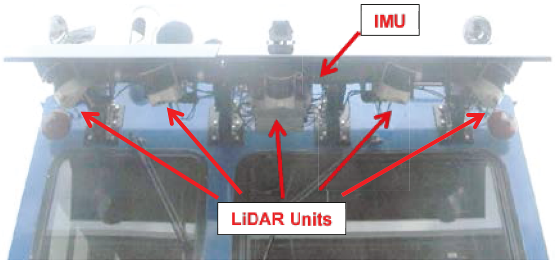

Figure 3. LiDAR Sensors and IMU Mounted to the Rear of DOTX 218

In this scanning system, data is continuously streamed from all LiDAR sensors, the IMU, encoder, and GPS receiver, and then recorded in real time. If the system is in "continuous mode," all survey data is recorded and data around grade crossings can be extracted with automated feature recognition algorithms that have been developed by University of Michigan researchers.

Also, the data can be buffered, then recorded, when events such as grade crossings are tagged manually by the car's observers. For each tagged event, LiDAR data, ROW images, plus location and railroad information available from survey data are recorded onto onboard storage devices for subsequent transfer to storage servers. For this purpose, developers used a message parsing and data handling scheme known as Lightweight Communications and Marshalling (LCM), which is used in robotic applications and satisfied the requirements for the needed number of data channels and high capture rates.

A typical three-dimensional contour map of a crossing rendered from an urban area is illustrated in Figure 4. The colors on the contours produced by the LiDAR surveying system in the vicinity of the crossings indicate near-grade elevation changes and measure the reflectivity of objects and road markings.

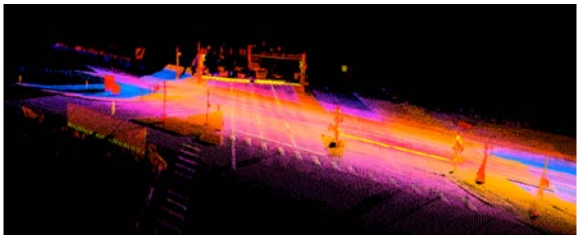

Figure 4. Three-Dimensional Map of Urban Grade Crossing Captured with LiDAR-Based System

When the system scans a grade crossing, the following information is generated:

- A three-dimensional map of the crossing
- A scalar parameter (e.g. "planar deviation") that represents the profile of the crossing
- The roadway/track crossing angle
- The name of the railroad and the appropriate subdivision
- The crossing location as described by GPS coordinates and milepost information
- Track class
- Track number

A feature that identifies the presence of gates and whether the gates are working at the time of train passage is being integrated into the system.

As this technology is being developed, survey data is being transferred to a server hosted by the University of Michigan. Users can search for grade crossings of interest based on GPS location, planar deviation, the measure of crossing evaluation, or survey identification number. The user interface for the database is shown in Figure 5. Users can open a three-dimensional map similar to the one shown in Figure 4 for viewing or download it from the database interface. Grade crossings can also be viewed through satellite imagery available from Google services. As data is being collected during ongoing FRA surveys, it is being uploaded to a storage server for use by FRA or any FRA-designated party. FRA is in the process of migrating data storage from this temporary development server to a system that will be integrated with other FRA data management systems.

elevation > 1000

Example Queries:

Searchable parameters:
latitude
longitude
elevation
roadway_width
planar_deviation
filename

Available Operators:
\>, >= greater than, greater than or equal to
<, <= less than, less than or equal to
== equal to

194 Crossings Found

filename DOTX18-2013031901004-142612.log
latitude 40.2468
longitude -103.8061
elevation 1327.8
roadway_width 5
planar_deviation 0.7616

Figure 5. Grade Crossing Database Interface

## RESULTS

After the system was installed in March 2013, FRA has evaluated the performance of the system while conducting several surveys as part of ongoing RD&T tests. More than one thousand grade crossings have been scanned during initial testing. Data collected from these crossings have been used to improve feature detection algorithms to enhance automated processing.

In November 2014, FRA compared survey data collected at a previously identified high-profile grade crossing by the DOTX 218 with data that was collected by a ground-based survey crew using high-density LiDAR scans, and RMS levels between the two surveys were very comparable. While the DOTX 218 survey data was collected at no additional cost to survey operations being conducted at the time, the ground-based survey required trained surveyors several hours to collect and process the data, resulting in survey costs of close to $3000. The cost differential between the survey methods demonstrates the value of the collected safety-related datasets.

## FUTURE ACTION

FRA is developing procedures for integrating the grade crossing survey data into existing information systems. In the very short term, the FRA's National Grade Crossing Inventory will be updated with the LiDAR-based data, and a process is being developed which provides LiDAR-based updates to the original reporting agency. Additionally, changing the inventory to include parameters not currently captured, such as profile elevation or characterization of sight lines, may be considered. As at-risk crossings are identified, FRA can work with municipalities as well as navigation service providers to post warnings for motorists.

## REFERENCES

1. American Association of State Highway and Transportation Officials. *A Policy on Geometric Design of Highways and Streets, 2004 Edition*. Washington, DC.
2. U.S. Department of Transportation. Federal Highway Administration. *Railroad-Highway Grade Crossing Handbook - Revised Second Edition.* Washington, DC. 2007.
3. Van Arman, Pindar, and Al-Nazer, Leith. "Automated Technology for Rail-Bases Highway-Rail Grade Crossing Surveying." JRC2008-63033. Proceedings of the 2008 IEEE/ASME Joint Rail Conference, April 22-23, 2008.

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## KEYWORDS

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