Accident Analysis and Prevention 82 (2015) 53–60

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Issues and challenges for pedestrian active safety systems based on real world accidents

Hédi Hamdane [a,b,c], Thierry Serre [a,*], Catherine Masson [b], Robert Anderson [c]

[a] IFSTTAR, TS2, LMA, F-13300 Salon de Provence, France
[b] Aix-Marseille Univ, IFSTTAR, LBA UMR_T24, F-13016 Marseille, France
[c] Centre for Automotive Safety Research—CASR, The University of Adelaide, SA 5005, Australia

ARTICLE INFO

Article history:
Received 2 February 2015
Received in revised form 30 April 2015
Accepted 22 May 2015
Available online xxx

Keywords:
AEB systems
Pedestrian detection
Safety performance
Accident reconstruction

ABSTRACT

The purpose of this study was to analyze real crashes involving pedestrians in order to evaluate the potential effectiveness of autonomous emergency braking systems (AEB) in pedestrian protection. A sample of 100 real accident cases were reconstructed providing a comprehensive set of data describing the interaction between the vehicle, the environment and the pedestrian all along the scenario of the accident. A generic AEB system based on a camera sensor for pedestrian detection was modeled in order to identify the functionality of its different attributes in the timeline of each crash scenario. These attributes were assessed to determine their impact on pedestrian safety. The influence of the detection and the activation of the AEB system were explored by varying the field of view (FOV) of the sensor and the level of deceleration. A FOV of 35° was estimated to be required to detect and react to the majority of crash scenarios. For the reaction of a system (from hazard detection to triggering the brakes), between 0.5 and 1 s appears necessary.

1. Introduction

Every year, more than 1.2 million people in the world die in traffic accidents and among these casualties 22% are pedestrians (WHO, 2013). This proportion of fatalities that are pedestrians is 14% in Australia and 16% in the EU-15 (OECD/ITF, 2013). Worldwide organizations such as the OECD (Organization for Economic Co-operation and Development) and the WHO (World Health Organization) have outlined a set of objectives and actions to enhance pedestrian safety. Among these measures, the development of new safety-based technologies in the vehicle is promoted. Passive safety measures such as energy absorbing bumpers and hoods are designed to reduce the injury outcomes for pedestrians. These devices are evaluated under regulatory and non-regulatory tests (EuroNCAP). Along with these passive systems, active safety systems are being developed and introduced to prevent crashes. These active systems use sensors to monitor the forward path of the vehicle in order to detect a pedestrian. Once a hazard is detected, these systems trigger various countermeasures to avoid or mitigate collisions. These measures may include autonomous emergency braking or autonomous steering (e.g., Broggi et al., 2009; Hayashi et al., 2012; Keller et al., 2011a).

Active safety systems are mainly composed of the three following components: sensors for detection, a unit for processing and actuators for triggering an emergency maneuver. Concerning the first component, in order to detect various obstacles, cameras operating in visible light or infrared radiation (Near, Mid, Far) as well as RADARs and Laser Scanners are used. These different sensors have complementary functions as described by Gandhi and Trivedi (2007). So the combination of multiple sensors allows more accurate detection. This is achieved by merging and filtering the data collected from the environment in order to distinguish pedestrians from other background obstacles. As soon as pedestrians are detected, they are tracked in order to predict any collision. If a crash is imminent, the system applies the appropriate countermeasure.

Several methods have been developed to assess the effectiveness of these systems and estimate their safety impact on real world crashes. Approaches based on numerical simulation have been explored to assess the effect of systems in various accident scenarios. These scenarios are provided from in-depth crash investigations and are simulated using simple models

---

[*] Corresponding author. Tel.: +33 4 90 56 86 53; fax: +33 4 90 56 86 18.
E-mail addresses: hedi.hamdane@ifsttar.fr (H. Hamdane), thierry.serre@ifsttar.fr (T. Serre), catherine.masson@ifsttar.fr (C. Masson), robert@casr.adelaide.edu.au (R. Anderson).

http://dx.doi.org/10.1016/j.aap.2015.05.014
0001-4575/

(Rosén et al., 2010; Seiniger et al., 2013). More complex methods (probabilistic methods as Monte Carlo) expand the scenarios by slightly varying the initial pre-crash conditions in order to cover a wider range of crash configurations (Lindman and Tivesten, 2006). Besides computational simulations, researchers are currently attempting to develop standardized on-track tests to assess the performance of these systems. However, these track tests are limited in numbers of test scenarios even if they are focusing on reference scenarios defined through cluster and statistical analyses of real world crashes (Ebner et al., 2011; Eckert et al., 2013; Lenard et al., 2014; Wisch et al., 2013).

Several active systems for pedestrian safety have already been introduced on the market such as the CWAB-PD (Collision Warning with Full Auto Brake and Pedestrian Detection) firstly used in the Volvo S60 MY2011 and the Eyesight system available in Subaru's 2013 models. The regulations and protocols are being developed (Schram et al., 2013) and some studies on the effectiveness of these active systems have been already presented. For example, Lindman et al. (2010) used a simulation based method to conclude that the CWAB-PD system may lead to a reduction of about 30% of all front-end accidents and 24% of pedestrian fatalities. Ando and Tanaka (2013) assessed two systems using "standard tests" (vehicle driving toward a pedestrian dummy positioned on the course). The results attest that the functionality of the systems depends on the vehicle speed to avoid collisions but it is limited at a certain speed (40 km/h). Although these systems are intended to effectively reduce pedestrian injury outcomes, the collision avoidance performance of these systems remains limited.

The objective of this study is to understand the functionality of these active safety systems to prevent pedestrian crashes in terms of detecting the hazard and triggering autonomous emergency braking (AEB). These issues explored in this paper are focused on the implication of using sensors with a wide field of view to detect pedestrians and the compromise between high effectiveness and a low false activation rate (Keller et al., 2011a,b). This paper will address the problem of defining criteria for AEB activation in terms of:

- the trigger time for emergency maneuvers, and
- the remaining distance before impact.

Indeed, these two parameters encompass the most critical aspect of the performance and effects of pedestrian active safety systems because they affect the amount that the speed of the vehicle can be reduced prior to impact. In this study, the trigger times (relative to the time of impact) and the distance before impact at which a system is able to trigger are analyzed through the simulation of real world crash scenarios based on in-depth accident investigation.

2. Materials and methods

In summary, the study uses a sample of crashes from in-depth accident databases. Each crash in the sample is reconstructed and modeled numerically. In parallel, a model representing the functioning of an AEB system has been established from a bibliographic research. Finally the system's model is coupled to the kinematic of the vehicle preceding the impact in order to evaluate the characteristics of the triggering of an AEB system in the sample of crashes.

2.1. Accident data

A sample of one hundred crashes was selected from two in-depth at-scene crash investigation databases: 60 cases were provided by CASR (Centre for Automotive Safety Research, University of Adelaide, Australia) and 40 cases were compiled from the IFSTTAR-LMA crash database (the laboratory of accident mechanism analysis of the French institute of science and technology for transport, development and networks, France). Both of these centers proceed in a similar way to perform in-depth investigations (Girard, 1993; Woolley et al., 2006). In particular, these in-depth studies consist of investigations by a multidisciplinary team, composed of a psychologist and a technician, and are made on the scene of the accident, at the same time as the intervention of the rescue services. Those performing the survey were asked to collect a maximum amount of data. Generally, this data consisted of the final positions of the vehicles, the marks left on the ground (tyres, fluids, debris, etc.), the point of impact on the vehicle (bonnet, windscreen, etc.), the direction of the impact, the weather conditions, the obstructions and also to collect statements of drivers, witnesses and make a record of any injuries on the basis of the medical report, etc. All these data were then pooled and compared in order to make an initial reconstruction of the accident and to make hypotheses regarding the process involved: direction of travel of the pedestrian, speed of the vehicle, etc. When the reconstruction proposed is in agreement with all indications available, it is adopted as being the most probable scenario. To summarize the data of the reconstruction, a global synthesis of the accident is drawn up by the investigators relating in details the story of the accident.

IFSTTAR-LMA crash cases include investigated accidents occurred between 1995 and 2011 near the townships of Salon-de-Provence and Aix-en-Provence. CASR accidents were investigated in the Adelaide Metropolitan Area in the period April 2002 to October 2005.

Data collected during each investigation included:

- Photographs and videos of the crash scene and vehicles involved.
- Statements of people involved in the crash, witnesses, and police.
- Details of the road environment, involved vehicles and pedestrians.
- Details of injuries from medical records.
- A site diagram of the accident drawing to scale including the marks observed on the scene (skid, debris, blood, etc.), the final position of the vehicle and the pedestrian, the estimated impact location and the estimated trajectories of the different subjects involved in the crash.

Some examples of these in-depth investigations have already been published (Hamdane et al., 2014).

The inclusion criteria of the cases used in this study were that the impact location on the roadway was known and the speed of the vehicle could be reliably assessed from standard crash reconstruction techniques.

The accidents were systematically clustered into four distinct groups according to the predominant features of the pre-crash sequence, as they might relate to the performance of the sensing system. These groups were obstacles which hid the pedestrian, curved vehicle trajectory, pedestrian crossing from the sidewalk and pedestrian crossing from the far side of the roadway.

2.2. Accident modeling

The first step in each was to graphically reconstruct it. The approximate trajectories of the vehicle and the pedestrian were extracted from the scaled accident diagram provided from the in-depth investigation. Obstacles that mask pedestrians were located also using the diagram. Then, a temporal reconstruction was set up to emulate the kinematics of both the vehicle and the