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LOW GROUND CLEARANCE VEHICLE DETECTION AND WARNING

SUMMARY

The Federal Railroad Administration's (FRA) Office of Research, Development and Technology (RD&T) sponsored a Small Business Innovation Research (SBIR) Phase II project from July 31, 2014, to July 29, 2016. This took place at the Advanced Technology and Research Corporation (ATR) facility in Beltsville, MD, to advance the Low Ground Clearance Vehicle Detection System (LGCVDS) concept for highway-rail grade crossings to provide a qualitative and quantitative assessment of the system under a set of representative conditions. A significant portion of the effort was devoted to assembling a viable sensor system. As the crossing profile is a critical component for the hang-up assessment, ATR developed a workflow to ingest crossing data collected by ENSCO, Inc., in order to derive a crossing profile representation that is suitable for the LGCVDS.

The ultimate concern for the LGCVDS is the reliable detection of hang-up conditions. Reliability considers both the false positive and false negative detection rates. ATR developed a technique for incorporating the various modalities of sensor errors to arrive at an error probability distribution that can be used to quantify the system reliability. Furthermore, this error model can be used to trade off the false positive detection rate against the false negative detection rate. Since the vehicle dynamics are an important consideration, an analysis was performed to quantify the impact on the LGCVDS.

The Phase II effort culminated in a series of trials performed at a test site using a representative vehicle. Data was collected under various conditions to support quantifying the repeatability of the vehicle profiling measurement.

BACKGROUND

Highway-rail crossings, at which there is an unusually abrupt change in the level of the road's surface as it crosses the tracks, pose a risk of low ground clearance vehicles becoming stuck on the tracks. There is an extensive body of literature including accident reports that shows the seriousness of the problems posed by the potential hang-up of low ground clearance vehicles at highway-rail grade crossings. ATR developed an interference detection algorithm during the Phase I of this SBIR project. In general, hang-ups occur where a long span between vehicle axles has a low-hanging section of chassis. The wide-spread axles can effectively straddle the raised crossing hump, allowing the chassis to reach closer to the road surface and make contact. Overhanging portions of the vehicle that extend forward of the front axles or backward from the rear axles may also contact the road, for example, when a level road suddenly transitions to a steep incline.

OBJECTIVES

This SBIR Phase II effort focused on further developing and testing the LGCVDS system. The system needed to handle a wide range of vehicle shapes and speeds. It must be robust enough to withstand adverse weather and visibility conditions, including heavy snow, rain, fog, or darkness. The keys to a deployable system will be the selection of a reliable and capable sensor and the implementation of more advanced tracking and profiling algorithms to process sensor data. Testing a completed demo system with diverse vehicles and environmental conditions will be important for quantifying system reliability.

METHODS

Sensing and Profiling System: ATR used the IFM 03D201 sensor as the baseline system in the final demonstration in Phase I. The sensor provided a three-dimensional point cloud at 30 Hz, which was processed to detect wheel-like objects in order to map the vehicle profile as it transits the sensor station. While this sensor demonstrated the feasibility of the LGCVDS concept, there were several deficiencies that impacted its robustness. In Phase II, ATR did a trade study for candidate sensors and developed an in-house light sensor system. This sensor system is comprised of a laser illumination source coupled with a high-speed camera. Figure 1 shows an example of the images collected by this system.

Figure 1. Laser stripe illuminating a bookcase

This system was coupled with a planar SICK Light Detection and Ranging (LIDAR) (LMS201), a distance measurement sensor, which was positioned a few inches above the roadway. The SICK sensor returned range measurements of the wheels of the vehicle. Wheel detection algorithms were developed to support tracking the vehicle position vs. time. Sensor fusion was applied to the SICK and structured light sensors to obtain estimates of the wheel base, wheel diameter, and underbody profile of the vehicle. The test setup is shown in Figure 2.

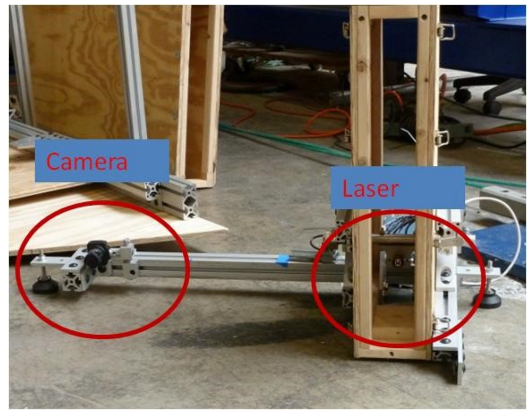

Figure 2. LGCVDS prototype sensor system

Crossing Profile Data: Generation of the interference curve requires accurate surveying of the crossing profile. During this phase of the project, ATR utilized the crossing data collected by ENSCO through a separate FRA sponsored effort. This data is deemed to be representative of the type of data that would be collected using high-precision survey equipment. ENSCO and the University of Michigan provided this data in the form of a point cloud similar to that shown in Figure 3. This data was collected by a rail car outfitted with multiple SICK LIDAR sensors.

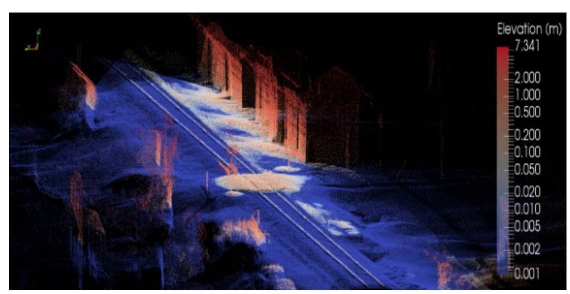

Figure 3. ENSCO point cloud for the 198 Church Ave., Louisa, VA, crossing

Using tools such as Paraview (an open source project from Kitware), ATR extracted the region that defined the crossing profile. The data was then rotated so that the axis of the crossing was aligned to the Y axis and the Z axis was up. A piece-wise cubic spline was then fit to the data. This cubic spline was then fed into the interference curve generation algorithm. An example of the curve fit to the filtered ENSCO point cloud data is shown in Figure 4.

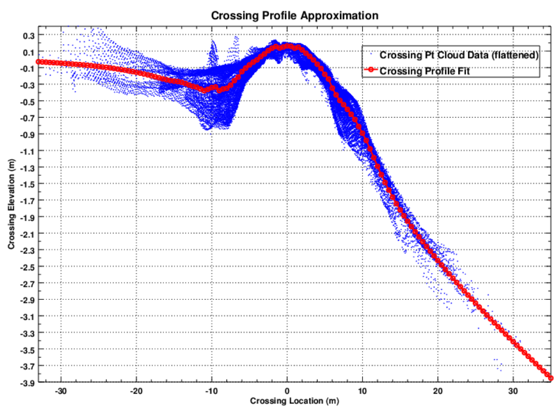

Figure 4. Crossing point cloud and curve fit approximation

Sensitivity Analysis and Derating Methodology: ATR conducted an error sensitivity analysis of the LGCVDS. This analysis was agnostic to the actual error characteristics of the measurement system. In this analysis, ATR identified the error sources from vehicle underbody estimations, vehicle horizontal location estimation, and vehicle profiling errors due to vehicle dynamics and sensor resolution.

The methodology calculates the partial derivatives of the interference curve with respect to the various error sources and incorporates the standard deviation of the error sources. It is then possible to evaluate a specific railroad crossing and a specific vehicle profile in order to estimate the false positive or false negative detection rate. A derating parameter was also introduced to trade off the false positive and false negative detection rates.

Vehicle Dynamics: ATR developed various vehicle dynamics models to analyze the effect of vehicle suspension dynamics on ground clearance. This provided an initial assessment of the hang-up prediction's sensitivity to this effect as well as its influence on selecting a proper derating factor. The commercial vehicle dynamics code MSC ADAMS with the Car/Truck module was used in the simulations.

RESULTS

A road-side test scenario was developed to assess the LGCVDS performance. The primary objective was to operate the LGCVDS under representative conditions and capture the error characteristics of the system. A police training facility of the State of Maryland, at 7310 Slacks Road, Sykesville, MD, was chosen for the testing (Figure 5).

Figure 5. Sykesville highway training course

For the testing, a 26-ft. flatbed truck was augmented with a hang-up feature, as shown in Figure 6. The crossing profile used for the test was the profile data of the Church Ave. crossing in Louisa, VA, as collected by ENSCO.

Figure 6. Flatbed truck with hang-up feature attached

The LGCVDS real-time visualization (shown in Figure 7) provides a means to assess the system performance in real time. It displays the true vehicle profile (colored blue) against the vehicle profile as measured by the LGCVDS (colored red), the boundary interference curve (colored green) and probabilistic assessment of the hang-up potential.

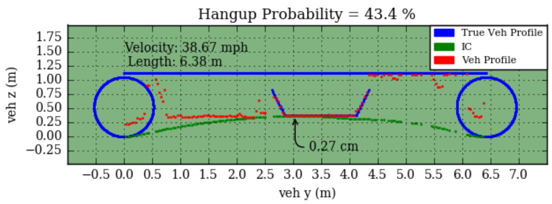

Figure 7. Example of the real-time visualization at the road-side testing

CONCLUSIONS

ATR has advanced the LGCVDS concept in the Phase II SBIR effort. A structured light sensor system was developed in-house. It was coupled with a planar LMS201. A sensor fusion algorithm was applied to estimate the underbody profile parameters while the vehicle was passing at a speed up to 50 mph. The hang-up detection algorithm makes a “go/no-go” decision in real time. Road-site testing validated the feasibility and effectiveness of the system. It also identified several limitations that impact its reliability. Recommendations were provided to further advance the LGCVDS system and how it may be effectively employed.

FUTURE ACTION

ATR has been awarded an FRA SBIR Phase II-B contract for further developing the LGCVDS and also exploring the commercialization opportunities of the system. The LGCVDS has also been extended from a road-side detection and warning system to a telematics-based solution, which seeks to integrate this innovative hang-up detection and avoidance algorithm into commercial telematics platforms already in use in the trucking industry.

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KEYWORDS

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