Transportation Research Part C 50 (2015) 150–159

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

Applying telecommunications methodology to road safety for rear-end collision avoidance

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ARTICLE INFO

Article history:
Received 20 January 2014
Received in revised form 23 June 2014
Accepted 28 July 2014
Available online 19 August 2014

Keywords:
Collision prevention
Road safety
Inter-vehicular sensing
Relative distance
Relative speed
Time To Collision

ABSTRACT

This work aims at applying telecommunications methodologies to road safety for preventing rear-end collisions. This contribution can be considered as a pilot study to verify and assess the reliability of a new model and procedure for collision warning system based on low-cost inter-vehicular communications (only a cheap radio transmitter/receiver mounted on each vehicle is needed), where Global Positioning Systems (GPS) and other distance vector-based networks are not employed. A signal processing method, namely the binomial test, aimed at detecting approaching sources in infrastructure-less vehicular communications is here proposed and discussed. The detection probability of the method is evaluated versus several driving conditions, in terms of relative speeds and distances between vehicles. In addition, the Time To Collision (*TTC*), generally required before declaring a correct detection by existing collision systems implemented in recent vehicles, is evaluated for several driving scenarios characterized by different setting parameters. Our numerical results confirm the validity of such an approach in preventing rear-end collisions, allowing a fast detection of approaching sources.

1. Introduction

Nowadays, one of the crucial priorities for the world society is the improvement of road safety. The World Health Organization (2012) assessed that all over the world 1.3 million people die each year in road crashes and fifty million people are injured. Effective and urgent actions are required as it is expected that road traffic injuries would become the fifth leading cause of death in the world, with 2.4 million deaths each year if no effective actions would be taken. The main cause of such critical situation could be found in the great and rapid increase of motorization despite slower improvements in road safety issues, from land use planning to road design and network management. It is estimated that the economic consequences of road unsafety reach between 1% and 3% of the respective Gross National Product (GNP) of the world countries, with a total of over 500 billion of dollars.

Among road accident typology the rear-end collision is surely one of the most frequent. According to the National Highway Traffic Safety Administration (NHTSA) General Estimates System (2012), in 2010 there were an estimated 1.7

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http://dx.doi.org/10.1016/j.trc.2014.07.008
0968-090X/

million police-reported rear-end crashes in the United States, representing about 32% of a total of 5.4 million crashes. In contrast, rear-end crashes comprised only about 5.6% of all fatal crashes in 2010, suggesting that while numerous, rear-end crashes are not especially lethal. Nonetheless, rear-end collisions represent a considerable national cost and there is keen interest in developing effective countermeasures for this type of crash. Almost the same situation could be found worldwide. For example in 2011 (ACI, 2012) the majority of road accidents recorded on Italian road network occurred between two or more vehicles (74.7%) and the most common type of accident is the frontal-side crash (71,069 cases with 883 deaths and 104,638 injuries), followed by rear-end collisions, which recorded 37,749 cases with 364 deaths and 62,389 people injured. The rear-end collisions account for about 10% of fatal accidents resulting in very high social costs.

According to the needs for further road safety improvements the new White Paper (European Commission, 2011) comes at a crucial time for European Transport, and in particular road safety. The White Paper recognizes progress made in the past decade to reduce road deaths. The European Union has renewed its commitment to improving road safety by setting a target of reducing road deaths by another 50% by 2020, compared to 2010 levels. Specifically one of the main measures of relevance to reduce deaths among road users includes the harmonization and deployment of road safety technologies: eCall, cooperative systems and vehicle-infrastructure interfaces. According to it, in the Decade of Action for Road Safety (World Health Organization, 2012) several activities are proposed for the required improvements. They are grouped into five pillars: road safety management, safer road and mobility, safer vehicle, safer road users, post-crash response. Specifically the third pillar is related to the development of safer vehicle, encouraging universal deployment of improved vehicle safety technologies for both passive and active safety through a combination of harmonization of relevant global standards, consumer information schemes and incentives to accelerate the uptake of new technologies.

The increasing interest of new in-vehicles technologies for road safety improvements is also demonstrated by the Directive 2010/40/EU of the European Parliament and of the Council (2010) on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport. The main aim of the Directive is to accelerate the deployment of these innovative transport technologies across Europe. This Directive is an important instrument for the coordinated implementation of Intelligent Transport Systems (ITS) in Europe. Specifically, in order to reach the main purpose of the Directive, several priority areas are identified. Among them the third one is "ITS road safety and security applications" with specific attention to develop "data and procedures for the provision, where possible, of road safety related minimum universal traffic information free of charge to users".

Nowadays, although many in-vehicle ITS devices are estimated to deliver substantial crash reductions, several studies evaluating the potential benefits of some of the safety technologies demonstrated that, in some cases, their costs greatly outweighed their benefits. According to a recent report on the estimation of the benefits of emerging vehicle technology (Anderson et al., 2011), BCR (Benefit Cost Ratio) values for forward collision detection and avoidance in passenger vehicles appear marginal given the present stage of development of the relevant technologies.

It is therefore really recommended to accelerate the deployment of cost-effective safety technology, equipping of these active and safety systems all the vehicles and not only those of new generation, while commonly these technologies are installed only in recent vehicles.

Under this perspective, the present work is aimed at replying to the need for improving active and passive safety measures for road driving, through new methods and technology for detecting hazard driving condition and avoiding or mitigating the consequences of a road accident, such as rear-end collision. The present work could be considered as a pilot study aimed at verifying and assessing the reliability and potential applicability of a new model and procedure for collision warning system, based on low cost inter-vehicular communications. The authors focus on infrastructure-less vehicular communications, where GPS and other distance vector-based systems are not employed. Our method, in fact, only need a cheap radio transmitter/receiver, mounted on each vehicle. In particular, our method tests the only signs of the difference between the envelope samples of the received signal. Then, the testing variable is obtained under the constant false alarm rate criterion, according to the binomial statistical distribution and used to discriminate between the presence and absence of the approaching transmitter.

The remainder of this work is organized as follows. Section 2 (Background) describes the basic frameworks of ITS for road safety. Then, the binomial test is depicted in Section 3 (Advanced technology for collision avoidance), along with the system model in Section 4 (The motion and propagation models). In Section 5 (Numerical results and discussions) the performance of the test is evaluated under typical operating settings and our concluding remarks are briefly summarized in Section 6 (Conclusions).

2. Background

2.1. ITS for Road Safety Improvements

During the last years, car manufacturers and researchers experimented several in-vehicle technologies, such as Advanced Driver Assistance Systems (ADAS), able to provide support to various aspects of driving. These systems are supposed to improve road safety as well as traffic efficiency. The most famous and deployed ADAS are the adaptive cruise control (ACC), the intelligent speed adaptation (ISA), the collision warning systems (CWS), the lane departure warning, the adaptive light control, the driver vigilance monitoring, the pre-crash vehicle preparation and parking aid. According to Farah et al. (2012) all these technologies are being developed for assisting drivers in their primary task of driving (i.e., lane departure