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Vision-based Pedestrian Protection Systems for Intelligent Vehicles

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Preface

This book is a natural evolution of the survey paper we published in the IEEE Transactions on Pattern Analysis and Machine Intelligence [121]. Therefore, we have followed the same point of view. On the one hand this means that we focus on vision-based solutions for pedestrian detection. Moreover, although we include some references from fields such as surveillance, robotics, and multimedia, the backbone context of the book is driver assistance, i.e., the development of pedestrian protection systems. On the other hand, we have organized the literature according to the main stages that a vision-based pedestrian protection system must incorporate. Moreover, we do not focus on the mathematical formalism behind each proposal. Rather, we try to explain the overall ideas so that interested readers can go to the original references to look into the details. Because of that, we think that novel researchers in this field, from the academia or the industry, can take benefit of this book. At this moment, [121] has received already more than 140 cites. We have informally collected feedback from some readers of [121] and we are glad to say that it seems that this paper accomplished its purpose, namely to give a quick overall organized idea of the field to novel researchers and even to experienced researchers of other fields (e.g., it was interesting to discuss with researchers of the machine learning community about detection vs classification). Thus, we hope that in the same line this book can be useful even for more researchers.

In this book more than 300 papers are referenced, which gives an idea of the enormous interest that vision-based pedestrian detection has deserved from both the computer vision and the intelligent transportation systems communities. We include more than 190 references that were not included in [121], more than 80 published after [121], which shows how active this field is. In spite of the amount of papers we reference, there are also many more that have not been included. We apologize for that, since all published works deserve their own acknowledgment given the effort of the authors. However, even a book like this one needs to limit the space in order to keep on focus. We do not provide a sort of best papers ranking, but we have chosen those papers that better allow us to illustrate the diversity of solutions available in the literature. Of course, this implies that papers that presented breaking ideas along this past decade are included.

It is worth to mention that vision-based pedestrian detection is a subfield of object detection in videos, which in turn deserves its own book given the enormous corpus of proposals generated so far thanks to advances in topics such as machine learning, image descriptors, computational power, etc. This means that some general object detection methods can be applied to pedestrian detection. However, we have focused on the literature that explicitly addresses pedestrian detection in its own. As we will see, modern pedestrian/object detectors mainly rely on image descriptors (features), pedestrian/object models (e.g., holistic, multi-aspect, part-based, etc.), and learning machines (e.g., SVM and AdaBoost variants). In this book we focus our explanations on the content more specifically related to vision, i.e., pedestrian image descriptors and models. While the machine learning algorithms used in the reviewed literature are of course mentioned, explaining how such algorithms work is out of the scope of the book.

This book is not done only thanks to the work of the authors, but many more persons and institutions must be acknowledged. First, we thank to the pedestrian detection community itself for addressing such a challenging and socially relevant problem. We thank also Springer for giving us the opportunity of writing this book. We thank to our daily collaborators at the Computer Vision Center (CVC) of Barcelona as well as at the Department de Ciències de la Computació of the Universitat Autònoma de Barcelona (UAB). Special thanks to the administrative and support staff who makes research easier. Many thanks to all the members of the CVC-ADAS group (www.cvc.uab.es/adas) for the hard work along the 10 years of life of the group and for being people that we really enjoy to work with. Special thanks also to David Váquez, Javier Marín, and Jiaolong Xu for kindly helping us to explain better some parts of this book. We want to give thanks also for the public funding we have received along the last years to support our research in the driver assistance context. In particular, we thank the following projects from the Spanish Government: TRA2011-29454-C03-01, TIN2011-29494-C03-02, TIN2011-25606, TRA2010-21371-C03-01, Consolider Ingenio 2010: MIPRCV (CSD2007-00018), TRA2007-62526/AUT, and TRA2004-06702/AUT.

Antonio M. López also wants to thank his Ph.D. supervisor Joan Serrat, as well as mentors Juan José Villanueva, and Bart M. ter Haar Romeny. Good supervisors and mentors are key for having a successful career, these boys are. Equally important is to have good Ph.D. students who help you to stay updated and active in the frontier of the research. Accordingly, thanks also to Antonio's Ph.D. students Daniel Ponsa, David Gerónimo, José M. Álvarez, David Vázquez, Javier Marín, Diego Cheda, Yainuvis Socarrás, Muhammad Rao, Jiaolong Xu, and Sebastián Ramos. In addition, many thanks also to researchers who have hosted these students during researcher stages and with whom I have enjoyed research and life discussions. Thus, many thanks to Theo Gevers, Krystian Mikolajczyk, Ludmila Kuncheva, Dariu Gavrila, Bastian Leibe, and Frédéric Lerasle. Thanks also to other CVC-ADAS Ph.D. students with whom I have actively collaborated as Carme Julià, Ferrán Diego, José C. Rubio, and Germán Ros. As head of the CVC-ADAS team, Antonio also wants to give special thanks to the members who fought to build the team from the scratch, namely Joan Serrat, Felipe Lumbreras, Angel

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David Gerónimo wants to thank his former Ph.D. supervisor and currently research collaborator Antonio M. López for the guidance and support during the last 8 years. Day by day, his attitude toward research has been an inspiring source for him to improve as a researcher. Many thanks also to his collaborators, research fellows and friends for the long and fruitful discussions: Angel D. Sappa, Joan Serrat, Daniel Ponsa, José M. Álvarez, David Vázquez, Javier Marín, Didier Devaurs, Hirofumi Uemura, Alejandro Mosteo, David Aldavert and Xuan Zou. Thanks also to David's hosts during research stays in Surrey and LAAS-CNRS, Krystian Mikolajczyk and Frédéric Lerasle, for their warm welcome to their labs. Finally, David wants to thank his family, specially to his parents Angel and Núria, and his sister Sara, for their support. Finally, David's most sincere acknowledgments are addressed to his wife Verónica, for her understanding and never-ending support, specially during the long and untimely hours spent in research.

Contents

Chapter 1
Introduction

Intelligent machines assist us in many situations of our everyday lives: medical diagnoses, communications, transportation, education, surveillance, etc. It is expected that during the current century machines will become even more integrated in our daily experiences, especially focused on improving aspects such as safety and comfort.

This book describes a type of systems aimed at avoiding pedestrian to vehicle collisions. These systems, formally known as Pedestrian Protection Systems (PPSs), must detect and track pedestrians, and provide the necessary outputs to the host vehicle in order to prevent potential accidents and even reduce their severity when unavoidable. The breakthrough of these systems occurred at the beginning of the twenty-first century thanks to the advances in sensing, the maturity of artificial intelligence and computer vision, and the increase in machines' computational power. In the last years intensive research efforts in this technology have been carried out by both public and private entities, which have projected their massive commercialization during this decade.

1.1 Automobile's Impact

When people are asked the most relevant technology that has changed most the landscapes of our cities during the last century, the automobile is a common answer. Indeed, the human development in the modern era is represented up to some extent by the automobile. It has changed societies not only in urban planning, industry and economy but also in demographic distribution and social interactions. Employment, leisure and relationships are all shaped to a greater or lesser degree by automobiles. This is clearly illustrated when comparing two families from the early 1900s and the 2000s. The former family bought their food and clothes in local stores, close to the living place, traveled to nearby working places, and the leisure travels were restricted to the nearby regions. Nowadays, most of the shopping activities are concentrated in

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large shopping malls out of the cities, working places are farther away and the leisure trips are not restricted to nearby regions but to whole countries and continents.

Like many other technologies, from the very beginning automobiles carried an undesirable dark side: traffic accidents. The first death by a motor vehicle was registered in Ireland on August 31st, 1869 [90]. Although the number of fatalities was low at the beginning, fatalities exponentially grew throughout the years given the popularization of cars. One and a half centuries later, road accidents represent the ninth cause of death worldwide, and the ONU predicts that in 2030 it will be the fifth [233]. Every year almost 1.2 million people are killed in traffic crashes, while the number of injuries rises to 50 million. Furthermore, attending to the increasing automobile productions in low and middle-income countries, these numbers are expected to rise considerably. Figure 1.1 illustrates the number of deaths per 100,000 population as a result of a traffic accident. As can be seen, high income countries and regions such as the United States or the European Union tend to have a lower number of fatalities than the rest, even though the number of vehicles in these countries is high. Before having a look at this map, one could have the wrong idea of thinking that a lower number of vehicles would be reflected in a lower number of traffic accidents and deaths. In the United States there are 0.8 vehicles per capita [66] (the USA is the most motorized country in the world). In Egypt this number is exactly the half [233], however the number of deaths per 100,000 inhabitants is three times the deaths in the USA. Nigeria, with only 0.3 vehicles per capita, has twice the number of deaths per 100,000 than the USA. In fact, it is the longstanding traffic regulation together with the consciousness-raising of this problem which have progressively decreased the number of fatal accidents in high-income countries. On the contrary, low-income

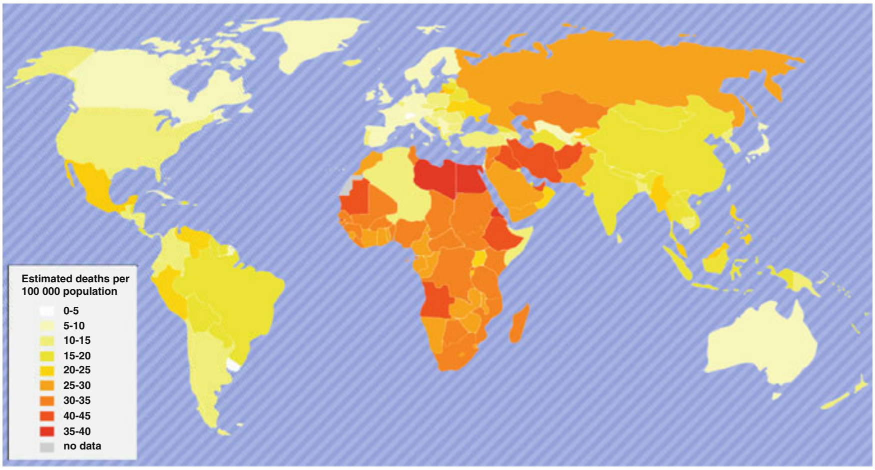

Fig. 1.1 Statistics of deaths related to traffic accidents in the world. It can be clearly seen that although rich countries have higher number of vehicles than low-income countries, the number of fatalities is lower thanks to the improved safety measures, government campaigns and regulation

countries tend to have a higher number of deaths given the opposite reason: lack of regulation in many aspects and low consciousness of the problem. Attending to this, as low-income countries evolve and start increasing their number of vehicles and transport networks the relevance of the problem arises.

According to the International Organization of Motor Vehicle Manufacturers [228], every year around 59 million passenger cars and 20 million commercial vehicles are produced worldwide. This represents an increase of 44 % and 17 % with respect to year 2,000 production, respectively. Although this rate will probably not sustain in very industrialized countries as a result of the increasing price of oil, the popularization of air travel and the *green* trends, it will be largely compensated by emerging economies such as China or India, with increases of 800 % and 400 % in total number of produced vehicles yearly from 2000 to 2010.

Figure 1.2 illustrates another dramatic fact related to the evolution of two emerging economies. On the one hand the United States and the European Union have average population and a big fleet of vehicles. On the other hand growing countries such as China or India have the biggest populations in the world but an average number of vehicles (between 0.2 and 0.5 per capita) [233]. As previously mentioned, having a smaller fleet does not lead to a lower number of accidents, as it is clearly appreciated in this figure. However, it is clear that as emerging countries increase their number of vehicles, the number of deaths will also rise if no solution is implemented. The most direct solutions to fix this problem are well-known given that they have been developed for decades: researching new technology to increase the safety of vehicles and infrastructures.

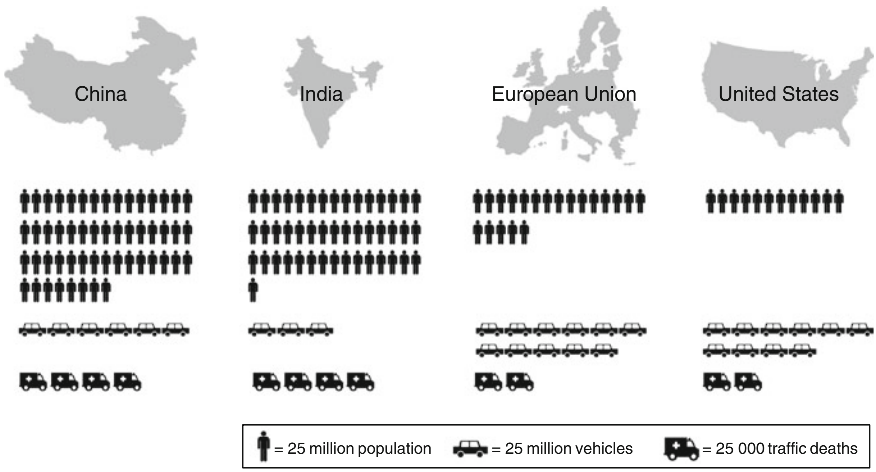

Fig. 1.2 Population, vehicle and traffic deaths statistics of two emerging economies (China and India) and two high-income ones (USA and European Union)