State-of-the-Art Analysis of Available Advanced Driver Assistance Systems

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***Abstract*—This paper presents a related work analysis of advanced driver assistance systems. These systems are aimed to help the driver in the driving process. They detect and alerts drivers with dangerous driving situations and behavior. Such systems use computer vision and machine learning algorithms to monitor and detect whether the driver is tired or distracted using front-facing camera while at the same time tracking road conditions using rear-facing camera. In addition, smartphone sensors, such as accelerometer, magnetometer, gyroscope and GPS, can help in identifying these dangerous events. Presented related work shows that there are two major types of driver assistant solutions available. They are solutions integrated in the vehicles and application for mobile phones that detect dangerous situations and makes alerts for drivers.**

I. INTRODUCTION

Advanced Driver Assistance Systems (ADAS) are systems to help the driver in the driving process (see Fig. 1). When designed with a safe Human-Machine Interface, they offer increased car and road safety. Safety features are designed to avoid collisions and accidents by offering technologies that alert the driver to potential problems, or to avoid collisions. Adaptive features may provide adaptive cruise control, automate braking, incorporate GPS/ traffic warnings, connect to smartphones, alert driver to other cars or dangers, keep the driver in the correct lane, or show what is in blind spots.

The EuroFOT consortium [1] published the findings of a four-year study focused on the impact of driver assistance systems in the Europe. The €22-million (US$27.4-million) European Field Operational Test (EuroFOT) project, which began in June 2008 and involved 28 companies and organizations, was led by Aria Etemad from Ford's European Research Centre in Aachen, Germany. Almost 1000 vehicles (cars and trucks) were equipped with ADAS and more than a thousand drivers participated. Data were collected from onboard computer systems, video recordings, driver surveys, and questionnaires submitted to drivers at the start of the FOT, at the end of baseline phase, and at the end of treatment phase.

The study [1] showed a decrease of safety risk up to 42% due to timely alert of the driver or an automatic adjustment of speed, and that over 90% of accidents involve driver behavior as a contributing factor.

Some examples of ADAS features are:

- Automotive night vision.
- Blind spot monitor.
- Collision avoidance system (pre-crash system).
- Driver drowsiness detection.
- Intersection assistant.
- Intelligent speed adaptation or intelligent speed advice (ISA).
- Lane departure warning system.
- Lane change assistance.
- Pedestrian protection system.
- Traffic sign recognition.

There are many forms of ADAS available. Some features are built into cars or are available as an add-on package, while aftermarket solutions are available for some late model cars.

Therefore current advanced driver assistance systems are divided into two categories:

- Manually installed mobile applications from application stores.
- Specific hardware and software, integrated into automobiles by manufactures.

Despite advanced safety features are equipped on premium sedans and high-end vehicles models, but the majority of drivers still do not have access to these safeguards. Some of mobile ADAS applications can be manually installed by users from marketplaces (Apple App Store[1] / Google Play[2]). These applications present itself as user assistance.

The rest of the paper is structured as follows. Section II presents an overview of existing at the moment ADAS solutions. Main results are summarized in Conclusion.

[1] https://www.apple.com/itunes/charts/free-apps/
[2] http://play.google.com/store

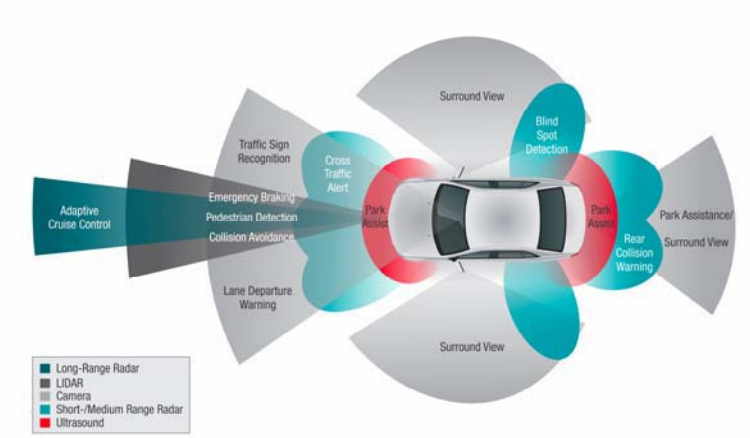

Fig. 1. A car equipped with ADAS (source: [2])

II. State-Of-The-Art

There are a lot of driver assistance systems available in the market at the moment and car manufactures are already working with ready-made solutions or make their own.

For instance, Mobileye [3] is the first company to introduce to the OEM production world a vision-only forward collision warning system for multiple vehicles. This is a technological company in the area of software algorithms, system-on-chips and customer applications that are based on processing visual information for the market of ADAS. Mobileye has developed a family of EyeQ vision processors and a broad range of algorithms for ADAS mono-camera for vehicle active safety applications. Software algorithms and EyeQ® chip perform detailed interpretations of the visual field in order to anticipate possible collisions with other licensed vehicles, pedestrians, animals, debris and other obstacles. These products are also able to detect roadway markings such as lanes, road boundaries, barriers and similar items, as well as to identify and read traffic signs and traffic lights.

IT Division of Movon Corporation [4] is the provider of Vision-based ADAS in automotive industry. Movon ADAS system was designed to prevent traffic accidents in advance caused by unintentional lane departure or forward collision. It includes core computer image processing technologies.

Another company specializing on driver assistance systems is Bosch Mobility Solutions [5]. The benefits they offer the customers are improved safety for occupants and other road users, avoidance of accidents, parking and maneuvering, mitigation of the severity of accidents, new safety functions by means of networking existing systems and components, modular safety systems and synergies due to expertise in system development and networking.

TRW [6] is a developer and innovator in the rapidly growing field of ADAS. These camera- and radar-based technologies assist drivers by providing information and acting on environmental data at the front, side and rear of vehicles to help warn drivers of impending danger. They can also provide intuitive cues or actions such as braking and steering inputs to help “coach” the driver to stay in lane or offer convenience functions like Adaptive Cruise Control.

Freescale complete solutions [7] are accelerating the availability of ADAS in mainstream vehicles. Freescale integrates leading technologies for microcontrollers, sensors and analog devices for ADAS enabling scalability, low power consumption and high levels of integration in these space-constrained applications. From today's safety assisted vehicles, to tomorrow's autonomous cars, Freescale is driving the world's most innovative ADAS solutions with our Auto, MCU, Analog and Sensors and Digital Networking portfolio expertise.

Autoliv Inc. [8] has developed a forward-looking Mono Vision Sensing System for BMW, which improves driver awareness and thereby has the capability to reduce traffic accidents, injuries and even fatalities for automobiles. For this specific design, Autoliv is the system integrator and provides the complete system of hardware including the camera (which is mounted between the rear-view mirror and the front windshield) and the electronic control unit, which includes an EyeQ2 chip provided by MobilEye. The main focus of this system is safety in respect to Forward Collision Warning, which alarms a driver to an imminent collision with the vehicles in front as well as in the case of an unintentional Lane Departure. The system supports automatic high beam switching with a smooth high/low beam transition, allowing for an optimal control of road illumination and increased night time driving safety. Traffic Sign Recognition, providing the driver with information about speed sign zones, which includes no-pass zones.

To make cars and trucks safer and more environment-friendly, Renesas Electronics [9] is developing components for electronic systems that result from the convergence of IT (information technologies) and control. In particular, they

now offer solutions that combine their R-Car V2H chip with support software, making it easier for automotive engineers to implement powerful ADAS functions. Their current ADAS implementations are already capable of surround monitoring and pedestrian recognition. In the next generation solution that's now in development, they plan to add support for collision prevention and automatic driving on specially designed roadways. For the generation of ADAS solutions beyond that, Renesas aims to enable automakers to build collision-free cars capable of automatic driving on everyday roads.

TDAx (TI's Driver Assistance SoC Family) [2] offers scalable and open solutions for ADAS applications to enable customers to innovate and differentiate. TDAx family supports common hardware and software architecture across camera based front (mono and stereo), rear, surround view and night vision applications, and mid- and long-range radar and sensor fusion systems. For instance, TI's TDA3x System-on-Chip is a highly optimized and scalable family of devices designed to meet the requirements of leading ADAS. Their processors enable broad ADAS applications by integrating an optimal mix of performance, low power, smaller form factor and ADAS vision analytics processing that aims to facilitate a more autonomous and collision-free driving.

WABCO [10] is a company that continuously improves vehicle safety while contributing to driver effectiveness. Technology leadership drives vision and activities to help mitigate most common causes of accidents involving commercial vehicles. This includes WABCO's innovative portfolio of ADAS: Adaptive Cruise Control with active braking, collision mitigation systems, autonomous emergency braking on moving and decelerating, autonomous emergency braking on moving and stopped vehicles and LDW system.

HARMAN [11] has developed a complete range of ADAS. It begins by keeping drivers intimately aware of their surroundings with rear-view and wide-angle camera applications. Virtual reality modeling is then blended with the camera images, to create a full surround view of the vehicle from any angle for safer driving and parking efficiency. Lane departure, blind spot and collision warning systems complement these visual tools, alerting the operator to actual or impending hazards. Recognizing that different drivers have different needs, HARMAN has also developed a Situational Human Machine Interface. This ensures that data and services are presented in the most intuitive manner based on current driving needs for daily commuting, a quick errand, or a weekend road trip.

Magna Electronics operating unit [12] in conjunction with Mobileye, its partner for image processing, has developed an innovative ADAS that uses a single, forward-looking video camera to provide safety and convenience features such as forward collision and lane departure warnings. More affordable than comparable systems, the Magna system has recently launched on General Motors vehicles in the North American market, available as an option on the 2012 Chevrolet Equinox and General Motors Terrain. Magna Electronics has collaborated on ADAS with Mobileye since 2005. The first product to be introduced was the Lane Departure Warning system based on the EyeQ1, launching also with General Motors on the Cadillac STS and DTS and Buick Lucerne. The second generation of Mobileye processor (EyeQ2) with General Motors demonstrates the continuing advancements and growth in features for both Magna and Mobileye.

Hyundai MOBIS [13] seeks to make ways for vehicles to be more advanced and intelligent by producing ADAS and driving parts for hybrid vehicles so that drivers all over the world can experience safer and more convenient driving in a cleaner environment. Keeping pace with the automotive trends, MOBIS is spurring the development of ADAS parts in order to facilitate safer and easier driving.

Panasonic Corporation [14] established Panasonic Automotive & Industrial Systems.

Subaru engineers developed ADAS technology called EyeSight [15], which sees the problem and initiates action to help avoid the danger.

As we can see, there are a lot of companies that provide advanced safety features for the vehicle drivers. The most popular features are: Pedestrian collision warning (PCW), Speed Limit Indication (SLI), Traffic Sign Recognition (TSR), High Beam Assist (HBA), Lane Departure Warning (LDW), Forward collision warning (FCW), Careless Lane Change (CLC), Lane Weaving and Drifting (LW), Tailgating (TG), Drowsy driving (DD), Headway monitoring warning (HMW), Inattentive driving (ID), and Head-up display (HUD). The comparison of described above solutions are shown in the Table 1.

However, only a tiny percentage of cars on the road today have these driver assistant systems. These technologies are quite new and accessible only in business and luxury vehicle segments. For this purposes a lot of mobile applications that providing advanced safety features are developing. The most interested mobile applications are presented in Table 2 and described below.

CarSafe [16] is a driver safety application for Android phones that detects and alerts drivers in case of dangerous driving conditions and behavior. It uses computer vision and machine learning algorithms to monitor and detect whether the driver is tired or distracted using the front-facing camera while at the same time tracking road conditions using the rear-facing camera. CarSafe also tries to solve the problem of processing video streams from both the front and rear cameras simultaneously by using a context-aware algorithm.

TABLE I. COMPARISON OF ADAS SOLUTIONS INTEGRATED IN VEHICLES

Technology / Company	LDW	FCW	HBA	CLC	LW	HMW	DD	ID	SLI/TSR	PCW
Mobileye	+	+	+		+	+			+	+
Movon ADAS	+	+	+			+				
Bosch Mobility Solutions	+		+	+			+		+	+
Hella	+			+		+				
TRW Automotive	+	+		+	+					
Valeo	+			+						
AISIN	+	+					+	+		
Freescale	+	+	+	+						
Autoliv	+	+	+	+						
Continental AG	+		+	+					+	
Delphi Automotive	+	+	+	+		+			+	+
Denso	+	+	+	+		+	+	+		+
Renesas	+	+	+	+		+	+	+	+	+
Texas Instruments	+	+	+	+		+			+	+
Wabco	+	+	+			+			+	
Gentex	+	+	+	+					+	+
Harman	+	+		+						
Magna	+	+								
Takata	+									
Ficosa	+	+		+						
ADASENS	+	+	+	+					+	
Hyundai MOBIS	+				+	+				
Panasonic Corporation			+							

This application has two main disadvantages. The first one is a lack of emotions, gestures and speech recognition. The second one is that it is not available for downloading in any application store (it has been developing for prototyping an approach).

The iOnRoad [17] is an Android- and iOS-based application that provides a range of personal driving assistance functions including augmented driving, collision warning and “black-box” like video recording. The application uses the GPS sensor, gyroscope, and video camera stream of the native mobile device for monitoring the vehicle position on the road. Application makes alerts for drivers with audio and visual cues in case of dangerous situations. The main weakness of this application is that it does not use front-facing camera for tracking driver behavior.

DriveSafe [18] is a driver safety application for iPhone-based devices that detects inattentive driving behaviors and gives corresponding feedback to drivers, scoring their driving and alerting them in case their behaviors are unsafe. It uses computer vision and pattern recognition techniques on the iPhone to assess whether the driver is drowsy or distracted using the rear-camera, the microphone, the inertial sensors and the GPS.

WalkSafe [19] is an Android-based application that aids people that walk and talk, improving the safety of pedestrian mobile phone users. WalkSafe uses the back camera of the mobile phone to detect vehicles approaching the user. It makes alerts for the user of a potentially unsafe situation. The application uses machine-learning algorithms implemented on the mobile phone to detect the front views and back views of moving vehicles. WalkSafe alerts the user of unsafe conditions using mobile phone sound and vibration.

Augmented Driving [20] is an iPhone-based application that uses the phone's built-in camera to view the road ahead. It detects the road obstacles, warning the driver of any potential hazards with voice notifications. This program provides a rather wide range of driving assistance features including vehicle headway, lane departure warning, speeding avoidance, video recording, and sound & voice output.

Driver Guard application [21] is an Android-based ADAS application that avoids accidents. It uses smartphone’s camera to monitor the scene in front of the driver, detect preceding cars, estimates the distance to all preceding cars and fires an alarm when driver approaches any car dangerously. This application also shows the driver’s current speed using GPS sensor and distance to the nearest car in front of the driver.

One more ADAS application is a MOVON FCW [4] that provides an Android-based implementation. It includes safety features such as forward collision warning, lane departure warning and camera capture.

One major disadvantage of the considered applications is that they are taking into account only watching by video camera conditions on the road. The research projects CarSafe, Augmented Driving, and iOnRoad is distinguished as they provide more significant safety features for drivers that other mobile applications mentioned above.

TABLE II. COMPARISON OF MOBILE APPLICATIONS FOR DRIVER ASSISTANCE

Technology / Application	iOS	Android	LDW	FCW	CLC	LW	HMW	DD	ID	SLI/TSR	PCW
iOnRoad	+	+	+	+	+	+	+				
CarSafe (no implementation)	–	–	+	+	+	+	+				
DriveSafe	+	–	+		+			+		+	+
AXA Driver AS	+	+	+		+		+				
WalkSafe	–	+	+	+	+	+					
MOVON FCW	–	+	+		+						
Augmented Driving	+	–	+	+				+	+		
Ldws hud	–	+	+	+	+						

III. CONCLUSION

The state-of-the-art analysis presented in this paper shows that there are two major types of ADAS solutions available. They are solutions integrated in the vehicles and applications for mobile phones aimed at early detection and alert of dangerous driving events. By integrating powerful sensors into top-end cars (e.g., cameras, radar and ultrasonic sensors), manufacturers are bringing similar forms of driver behavior monitoring to the consumer market. These systems (like [21], [23]) warn the driver using acoustic (e.g., playing a voice recording [23]), tactile (e.g., seat and steering wheel vibration) and visual (e.g., a blinking coffee-cup icon on the dashboard [21]) alerts when dangerous driving conditions are detected. In recent years, the prices of safety technologies have fallen but at the moment these technologies are still not available in entry-level vehicles. In contrast, mobile phone-based solutions can be used in all cars (new or old) and represent a cheap and disruptive technology.

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