Aix-Marseille Université – University of Adelaide

Improvement of Pedestrian Safety: Response of detection systems to real accident scenarios

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Jury

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An internationally joint supervised thesis between the University of Aix-Marseille and the University of Adelaide under an agreement signed by both parties including the PhD student and the supervisors.

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Preface

Through common activities shared in the field of pedestrian safety, collaboration has been materialised between two institutes, the French institute of science and technology for transport, development and networks (IFSTTAR) in France, and the University of Adelaide (through its research centre, the Centre for Automotive Safety Research – CASR) in Australia. This collaboration started in 2007 through the framework of the IHRA (International Harmonization Research Activities) that aims to develop standard safety evaluation procedures in vehicle technologies. Based on these events, a Memorandum of Understanding has been signed by both institutes in 2009[1].

Over the years, IFSTTAR and CASR have been performing common research activities such as comparison of accident investigation methods, accident reconstruction modelling and numerical simulation of pedestrian accidents. Exchange of researchers and students have been realized resulting in effective work and several articles published in common.

This PhD project is a continuation of this collaboration between the two institutes IFSTTAR and CASR. It is enrolled within a "cotutelle agreement" signed between the University of Aix-Marseille and the University of Adelaide. It is performed in cooperation with CASR and two research laboratories of IFSTTAR (the LMA –Accident mechanism laboratory– and the LBA –Applied biomechanics laboratory–).

[1] At that time, IFSTTAR was named INRETS. A renewal of the Memorandum of Understanding has been signed in 2013 to extend the duration to 4 years.

Abstract

The scope of this research concerns pedestrian active safety. Several primary safety systems have been developed for vehicles in order to detect a pedestrian and to avoid an impact. These systems analyse the forward path of the vehicle through the processing of images from sensors. If a pedestrian is identified on the vehicle trajectory, these systems employ emergency braking and some systems may potentially employ emergency steering. Methods for assessing the effectiveness of these systems have been developed. But, it appears difficult to determine the relevance of these systems in terms of pedestrian protection. The general objective of this research was to test the response of these systems in many accident configurations.

The first step consisted of gathering a sample of a hundred of accidents involving vehicles with pedestrians. These accidents were provided from accident databases of two laboratories LMA and CASR. Data of these accidents were recorded in sufficient detail from in-depth investigation which enables reconstructing the trajectory of the vehicle and pedestrian prior to the collision.

The second step was to analyse qualitatively and quantitatively the data of the selected accidents. These accidents were reconstructed to simulate the pre-crash conditions. From this accident reconstruction, factors relevant to the primary safety of pedestrians were deduced.

The next step consisted of coupling the vehicle dynamic behaviour with a primary safety system in order to confront these systems to real accident configurations. The potential of these systems is studied by verifying the feasibility of deploying an autonomous emergency manoeuvre during the timeline of the accident and according to the vehicle dynamic capabilities: i.e. verifying the possibilities in terms of crash avoidance. Based on this procedure, three modelling methods were developed: a first method testing a system to each accident configuration and two others using graphs of evaluation from a parametric study realised on a generic system. The results of the three methods were then discussed.

Finally, as a perspective, the last study will approach crash mitigation. As a consequence of an active safety system response, the vehicle impact speed is reduced. The effect of speed reduction on variations in impact conditions will be then addressed to measure the potential safety impact of these systems on pedestrian protection.

Abstract in French

Le contexte général de cette recherche concerne la sécurité active des piétons. De nombreux systèmes embarqués dans les véhicules sont actuellement développés afin de détecter un piéton sur la chaussée et d'éviter une collision soit par une manœuvre de freinage d'urgence soit par une manœuvre de déport. La plupart de ces systèmes d'aide à la conduite sont basés sur des systèmes de détection (caméras, radars, etc). Ils analysent la scène en temps réel, puis effectuent un traitement d'images dans le but d'identifier un potentiel danger. Or il apparaît difficile de déterminer la pertinence de ces systèmes en termes de sécurité routière. L'objectif général de ce travail est ainsi d'estimer cette pertinence en confrontant les systèmes à de multiples configurations d'accidents réels.

Une première étape a consisté à sélectionner une centaine de cas d'accidents réels impliquant des piétons percutés par des véhicules motorisés. Ce recueil s'est effectué à la fois dans les laboratoires LMA et CASR. Ces deux laboratoires ont des méthodes similaires d'investigation des accidents de la route. La qualité et la quantité d'information sur chaque accident recueilli permet de récupérer les données nécessaires pour la reconstruction cinématique d'un accident.

Dans une seconde étape, une analyse qualitative et quantitative est réalisée sur l'échantillon d'accidents sélectionnés. Ces accidents ont été par la suite reconstruits cinématiquement modélisant avant impact les trajectoires des véhicules et piétons impliqués. Une analyse de ces reconstructions a permis de dégager les enjeux dans l'espace et dans le temps qui influencent la sécurité primaire du piéton.

L'étape suivante a pour but de tester les systèmes de détection des piétons dans les configurations d'accidents reconstruits en les associant à la cinématique des véhicules. Le test de performance de ces systèmes a été alors réalisé en vérifiant leurs compatibilités au regard de la chronologie des accidents; i.e. vérifier la possibilité d'évitement des accidents. À partir de cette procédure, trois différentes méthodes de modélisation ont été développées : une première méthode évaluant un système pour chaque configuration d'accidents et deux autres méthodes utilisant des graphes tracés à partir d'une étude paramétrique d'un système générique. Ces méthodes ont été par la suite évaluées.

Enfin, une extension de la méthodologie précédemment décrite est proposée comme perspective pour aborder la phase d'impact du piéton contre le véhicule. En conséquence d'un déclenchement d'un système actif, la vitesse d'impact est réduite et donc les conditions du choc sont modifiées. Une méthode a été développée pour étudier les effets de cette réduction de vitesse en analysant les conséquences sur les risques lésionnels du piéton.

Statement of originality

To the best of my knowledge and belief, this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution that was not mentioned in the agreement signed between the University of Adelaide and the Aix-Marseille Université. It contains no material previously published or written by another person, except where due reference has been made in the text.

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List of publications

- H. Hamdane, T. Serre, C. Masson and R. Anderson (2016). Relevant factors for active pedestrian safety based on 100 real accident reconstructions. International Journal of Crashworthiness, Volume 21 (1), p. 51-62.

- H. Hamdane, T. Serre, C. Masson, R. Anderson (2015). Issues and challenges for pedestrian active safety systems based on real world accidents. Accident Analysis & Prevention, Volume 82, September 2015, p. 53–60.

- H. Hamdane, T. Serre, R. Anderson, C. Masson and J. Yerpez (2014). Description of pedestrian crashes in accordance with characteristics of Active Safety Systems, Proceedings of the 2014 IRCOBI conference, Berlin, Germany, 10-12 September 2014.

- H. Hamdane, T. Serre, R. Anderson and J. Yerpez (2014). Accident simulation and reconstruction for enhancing pedestrian safety: issues and challenges, Proceedings of the 6th ESAR conference, Hannover, Germany, 20-21 June 2014.

- H. Hamdane, R. Anderson, C. Masson, M. Llari and T. Serre (2014). Assessment methodology of Active Pedestrian Safety Systems: an estimation of safety impact, Proceedings of the 3rd SIMBIO-M conference, Marseille, France, 19-20 June 2014.

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List of abbreviations

- ADAS: Advanced Driver Assistance System
- AEB: Autonomous Emergency Braking
- AES: Autonomous Emergency Steering
- AIS: Abbreviated Injury Scale
- CASR: Centre for Automotive Safety Research
- Euro NCAP: European New Car Assessment Program
- FoV: Field of View
- GIDAS: German In-Depth Accident Study
- IFSTTAR-LMA: French institute of science and technology for transport, development and network, Laboratory of accident mechanisms analysis
- LTTB: Last Time To Brake
- TTB: Time-To-Brake
- TTC: Time-To-Collision
- Ped-AEBS: Pedestrian Autonomous Braking System
- Ped-CAMS: Pedestrian Collision Avoidance and Mitigation System
- WAD: Wrap Around Distance