Transportation Research Part C 18 (2010) 351–366

Contents lists available at ScienceDirect

Transportation Research Part C

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

An analysis of communication and navigation issues in collision avoidance support systems

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ARTICLE INFO

Article history:
Received 31 January 2008
Received in revised form 10 December 2008
Accepted 4 May 2009

Keywords:
Collision avoidance support
Vehicular communications
Navigation
V2V
INS
Cellular networks
DGPS
VANET

ABSTRACT

Collision avoidance support systems (CASS) are nowadays one of the main fields of interest in the area of road transportation. Among the different approaches, those systems based on vehicle cooperation to avoid collisions present the most promising perspectives. Works available in the current literature have in common that the performance of such solutions strongly relies on the operation of two on-board subsystems: navigation and communications. However, the performance of these two subsystems is usually underestimated when the whole solution is evaluated. Collision avoidance support applications can be considered among the most critical vehicular services, and this is the reason why this paper focuses on the performance issues of these two subsystems. Main issues regarding navigation and communication performance are discussed along the paper, and a study of the literature in the field is completed with the evaluation of different system prototypes. Communication and navigation tests in real environments yield further conclusions discussed in the paper.

1. Introduction

The advanced driver assistance systems (ADAS) are one of the prime work lines in the field of intelligent transportation systems (ITS). With the aim of decreasing the number of deaths and injuries caused by traffic fatalities, ADAS developments try to automate the traffic perception and, in general, the driving task. Collision avoidance support systems (CASS) can be considered, nowadays, one of the main researching lines in ADAS. These systems are designed to detect oncoming collisions and warn the user with time enough for making possible an evasive manoeuvre, or directly perform an automated control action. The relevance of CASS solutions has grown to such point that a great number of researchers take it as the reference service in the design of communication architectures in the ITS field. Nowadays, several approximations study the CASS problem from different points of view. In autonomous solutions, the subject vehicle is equipped with radars or vision sensors which provide pose information about the rest of the vehicles in the traffic environment. Although these systems can potentially offer a complete vision of the obstacles the vehicle can find on the road, they are restricted to the sensing capabilities, and generally are not cost efficient solutions. In distributed or cooperative solutions, on the other hand, using wireless communications, vehicles can share useful information to infer dangerous states. The concept of cooperative driving appeared in early nineties (Varaiya, 1993) and, gradually, more and more works started to be published. Depending on the level of

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doi:10.1016/j.trc.2009.05.007

cooperation among vehicles, the object vehicle can track the surrounding vehicles, in order to detect risk conditions, or directly receive or send a traffic event when it is necessary. In the first case, a periodical transmission of state messages to surrounding vehicles must be maintained, whereas in the second scenario only one message sent by an affected vehicle (or the one which detects the problem) is propagated in the network when it is necessary.

This paper is focused on a generic distributed CASS, and main requirements for any level of cooperation among vehicles will be embraced. Some works in the literature mention several technologies which has to be integrated in the on-board unit (OBU) of a CASS. Our study is focused on the relevance of the wireless network and the navigation subsystems, considering the main architectural elements of a distributed CASS. Too often, current proposals assume ideal performances of these subsystems, but the reality is very far from this assumption. In wireless communications, several transmission problems arise in a real V2V mobility scenario and, as it is further explained, the obtained performance is directly related to the technology used. Common network simulations do not consider many external factors of real mobility scenarios. The performance of the navigation subsystem in CASS solutions is even more underestimated. Although there are many collision avoidance systems that propose novel protocols for vehicle to vehicle communications (V2V), the relevance that the positioning subsystem has in the system performance has not sufficiently considered. Most of the approaches available in the literature include the GPS position in the messages broadcasted by vehicles. However, even though the messages can efficiently reach the destination, if the reported position has been distorted by external factors at the source equipment, the overall performance will be affected.

The rest of the paper will be focused on performance issues regarding the wireless network and the positioning system, and its weight in a distributed collision avoidance solution. Real tests have been carried out using on-board prototypes, with the aim of emphasizing key performance factors. Main objectives of this paper are:

- to ascertain the requirements of CASS's regarding their two main subsystems, navigation and communication,
- to analyze current solutions in the literature and address main CASS feasibility problems,
- to identify a feasible solution for communication and navigation units in the case of study,
- to analyse cellular network (CN) potential in vehicular communications and its feasibility in a CASS,
- to determine sensors contribution to the navigation subsystem according to the CASS needs,
- to validate the prototype results taking into account CASS requirements.

The paper is organized as follows: Section 2 analyzes existing works in collision avoidance systems and performance evaluation. Section 3 treats the different architectural elements of a CASS, and pays a special attention to communication and navigation subsystems. Section 4 describes the on-board unit designed for the tests and analyzes the results obtained from real tests carried out over several traffic environments. Finally, Section 5 concludes the paper.

2. Related work

It has been stated that several technologies have been considered in the literature to deal with the requirements of a collision avoidance system. Radar sensors are one of the most extended information sources for obstacle detection in autonomous collision avoidance systems. In (Shen et al. (2006)) a radar-based tracking architecture is used to enable the object vehicle to predict collisions in highways. A similar system is described in Jamson et al. (2008), where a study of the impact of such systems in drivers has been conducted, taking into account realistic scenarios through a simulator. As this work states, the usefulness of the forward collision warning system used is indisputable under any environment, and independently of the driver profile. Vision-based systems are also applied over autonomous CASS (Toulminet et al., 2006). However, visibility problems can degrade the performance of the system. In order to deal with this problem, hybrid solutions based on both radar and vision sensors have been developed (Amditis et al., 2005).

Regarding distributed collision avoidance systems through wireless communications, many works can be found in the literature. Misener et al. (2005), for example, give a cooperative CASS which uses 802.11b V2V communications. This work presents a complete prototype where the human–machine interface (HMI) has been completely developed and tested in field trials. Ueki et al. (2005) propose another CASS based on 802.11b, and give different approaches to detect a crash, sharing state information. The authors also include a study of 802.11 transmission problems in urban canyons, which concerns the purposes of the current paper. Shladover (2005) and ElBatt et al. (2006) use dedicated short range communications (DSRC) in collision avoidance systems. The latter evaluates the network performance in terms of latency and probability of reception of packets, according to several traffic conditions. The problem of routing an eventual traffic incidence through the network, where the subject vehicle is not in charge of inferring a potential collision, is evaluated in Biswas et al. (2006). Authors demonstrate how the propagation delay of the multi-hop network affects the CASS performance at some hundred meters of a collision, provoking new crashes in a convoy of vehicles.

Some authors who describe some performance issues of both communication and navigation subsystems in a CASS are Ammoun et al. (2006); Ueki et al. (2004), although a detailed study of these problems is not given. Korkmaz and Ekici (2006) include a deeper study about the impact of positioning problems over a location-based V2V routing protocol. Sengupta et al. (2007) evaluate the navigation system used in a CASS, which considers, as our proposal, an extended Kalman filter to integrate information from several sensors. However, this analysis is not directed to the CASS performance, and