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RESEARCH RESULTS

FRA OFFICE OF RAILROAD POLICY & DEVELOPMENT

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LOW GROUND CLEARANCE VEHICLE DETECTION AND WARNING

SUMMARY

A Low Ground Clearance Vehicle Detection System (LGCVDS) determines if a commercial motor vehicle can successfully clear a highway-rail grade crossing and notifies the driver when his or her vehicle cannot safely traverse the crossing. That is, differences in elevation between the roadway and track at some locations are such that certain vehicles are more likely to become immobilized with the attendant risk of being struck by an oncoming train.

To create such a detection system, FRA's Office of Research and Development awarded a Small Business Innovation Research (SBIR) Phase I contract to Advanced Technology and Research (ATR) of Columbia, MD to assess whether an LGCVDS is feasible and, if it is possible to develop a conceptual design for such a system.

Specifically, ATR was asked to develop a reliable automated active system which would be installed at approaches to identified high-profile grade crossings. The LGCVDS should be self-powered so it can operate off the grid for multiple years with minimal maintenance. It should also function regardless of extreme temperature, severe weather, or visibility conditions, including heavy snow, rain, fog, or darkness.

This Research Results Report will describe the results from ATR's SBIR Phase I study, which included:

- Developing a requirement analysis for its LGCVDS
- Performing a survey of crossing scenarios using satellite imagery of 40 grade crossings in Florida which have a high risk of vehicle hang-up,
- Evaluating potential sensor technologies for use in the LGCVDS
- Investigating LGCVDS feasibility by collecting preliminary data from a moving vehicle with an appropriate sensor.
- Defining keep-clear regions under vehicle based on inter-axle distances and the specific geometry of the grade crossing via an interference boundary.
- Building an algorithm that can predict vehicle hang-ups by scanning the vehicle's underbody and comparing it with the interference boundary
- Developing a complete system concept design with installation recommendations
- Creating a preliminary integrated system to demonstrate the feasibility of the LGCVDS

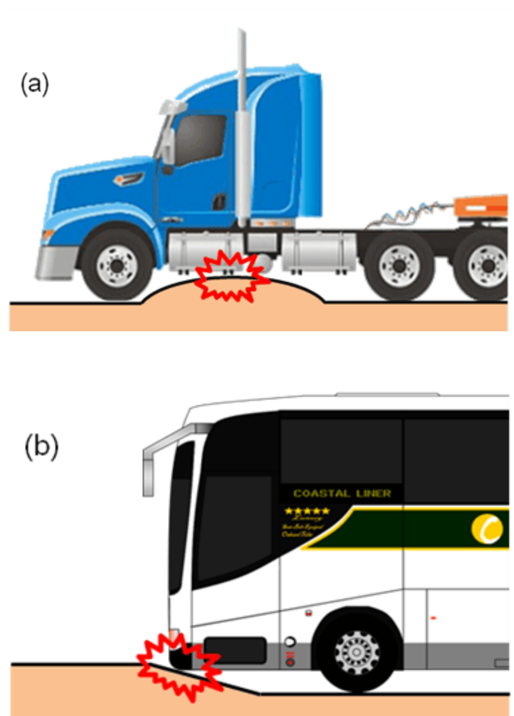

Figure 1. (a) A truck could hang up when its wheels straddle a road hump (b) The front overhang of a bus could hang up on a sudden steep incline

If ATR is awarded an SBIR Phase II to perform additional work, the company will continue to refine the system design, further develop the detection algorithm, investigate other COTS detection sensors, and build a prototype that will be used for system testing and demonstration.

Background

When vehicles with low ground clearance go over certain highway-rail grade crossings, they face hang-up risks at locations where the level of the road surface changes abruptly as it crosses. Such high profile highway-rail grade crossings are located throughout the United States, typically on local and collector roads, and in rural or urban areas.

Though vehicles at high profile crossings are warned by passive signage, serious accidents occur when a vehicle becomes stuck on the hump of a crossing while attempting to traverse it and is struck by a train.

A reliable active LGCVDS would detect low clearance vehicles as they approach a crossing, then trigger wayside active warnings that alert the driver and give him or her sufficient time and distance to stop.

The American Railway Engineering and Maintenance-of-Way Association (AREMA) has specified an ideal highway-rail grade crossing profile in its Manual for Railway Engineering (1993). This exemplar profile has a limited road grade that is designed to avoid hang-up or high-centered problems. If a crossing does not conform to these guidelines, certain types of vehicles may encounter problems when they traverse the profile. Figure 2 shows the profile of a crossing in Florida [1] that is well outside the AREMA design guidelines and prone to hang-ups.

Objectives

ATR focused on developing a LGCVDS concept that addresses the requirements for preventing hang-ups at real world grade crossings. The company's goals were to establish the feasibility of such a system and make recommendations for implementation in the follow-on Phase II.

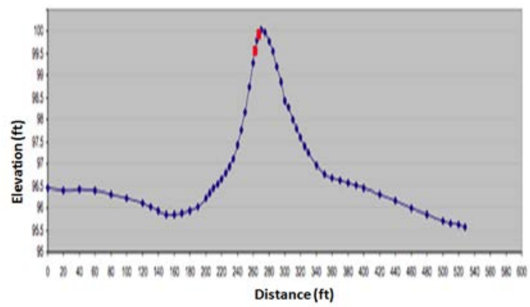

Figure 2. Profile of Crossing #620927L in Green Cove Spring, Florida (from Sobanjo, 2006) [1]

Survey of Grade Crossings

In order to establish system requirements for the LGCVDS, ATR surveyed 40 high-profile grade crossings in Florida, which are identified in [1] and the locations are indicated on the map in Figure 3. The survey used satellite imagery from Google Maps to identify patterns and trends of the roadways that lead up to a grade crossing.

The survey results indicate that the LCGVDS may only need to monitor a single lane per direction at any given scanner installation site. , Based upon this initial analysis, feeder roads with multiple lanes per direction (also called *super-feeders*) are rare – even at 500 feet radius from the crossing, 73% of the crossings surveyed do not have such super-feeders.

Since all of the roadways at these grade crossings, only have one lane in each direction, it is highly unlikely that a vehicle that approaches a crossing via a super-feeder and turns onto a crossing road would be driving in any lane other than the one closest to the crossing (i.e. the designated turning lane).

The survey also indicates that some crossings are not perpendicular to the road and that there will be occasions where a long vehicle will still have to execute a turn as it crosses the tracks. In fact, 30 of the crossings (73%) had either skewed tracks or were near an intersection/corner.

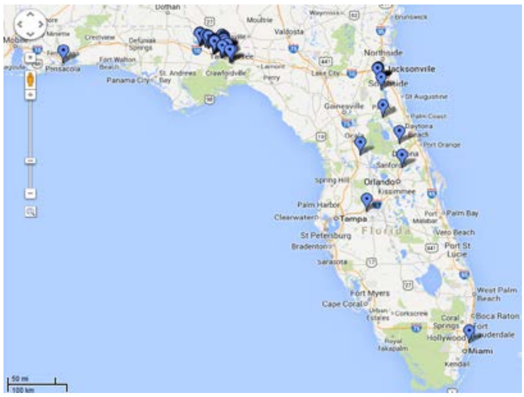

Figure 3. Blue markers identify high-profile grade crossings [1],

Hang-Up Prediction Algorithm

ATR uses an intelligent screening process to predict if a hang-up will occur at a grade crossing. The prediction method employs a customized contoured interference boundary which uses a clearance height requirement that varies along the length of the vehicle.

A contoured boundary would consist of a three-dimensional surface defined in a vehicle-fixed coordinate system. If any part of the vehicle extends lower than the interference surface, a hang-up risk would be detected.

Figure 4 illustrates the difference between the simplest uniform minimum clearance threshold (which is flat and colored in green) and an ideal contoured interference boundary (which is colored in blue). Portions of the vehicle that extend into the shaded region (colored in pink) would result in false positive hang-up predictions by flat threshold criteria, but the vehicle would be correctly allowed to pass using the contoured interference boundary criteria.

A hang-up prediction algorithm was developed based on the interference boundary concept and implemented in MATLAB and C/C++. To detect a hang-up, the vehicle underbody must interact with the interference boundary. When the vehicle has more than two axles, the resulting interference boundary is a compound curve that is made up of multiple segments from the interference boundary between every two inter-axles.

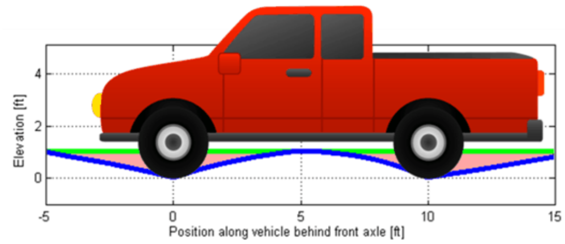

Figure 4. Comparison of a flat versus a contoured interference boundary

Survey of Detection Sensors

The LGCVDS algorithm relies on two measurements to assess the hang-up risk of each vehicle approaching the crossing. A measurement of the vehicle's wheelbase or inter-axle distances is used to establish the appropriate interference curve, and a 2D side-view profile of a portion of the underbody near the interference boundary is compared with the interference curve to detect hang-up risks.

ATR has evaluated a wide range of sensor technologies for use in underbody detection, including through-beam laser sensors, laser beam range sensors, line scanning LIDAR, flash LIDAR, time-of-flight cameras, structured light, and MMW radar. Since flash LIDAR benefits from the projected cost reductions and reliability improvements generated by potential applications in the automotive sector, it appears to be the most cost effective and feasible method for generating underbody profiles in the near future.

Proof-of-Concept Demonstration

ATR developed a proof-of-concept system that demonstrated the feasibility of the formulated interference boundary concept and the active detection algorithm.

The system was tested in a crossing scenario that involved a cargo van with a low-hanging underbody attachment that approached a wooden model of a single-track highway-rail grade crossing. A low-end flash LIDAR sensor measured the low-hanging portions of the van underbody while the vehicle was moving at 10 miles per hour. Their system reached a go/no-go decision in real-time using simplified data processing algorithms to construct a vehicle profile and perform the interference boundary comparison. The predicted results were validated by observing the van drive over the model crossing platform.

Conclusions

ATR has studied the LGCVDS concept with surveys, analysis, modeling & simulation, and hardware demonstration; refined the proposed LGCVDS concept; and achieved a feasible and cost-effective design solution in this SBIR Phase I contract. In the follow-on phases, ATR will evolve the feasible LGCVDS concept and seek to demonstrate it as an effective and reliable system. The system should be employed on highway-rail crossings and steep humps on roads.

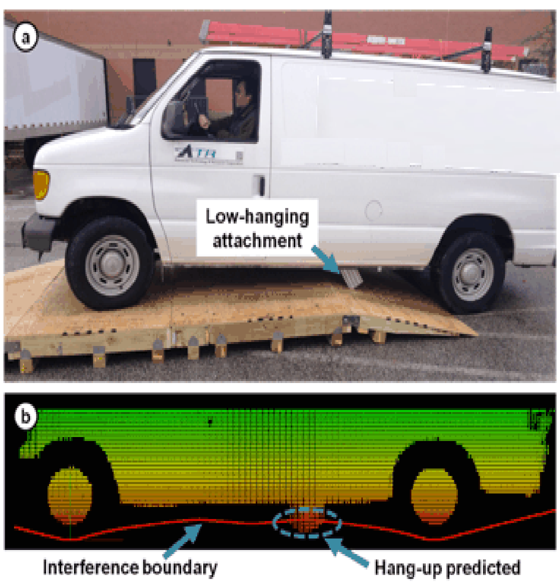

Figure 5. a) Van with low-hanging attachment driving over simulated single-track crossing in proof-of-concept demo; b) Assembled vehicle profile with overlaid interference boundary showing predicted hang-up

REFERENCES

[1] John Sobanjo, Design Guidelines for Highway Railroad Grade Crossing Profiles in Florida. Prepared for FDOT, Florida State University, Dept. of Civil and Environmental Engineering, May 2006.

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