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4 authors:

Adam Ziębiński
Silesian University of Technology

Rafał Cupek
Silesian University of Technology

Damian Grzechca
Silesian University of Technology

Lukas Chruszczyk
Silesian University of Technology

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Review of Advanced Driver Assistance Systems (ADAS)

Adam Ziebinski[a], Rafal Cupek[a], Damian Grzechca[b], Lukas Chruszczyk[b]

[a]*Institute of Informatics, Silesian University of Technology, Akademicka 16, 44-100 Gliwice, Poland*
[b]*Institute of Electronics, Silesian University of Technology, Akademicka 16, 44-100 Gliwice, Poland*

Abstract: New cars can be equipped with many advanced safety solutions. Airbags, seatbelts and all of the essential passive safety parts are standard equipment. Now cars are often equipped with new advanced active safety systems that can prevent accidents. The functions of the Advanced Driver Assistance Systems are still growing. A review of the most popular available technologies used in ADAS and descriptions of their application areas are discussed in this paper.
Keywords: ADAS, automotive safety systems, radar and vision sensing, data fusion.

INTRODUCTION

The number of road traffic accidents is one of the major societal problems in the world today. According to estimated data from the WHO, 1.2 million people are killed and as many as 50 million are injured each year [1]. In Germany over 200 000 accidents at speeds of up to 30km/h occur every year within built-up areas. The German Association of Insurances reported that approximately 50% of rear-end collisions occur without any braking and 70% with insufficient brake intensity. Many of these accidents could be avoided if the automatic systems were used to help humans when braking. Advanced Drive Assistance Systems (ADAS) cannot completely prevent accidents, but it could better protect us from some of the human factors and human error is the cause of most traffic accidents. To counteract traffic accidents, we could change human behavior, adopt vehicle-related measures and a physical road infrastructure related measures. Another approach is to transition from a passive safety measures to the active safety measures. Passive safety measures include airbags, the structure of car body, seatbelts and head restraints. Active safety measures include electronic stability control (ESC), anti-lock braking systems (ABS) and other Advanced Driver Assistance Systems like intersection collision avoidance (ICA) and line keeping assistant (LKA). Now, in order to avoid accidents, we can use ICT (Information and Communication Technology) based ADAS applications, which continuously assist drivers with their driving tasks. The paper delivers an overview of chosen and the most popular components and technologies for intelligent transportation systems. This analysis does not cover whole range of possible options but shows selected representative examples of given technologies.

CURRENT ADAS SOLUTIONS

Accident reduction systems become crucial for automotive companies because consumers put much more attention on safety. In order to prevent traffic accidents, a roadmap for fully autonomous driving has been created. The development of driver assistance systems began with Anti-lock Braking System (ABS) introduced into a serial production in the late 70s of the twentieth century. A roadmap concept consists of the following sensors:

- proprioceptive sensors - able to detect and respond to danger situation by analyzing the behavior of the vehicle;
- exteroceptive sensors – (e.g. ultrasonic, radar, lidar, infrared and vision sensors) able to respond on an earlier stage and to predict possible dangers;

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- sensor networks - application of multisensory platforms and traffic sensor networks.

ADAS provides additional information from the car surrounding environment to support a driver and assist in implementing critical actions. The synchronization of a driver's actions and the information from the environment is essential for the efficient performance of the various applications of ADAS [2]. In the Adaptive Cruise Control system (ACC), three radar sensors are usually needed because two short range radars are used to detect objects in the adjacent lane and one long range radar is used to detect objects in-path . As Driver Assistant Systems (DAS) and Active Safety Vehicles (ASV) with various functions become popular, it is not uncommon for multiple systems to be installed on a vehicle. If each function uses its own sensors and processing unit, it will make installation difficult and raise the cost of the vehicle. As a countermeasure, research integrating multiple functions into a single system has been pursued and is expected to make installation easier, decrease power consumption and vehicle pricing [3]. Road boundaries can give useful information for evaluating safe vehicle paths in intelligent vehicles. Much previous research has studied road boundary detection, using different types of sensors such as vision, radar, and lidar. Lidar sensors, in particular, show advantages for road boundary extraction including high resolution and wide field of view. However, none of the previous studies examined the problem of detecting road boundaries when roads could be either structured or unstructured [4]. Current market trends are integration of LKS and ACC (Adaptive Cruise Control), referred to as the LKS+ACC system. The overall structure of lane detection is the same as the conventional method using monocular vision: EDF (Edge Distribution Function)-based initialization, sub-ROI (Region Of Interest) for left/right and distance-based layers, steerable filter-based feature extraction, and model fitting in each sub-ROI. Results indicate that such a simple adaptive ROI can overcome occlusion of lane markings and disturbance of neighboring vehicles [5]. They exploit the removed perspective domain given by inverse perspective mapping (IPM) to define a fast and efficient likelihood model. Additionally, the Markov Random Fields (MRF) allow treatment of dependencies between the motions of targets, next to state-of-the-art methods for vehicle tracking, i.e., independent target tracking with Kalman filtering (KF) and joint tracking with particle filtering [6]. Another image-based approach is based on a stereo-vision camera system. Position, orientation, and full motion state, including velocity, acceleration, and yaw rate of a detected vehicle, are estimated from a tracked rigid 3-D point cloud. This point cloud represents a 3-D object model and is computed by analyzing image sequences in both space and time, i.e., by fusion of stereo vision and tracked image features [7], [8]. Starting from an automated initial vehicle hypothesis, tracking is performed by means of an extended Kalman filter. The filter combines the knowledge about the movement of the rigid point cloud's points in the world with the dynamic model of a vehicle. Radar information is used to improve the image-based object detection at far distances. The proposed system is applied to predict the driving path of other traffic participants and currently runs at 25Hz (640x480 resolution images). Lane recognition is important ADAS component needed for a variety of driver assistance systems. For example Lane Departure Warning (LDW) and Lane Keeping rely on information provided by a lane estimation algorithm. One important step of the lane estimation procedure is the extraction of measurements or detections which can be used to estimate the shape of the road or lane. These detections are generated by white lane markers or the road border itself. Lane estimation has for many years been under heavy development using a gray scale camera. Passive camera based systems can be degraded on its performance under certain circumstances, e.g. at dynamic changes of ambient brightness. Cooperative Intersection Collision Avoidance Systems (CICAS) detects information via vehicle-based sensors, which can be combined to produce better real-time knowledge of the dynamic “state map” of an intersection. That information can be calculated by the intelligence system in each car and can alert a driver about impending hazards. Traffic Sign Recognition is a display on the instrument panel that reminds drivers of the current speed limit. This is achieved through the use of the same camera system that can also recognize speed limit signs. Navigation systems also support this solution by storing information about the speed limit on an unsigned road. The curve warning and Adaptive Cruise Control are examples of ADAS application that use this information. The Adaptive Cruise Control application can determine whether a tracked vehicle is temporarily lost due to an upcoming curve. Once this is done, ACC can now maintain the vehicle's speed and the appropriate following distance. This system follows the flow of the traffic that is ahead of the vehicle even if its forward progress is only stop-and-go, which is useful especially in traffic-jams. The Blind Spot Detection (BSD) helps a driver when he pulls out in order to overtake. Sensors monitor the road area behind and next to the vehicle and warn the driver if he tries to pull out when there is no room. The system is especially useful in heavy traffic on multi-lane freeways or highways as well as in urban traffic. The Rear Cross Traffic Alert (RCTA) can allow accidents when reversing out of a parking space that often involve personal injuries to be avoided. The solution is based on two short-range radar sensors that monitor a 120-degree angle. When the ADAS detects an imminent collision, it will alert the driver by a sound and LEDs will light up in the interior rear-view mirror. ADAS can also automatically brake the vehicle when the alert sounds. This system can be used to reliably calculate the collision trajectory and speed of the crossing vehicle and how far away it is, which allows the ADAS to be improved by this new warning function. Emergency Brake Assist (EBA) ensures optimum braking by detecting critical traffic situations. When EBA detects an impending collision, the braking system is put on emergency standby. Next, the driver is alerted and a slight pre-brake begins in order to save valuable stopping distance. The city version of EBA could prevent many low-speed rear-end collisions. It has been especially optimized for use in urban traffic. Intelligent headlamp control (IHC) provides optimal night vision. The headlamps are set to provide optimum lighting via a continuous change of the high and low beams of the lights. Another important parameter is a data acquisition and processing rate. It has been assumed that driving with 90 km/h speed, spacial resolution of detection is not greater than 1m. Therefore radar, visual or IR camera must read and process at least 25fps. In addition to the above-mentioned many new applications are being developed and optimized continuously to enhance the safety [11] of passengers and pedestrians or animals and also to provide more comfortable and economical driving. Summary of view angles and maximal operational distance for selected sensors is presented in the fig. 1 and tab. 1.

REQUIRED HARDWARE ADD-ONS FOR ADAS

ADAS are required because of the traffic increase and by national and international regulations. ADAS applications may avoid accidents and any concomitant injuries or possible fatalities. ADAS use surrounding sensors such as radar, infrared, video or ultrasound to monitor and analyses a vehicle's environment [12]. Various companies such as Continental, Delphi Automotive, Bosch, Freescale, Texas Instruments and many other suppliers provide different types of ADAS solutions for End-User Applications. The SRL sensor is an infrared laser sensor that work on the principle of the pulse transit time method. The distance to the reflecting object (accuracy: ± 0.1 m ± 10%) can be determined without contact. The SRL sensor uses three independent channels and in addition to the distance also the speed (accuracy: ± 2 km/h ± 10%) of multiple objects is able to determine. A field of view of 27° in horizontal and 11° in vertical direction is reached. The SRL sensor is used for a measurement range of 1 m to 13.5m. In the event that there is too little distance, the driver is warned of a possible collision. In addition, the sensor is used for object detection in areas that are not visible. The SRR-Sensor, which is based on pulse compression modulation. The sensor measures the distances to an object up to 50m, the relative velocity and the angular relationship between two or more objects simultaneously in real-time. Usually, SRR operates in 24GHz (ISM band). The sensor can reach a field of view of up to ±75°. The SSR-Sensor is used for Blind Spot Detection (BSD) and monitors the area behind and next to the vehicle. The function of the BSD is to warn the driver when there are

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objects in the blind spots with a visual or audible signal in order to avoid potential accidents especially during lane change maneuvers in heavy traffic. Another system that the SRR-Sensor is used for is the Lane Change Assist (LCA), which monitors the street lanes and gives the driver a visual or audible warning if he attempts to make a lane change. The SRR-Sensor is also used for the Rear Cross Traffic Alert (RCTA), which is designed to avoid accidents when reversing out of a parking space. The Multi-Function Camera is available in a mono or stereo version. The camera is able to measure the distance to objects in front of the car in a range between 20-30m. Furthermore, the camera can detect whether and where an object is moving. Because of these features, the stereo camera can be used for different advanced driver assistance functions like the Traffic Sign Assist (TSA). The TSA automatically recognizes traffic signs and is therefore able to provide important information such as speed limits to the driver. Furthermore, the ACC and the EBA are other applications of the camera. For this function, the distance to the traffic in front is measured in order to avoid rear-end collisions. In addition, the camera is used for the LDW, which provides the driver with a haptical warning like steering wheel vibrations to change the lanes, for example. The camera is also used for IHC, which optimizes the changes between full-beam and dipped headlights during night-time drives. The system uses integrated Radar and Camera Sensor Fusion System (RACam) is the complete system enables blind spot detection, lane change merge aid and cross traffic alert. Complete RACam system incorporates radar sensing, vision sensing and data fusion in a single module that enables ACC, LDW, forward collision warning, and autonomous braking for pedestrians, vehicles, animals and general objects. RF part of the system uses 76GHz short range radar. One factor of active security system is a human face detection. While impossible to be achieved by radar, it can be easily implemented by visual/IR camera. There can be assumed that average adult face width equals 16cm and there are needed at least 3 horizontal pixels for proper detection (tab. 2). Required numbers of horizontal pixels in scene (thus in the sensor) is 1500 – 1875. Therefore Full HD resolution (1920 x 1080 pixels) is required for the visual camera. The goal of the Infrared (IR) camera is different: human/animal detection by means of particular temperature features. Typically, even in worst case of winter conditions, adult's face open-skin dimension is at least 16cm and a single IR pixel is sufficient to detect it (tab. 2). Calculated FOV is 87.4m and required number of horizontal pixels in scene (thus in the sensor) is 546. Therefore 640 x 480 resolution is required for the IR camera. Another important parameter is a camera frame rate. It has been assumed that driving with 90km/h speed, spacial resolution of detection is not greater than 1m. Therefore both visual and IR cameras must process at least 25fps.

CONCLUSIONS

The ADAS from different manufacturers that are described above are slowly becoming standard equipment and are now produced for more expensive vehicles or luxury vehicles. These systems can perform a greater number of functions. Although the use of the ADAS greatly increases road safety, it is important for drivers to learn how it works and is used. In time users will trust these systems. It is more important that ADAS manufacturers anticipate how these systems are used in a number of situations on the road. In addition to testing individual systems, it is increasingly important to prepare tests of all of the systems that operate in parallel. The use of an increasing number of sensors and ADAS additionally enables the implementation of advanced inference systems. It also allows the construction of these systems based on artificial intelligence, which is a step towards automated driving. The progress can be observed through the publications, contests and mass media. However, the details of these solutions are usually kept secret and little information of this type is available.

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