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IVVI 2.0: An intelligent vehicle based on computational perception

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ABSTRACT

This paper presents the IVVI 2.0 a smart research platform to foster intelligent systems in vehicles. Computational perception in intelligent transportation systems applications has advantages, such as huge data from vehicle environment, among others, so computer vision systems and laser scanners are the main devices that accomplish this task. Both have been integrated in our intelligent vehicle to develop cutting-edge applications to cope with perception difficulties, data processing algorithms, expert knowledge, and decision-making. The long-term in-vehicle applications, that are presented in this paper, outperform the most significant and fundamental technical limitations, such as, robustness in the face of changing environmental conditions. Our intelligent vehicle operates outdoors with pedestrians and others vehicles, and outperforms illumination variation, i.e.: shadows, low lighting conditions, night vision, among others. So, our applications ensure the suitable robustness and safety in case of a large variety of lighting conditions and complex perception tasks. Some of these complex tasks are overcome by the improvement of other devices, such as, inertial measurement units or differential global positioning systems, or perception architectures that accomplish sensor fusion processes in an efficient and safe manner. Both extra devices and architectures enhance the accuracy of computational perception and outreach the properties of each device separately.

1. Introduction

Traffic accidents are one of the main health risk problems. Globally, as the number of vehicles on the road increases so does the number of fatalities and injuries. As a consequence of road accidents, every year approximately 1.2 million people are killed and 50 million disabled or injured (WHO, 2009). Not only are road traffic accidents the eleventh cause of death in the world, but it is the only cause of death among the worst twelve which is not related to illnesses or diseases.

Human errors are the cause of most traffic accidents. Drivers' inattention and wrong driving decisions are the two main errors. Governments are trying to reduce the said accidents with infrastructure improvement and educational campaigns, but they cannot be completely eliminated due to the human factor. The speed of vehicles on the road is directly related to the risk factor associated with accidents and is also responsible for the consequences (WHO, 2008). Excess velocity on the road within areas of a determined speed limit and inappropriate driving speed are the main cause of traffic accidents, i.e. driving at an excess velocity when considering parameters such as: the driver, the volume of the traffic, and the condition of the vehicle and the road. That is why Advanced Driver Assistance Systems (ADAS) can reduce the number, danger and severity of traffic accidents. Several ADAS, which nowadays are being researched for intelligent vehicles, are based on Artificial Intelligence, Laser and Computer Vision technologies (Guan, Bayless, & Neelakantan, 2012; Milanés et al., 2012).

ADAS are designed to help human drivers. Thus, there are examples of road lane detection (Collado, Hilario, de la Escalera, & Armingol, 2008; Zhou, Xu, Hu, & Ye, 2006), and obstacles recognition and avoidance in the vehicle's path such as either vehicles (Musleh, de la Escalera, & Armingol, 2012b) or pedestrians (Musleh, de la Escalera, & Armingol, 2011; Soquet, Perrollaz, Labayrade, & Auber, 2007) or other elements, like traffic lights and marks on roads (Franke et al., 2001). ADAS are on-board vehicle systems which focuses on the driving process. One of the main objectives of this technology has been to increases driver awareness by providing useful information.

There are a large variety of systems on the market that employ cameras based on Computer Vision, Radar, Light Detection Ranging (LIDAR) and Ultrasonic Sensors to support ADAS. These sensors are critical to support the aim of intelligent vehicles, such as the IVVI vehicle that has been conceived at Intelligent Systems Lab to

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incorporate our developed technologies to foster the implantation of next generation of vehicles and its growing potential for the Transportation Sector (Fig. 1).

The advancement of sensors and computation devices have allowed in-vehicle technology rapidly advancing and a complete standardization in present and forthcoming vehicles. The applications that require object detection, such as vehicle collision avoidance (Chang, Tsai, & Young, 2010), have reached a growing interest in vehicle manufacturers due to increasing safety conditions for both passengers and pedestrians (Guo, Ge, Zhang, Li, & Zhao, 2012). These advances have influenced a number of in-vehicle applications already available in the automotive sector, such as a system developed by Mercedes that monitors the space available on both sides and behind the vehicle and that is capable of detecting other vehicles. It notifies the presence of other close by vehicles when changing lane (Daimler, 2013a). The parking assistant developed by Bosch (2013) employs a total of six sensors on the front and rear of the vehicle and measures the parking space which is indicated to the driver using an acoustic emission whose characteristics are in function of the size of the space available. Driver behaviour monitoring system is another safety application to be implemented in vehicles to a widespread transition to intelligent vehicles. Another driver monitoring system has been developed for Nissan which monitors the attention of the driver and detects possible symptoms of drowsiness (Nissan., 2013). The lane departure system of Iteris (2013) warns drivers of unintentional lane changes in areas where the lanes are marked. It detects both continuous and discontinuous lines even when the road markings are not clearly visible. Other innovations have demonstrated also the possibility to improve safety and mobility, this is the case of Mercedes Corporation, where a multipurpose device has been constructed, named DistronicPlus, which among other features has an adaptive cruise control function. This is used specifically for traffic jam situations where the system can take control of the car and maintains automatic user preselected security distances between vehicles by braking and accelerating (Daimler, 2013b).

Intelligent transport system and road safety applications are common topic in expert systems, thanks to the recent advances in information technologies, modern applications are used to enhance the vehicle positioning, prevent road accidents or in the event of an accident, mitigate the harm of the agents involved: in Bhatt, Aggarwal, Devabhaktuni, and Bhattacharya (2014) authors proposed a hybrid fusion scheme based on low cost INS systems to overcome the eventual signal loss in GPS systems. In Castro, Delgado, Medina, and Ruiz-Lozano (2011) a fuzzy logic base system is presented for pedestrian accidents avoidance. Adaboost and SVM system for pedestrian detection is presented in Guo et al. (2012), and also SVM algorithm fused with laser scanner information is presented by García, García, Ponz, de la Escalera, and Armingol (2014) for pedestrian detection and tracking. In Conesa, Cavas-Martínez, and Fernández-Pacheco (2013) vehicles driving in opposite direction are identified by means on an agent based architecture. A different approach, but also related with traffic security is presented on Abellán, López, and De Oña (2013) where an algorithm to identify the severity of the accidents based on decision trees is presented. Finally driver drowsiness is analyzed based on computer vision algorithms and biological measurements in Jo, Lee, Park, Kim, and Kim (2014). All these applications represent important advances in the latest years in the expert system field related to the road safety and intelligent transport systems topics. In further sections, ADAS systems applications developed in the research platform IVVI 2.0 are presented, each of them provides new and novel solution on their respective fields.

Following with recent innovations over the past decade, scientists and engineers at Intelligent Systems Lab have developed intelligent systems in industry and academia to solve a wide variety of safety problems in vehicles, adapting to market needs of the burgeoning vehicle industry. These in-vehicle systems have favoured vehicle manufacturers due to difficulties of integrating devices together with safety applications, which can cope with the widespread changes on the vehicle environment. So, this work presents our contribution to intelligent transportation systems (ITS) by means of devices that deal with machine vision, laser scanning, inertial measurement, GPS positioning and computer-based processing technology. The on-board applications are obstacle and

Fig. 1. IVVI 2.0 intelligent vehicle from Intelligent Systems Lab.