Necessity of Vehicle to Rail Infrastructure Communication for Grade Crossing Warning & Safety

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ABSTRACT
Vehicle area network (VAN) services have been launched in the U.S. and EU with a focus on vehicle-to-vehicle (V2V) interactions. However, V2V is not the whole story of the VAN concepts. As a case study of vehicle-to-infrastructure (V2I) communication, this position paper tries to show the necessity of vehicle-to-rail infrastructure networking with respect to the warning system at grade crossings. After describing the challenges of the current warning systems at grade crossings, we delineate a series of research plans about the possibility of the use of in-vehicle auditory warnings, plausible distracters, and the optimization of the information via V2I communication, which will lead to the ultimate conclusion of the necessity of V2I communication. We hope that this paper could contribute to the extension of the VAN concept and facilitate a debate on this topic in the Automotive UI community.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation (e.g., HCI)**]: User Interfaces – Evaluation/methodology, Interaction Styles (e.g., commands, menus, forms, direct manipulation), Auditory (non-speech) feedback, Voice I/O, User-Centered Design

J.4 [**Computer Application**]: Social and Behavioral Sciences – Psychology

General Terms
Design, Experimentation, Human Factors

Keywords
Auditory warning; grade crossing; VAN (vehicle area network); vehicle-to-infrastructure communication

1. INTRODUCTION
With the advances of networking technologies, people experience literally "seamless services" in any contexts, including their home, workplace, or even on-the-go. This trend is also pervasive in a vehicle domain, which leads to what we call "vehicle area network" (VAN) or social car research [1]. Fairly recently, a couple of big projects about VAN services have been launched with a focus on vehicle-to-vehicle networking (V2V) [e.g., 2, 3]. However, V2V is not the only one consideration of the VAN concepts, but VAN services can be classified into four categories: IV (Intelligent Vehicle), V2V (Vehicle-to-Vehicle), V2B (Vehicle-to-Business), and V2I (Vehicle-to-Infrastructure) [4]. The present paper focuses on V2I. To illustrate, V2I can include an intelligent traffic guide that helps drivers to decide "stop or go" on the yellow light. Free parking slot finder is another example of the V2I service. Drivers can get customized infomercial (information + commercial) fitting to their situations even though it also seems close to V2B. For more examples of VAN services, see …….[5].

We propose the vehicle to rail infrastructure communications to improve highway rail at-grade crossing safety. Fatalities that take place at highway grade crossings (together with trespasser fatalities) form the great majority of rail related fatalities annually. Given that human errors account for more than one third of all train accidents in the U.S. [9], one of the potential approaches to reduction of grade crossing fatalities and accidents may be to provide drivers with optimized warnings and to decrease a chance for missing warnings. Currently, there are two main types of warnings to drivers in the highway grade crossings; visual and auditory warnings. Given that drivers' vision is already heavily taxed while driving, auditory warnings may hold greater potential to improve driver safety.

To demonstrate the necessity of V2I in this grade crossing context, Michigan Tech has planned a series of research activities to investigate the effects of auditory warning cues on driver behaviors at rail crossings and explore optimal alternative designs to compensate for the issues of the current warning systems via vehicle-to-rail infrastructure communication. When it comes to a constituent of V2I communication in grade crossings, it can include drivers (or the in-vehicle systems), locomotive cab operators, and grade crossing systems. The three phases of research include: (1) comparing the effects of warning types (visual, traditional auditory, and novel in-vehicle auditory warnings) when approaching the rail crossings, (2) analyzing the interaction effects between auditory warnings and auditory distractions at railroad crossings, and (3) designing optimal auditory warnings by considering warning sources, timings, and appropriate contents.

2. CHALLENGES AND NECESSITY OF

V2I FOR GRADE CROSSINGS

Under current practices, railroads sound locomotive horns or whistles in advance of grade crossings [6]. Under the Federal regulation, locomotive engineers must sound train horns for a minimum of 15 seconds, and a maximum of 20 seconds, in advance of all public grade crossings. Grade crossings with active warning devices (gates and lights) have also bells as additional auditory warnings. One of the current auditory warning issues is that it has multiple exceptions (e.g., if a train is traveling faster than 45 mph, if a train stops in close proximity to a crossing, or when engineers can't precisely estimate their arrival at a crossing, etc). In these exceptional cases, the auditory warning convention might be different or could even disappear. Moreover, local governments or public agencies are able to establish "quite zones", which are equipped only with conventional visual warning devices such as flashing lights and gates. Therefore, a supplemental auditory warning is necessarily required for this situation. On the other hand, the traditional auditory warnings at rail crossings could be masked by varied distraction sources, such as in-vehicle music, speech with passengers, or phone calls. Based on this background, in-vehicle auditory warnings at grade crossings can be an alternative approach to reduce grade crossing fatalities and accidents, making vehicle-to-rail infrastructure communication necessary.

3. ON-GOING PROJECTS

3.1 Warning Types

First, we will determine the incremental effects of auditory warnings including both novel in-vehicle signals and traditional train horns and crossing bells, in addition to visual warnings for the driver when the car is approaching rail crossings. Some navigation devices (e.g., TomTom, Garmin, etc.) provide a visual symbol about the rail crossings, but they do not provide auditory warnings. Auditory researchers have applied a number of auditory cues to the in-vehicle contexts (e.g., speech cues, auditory icons [7] – representative part of sounds of objects or events, and earcons [8] – short musical motives as symbolic representations of objects or events). However, there is still a debate about the best auditory cue. This study compares all of those types of auditory cues at a variety of crossing types and sees whether in-vehicle auditory warnings can equal or improve conventional ones. Drivers will complete a simulated drive that will include a series of rail crossings with diverse auditory cues.

3.2 Distraction and Masking

Next, we will assess the effects of auditory distractions on drivers' ability to recognize railroad crossings in advance and prepare for it accordingly. Plausible in-vehicle auditory distractions will include sound-based (music), speech-based (news), and cognitive-based (cell-phone conversation) ones. The intent of this study is to understand what type of auditory warnings (traditional ones and various in-vehicle ones) at crossings are less masked by auditory distracters and more effectively alert distracted drivers.

3.3 Optimization of Warnings via V2I Networking

Finally, we will explore more specific details of auditory warnings. Currently, train horns must be sounded in a standardized pattern of 2 long, 1 short, and 1 long and the horn must continue to sound until the lead locomotive or train car occupies the grade crossing [6]. Taken the results of the previous phases, optimal warning alternatives will be designed and tested in terms of auditory cue types, sources, and timings (when to provide auditory cues and how many warnings to provide). In this phase, we are specifically interested in warning contents (e.g., how to synchronize the warning with the arrival to the rail crossing with the current car speed, whether there is an approaching train, where the train is coming from, etc.). Some of the information should be obtained via the communication with locomotive operators or grade crossing systems. We are also interested in measuring drivers' perceived performance and subjective safety in addition to objective performance in their readiness.

4. CONCLUSIONS & FUTURE WORKS

This research will provide a deeper understanding of how drivers can be more effectively prepared to approach railroad crossings with newer types of auditory warnings, and that could be possible only with appropriate V2I communication. As an outcome, this research can also inform the decisions on how to design optimized auditory warnings and when to provide drivers with critical auditory warning information. The timing and the range (i.e., trigger zone) of the communication and who is in charge of communication (e.g., driver and operator or in-vehicle – i.e., automation) need to be further addressed.

5. REFERENCES

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