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RAIL CROSSING VIOLATION WARNING APPLICATION – PHASE II

SUMMARY

Built upon prior proof-of-concept work performed by the Battelle Memorial Institute and sponsored jointly by the Federal Highway Administration (FHWA) and the Federal Railroad Administration (FRA), the Rail Crossing Violation Warning (RCVW) Phase II system incorporated refinements to the software and hardware to achieve improved performance and enhanced system functionality. Researchers performed system design and development for Phase II at Battelle in Columbus, OH, from September 2018 to July 2021. The system demonstrated the potential for leveraging real-time Connected Vehicle (CV) concepts to enhance and transform rail crossing safety. Figure 1 illustrates the RCVW system concept.

In addition to an overall improvement to the RCVW algorithm, Phase II incorporated the following refinements:

- Use of an Institute of Electrical and Electronics Engineers (IEEE) 1570 Standard serial communication device, that provides a fail-safe and closed-loop response, to interface the preemption signal of a track-circuit-based train detection system to the Roadside Based Subsystem (RBS)
- Use of Controller Area Network (CAN) bus to access vehicle status data as input to the Vehicle Based Subsystem (VBS)
- Improvement of the Global Navigation Satellite System's (GNSS) positional accuracy by the use of a dual phase real-time kinematics (RTK) vehicle positioning system
- GNSS correction data broadcast over a Dedicated Short-Range Communications (DSRC) radio link
- Updated Driver-Vehicle Interface (DVI) visual and audio alerts based on published human factors design reports for CVs and in-vehicle safety applications.

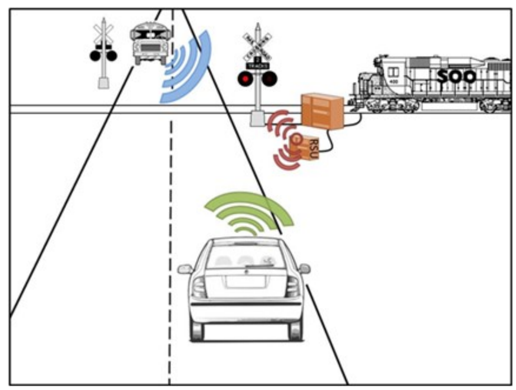

Figure 1. RCVW Application Concept

BACKGROUND

Highway-rail grade crossings continue to pose a significant safety concern with many transportation departments. There has not been a significant decrease in the frequency of highway-rail intersection (HRI) incidents involving motor vehicles, fatalities, or injuries over the past 8–10 years. The leading causes of HRI incidents are distracted drivers and driver judgement errors. Phase I of the RCVW program demonstrated the potential for leveraging real-time CV concepts to enhance and transform rail crossing safety by successfully designing, developing, and testing a prototype RCVW system (Neumeister, Zink, & Sanchez-Badillo, 2017). Phase II incorporated refinements to the software and hardware to achieve improved performance and enhanced system functionality.

OBJECTIVES

To transform the Phase I RCVW proof-of-concept prototype into a more reliable, accurate, and widely applicable system, the following modifications and enhanced capabilities were incorporated:

- Enhancements and modifications to the RCVW algorithm, to include additional parameters such as vehicle type and length, configurable vehicle deceleration rate, configurable road grade, and monitoring of system fault checks
- Integration of CAN bus vehicle status-based data to enhance the RCVW's algorithm performance
- Improved vehicle based relative road position solution
- Integration of an IEEE 1570 Standard serial communication device that provides a fail-safe and closed-loop response to the preemption signal
- Redesign of the DVI messaging and graphics based on human factors studies

METHODS

The RCVW Phase II stopping-distance calculation is based on the current American Association of State Highway and Transportation Officials (AASHTO) Green Book Stopping Sight Distance formula. The RCVW stopping distance formula includes the AASHTO 90th percentile perception-reaction time of 2.5 seconds, deceleration values, data communication latency, road grade, and Global Positioning System (GPS) related errors.

Phase II explored the possibility and potential advantages of incorporating information sourced from the vehicle itself. With support from the Original Equipment Manufacturer (OEM), researchers evaluated the potential advantages of using vehicle speed and acceleration data provided via CAN bus.

Phase II involved replacing the vehicle-based GPS module used in Phase I with an RTK dual phase GNSS system able to receive signals from both, GPS and Global Navigation Satellite System (GLONASS) satellites. The RBS incorporates an RTK base station, which broadcasts Radio Technical Commission for Maritime Services (RTCM) corrections over the existing DSRC radio link. These corrections are received by the VBS and used to increase location accuracy to a sub-decimeter level (i.e., in optimal conditions). The algorithm was modified to include a "snap to lane" function which detects when the vehicle location data is deviating excessively and automatically "Snaps" the vehicle to the lane based on its previous heading.

The Phase II HRI status module was enhanced to interface with both, a voltage-based interconnection circuit and an IEEE 1570 compliant interface. The IEEE 1570-2002 standard defines the logical and physical interface between the railroad grade crossing equipment and traffic signal controller by using fail-safe and closed loop principles, as required by Federal regulations. The IEEE 1570 interface protocol follows the architecture defined in the National ITS Architecture, while maintaining independence between railroad and roadway systems.

An updated set of DVI graphics and auditory messages was created based on a human factors study which assessed messaging requirements of the system as a whole. The study focused on messages that support both rapid driver comprehension and timely response. It resulted in the creation of two new alerts—Inform and Warning—to deal with distracted drivers. Figure 2 presents the graphic used for the Warning message.

Figure 2. Train Warning Graphic Message

RESULTS

Three days of field tests took place by subjecting the system to several road conditions, such as wet/dry pavement, different road grades, obstructed GPS satellite view as a result of foliage, and different vehicle speeds. A heavy truck and a light vehicle were instrumented for the purpose of observing the performance of the RCVW algorithm when applied to different vehicle types. Vehicle speed and deceleration were controlled by a braking and throttle robot.

Across all test scenarios, researchers found the RCVW system would reliably warn the driver when the vehicle was approaching an active HRI and reached a point where the driver should begin decelerating to stop safely prior to reaching the stop bar.

GPS analysis on the heavy truck showed that location accuracy was degraded and is suspected to be a result of the positioning of the GNSS antenna (i.e., next to vehicle overhang). Longitudinal location accuracy for both vehicles also degraded linearly as speed increased indicating a system processing latency effect on accuracy. However, system performance regarding warnings, alerts and vehicle stopping were not impacted due to the warning distance equation accounting for measured processing latency and GPS accuracy. The system maintained a fixed RTK positioning solution across all test cases.

CAN bus based speed was used for the light vehicle calculations and GPS-based speed was used for the heavy truck. Both proved to be highly accurate. Accuracy of CAN bus-based acceleration data was suboptimal, so it was not used by the warning algorithm.

The RCVW system successfully interfaced with an IEEE-1570 compliant device effectively receiving and processing HRI status and communication link integrity.

The use of a braking and throttle robot precluded the verification of the effectiveness of the upgraded DVI graphics and auditory messages.

CONCLUSIONS

The performance of the RCVW system shows that a reliable system for enhancing safety at active HRIs can be built using currently available technology. Current GNSS solutions offer the accuracy required for precise positioning of moving vehicles critical to safety related applications. However, an RTK based approach may require additional infrastructure. Although DSRC was used to communicate data between vehicles and the RBS, any short-range, low latency, wireless transport capable of covering the approach zones to crossings could be used for this purpose.

Test results showed that the warning distances calculated by the RCVW Phase II algorithm allowed the vehicles to stop safely prior to the HRI stop bar. This also ensures a minimal amount of nuisance warnings for approaching vehicles.

Data from this phase of testing showed that using an RTK enhanced GNSS system to derive vehicle speed yielded readings within 0.1 mph of the CAN bus readings. Therefore, CAN bus data is not required in this safety critical application. This would remove the need for custom integration with each vehicle manufacturer and enable implementation of a more generic solution usable with any vehicle.

FUTURE ACTION

Additional field testing should be conducted to validate the effectiveness of the updated audio and graphic alerts and warnings as well as to identify opportunities to refine and harden the overall RCWV system.

Outreach to different stakeholders such as vehicle manufacturers, local and State agencies, and the different railway companies to demonstrate the RCWV system should be conducted. With their support, model deployments and pilot installations across the United States can be performed to evaluate the efficacy of the system in real life scenarios.

Adaptation of the RCVW system to novel and upcoming communication protocols such as C-V2X should be researched and implemented to increase system compatibility and functionality.

Research into additional functionality of the system such as implementation at crossings with multiple train tracks and track fouling alerts should be explored.

REFERENCES

Federal Railroad Administration. (2021). *Office of Safety Analysis*.

Neumeister, D., Zink, G., & Sanchez-Badillo, A. (2017). *Prototype Rail Crossing Violation Warning Application Project Report*. Report No. FHWA-JPO-18-609. Washington, DC: Federal Highway Administration.

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KEYWORDS

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