Advanced Driver Assistance Systems

Ravindra B.S and Vijay Kumar K.V
Mistral Solutions Pvt. Ltd., India

Statistics shows that close to 93 percent of the road accidents around the globe are caused due to some form of human error. This includes but is not limited to misjudgment, inexperience, distraction and driver fatigue. With the growing number of urban population and car users, the number of accidents is bound to go only one way and that is upwards.

To counter this, the Automotive Industry is moving towards solutions that can offer active assistance to vehicle drivers so as to minimize human errors and avoid possible accidents. One such solution is the Advanced Driver Assistance System which helps in minimizing these errors by alerting drivers of various conditions that could potentially result in an accident.

In this paper, we examine the Advanced Driver Assistance Systems [ADAS] and its various components/features.

Typically driver assistance systems can be classified into 3 broad-level groups

- Passive systems
- Active systems
- Co-operative systems

While the passive systems viz. airbags, seat belts etc. is aimed at minimizing damage after an accident, active systems aim towards accident prevention.

In Co-operative systems, cars on the road communicate with each other or with central information systems via custom messages and exchange information. This information exchange will alert drivers of the traffic ahead and helps in accident prevention or in optimizing the path to the destination. The indicative list of information shared would be hazardous situations at intersection, accident detection on the path, intimation of construction or repair works blocking roads that can alert drivers to take alternate routes and traffic information construction site and maintenance information, traffic Information among others.

ADAS use-cases are implemented by intelligently processing the information obtained from cameras and/or other sensors. Some of the driver assistance systems have been made mandatory in a few countries and some are expected to be made mandatory in the coming years.

Following are some active driver assistance systems that give feedback and alerts drivers or assist in preventing possible collision/accidents.

- Lane departure warning system
- Traffic sign recognition
- Pedestrian protection system
- Blind spot detection
- Driver drowsiness detection
- Adaptive cruise control (ACC)
- Lane change assistance
- Collision avoidance system (Pre-crash system)
- Intelligent speed adaptation or intelligent speed advice (ISA)
- Night Vision
- Adaptive light control
- Automatic parking
- Vehicular communication systems
- Hill descent control
- In-vehicle navigation system with Traffic Message Channel for providing up-to-date traffic information.
- Electric vehicle warning sounds used in hybrids and plug-in electric vehicles

In the following section, we will explore the leading ADAS systems in detail.

Lane Departure Warning
Lane Departure Warning systems notify drivers when the vehicle begins to move out from the current lane without the indicator turned on. These systems are designed to prevent accidents due to driver inattention and drowsiness.

Image source: http://www.bmw.ca/

Two main types of Lane Departure Warning/Assistance exists –
- Systems which alerts driver when it detects Lane departure

- Systems which takes action after waiting for driver action. This is commonly referred as Lane Keeping Systems (LKS).

Sensors employed for implementing LDW systems include video, laser and infrared sensors. LDW systems depend on proper lane markings to work efficiently. These systems cannot interpret Broken/Faded/Snow-covered lines.

Traffic Sign Recognition (TSR)

TSR systems identify and recognize Traffic signs the drivers are alerted of the signs on road and are prompted to take appropriate action. Some systems even take control of the car based on the recognition. An application of such a system would be to recognize the speed limit from the sign board by analyzing the video input data and adjust the speed of the vehicle accordingly. Future Driver Assistance will involve mounting of one or more front cameras on the Car which will provide the necessary video input to the TSR Module. The TSR module/algorithm can then utilize the information and perform pattern recognition to check for traffic signs in the incoming video stream.

Image source: http://www.safeny.ny.gov

Adaptive Cruise Control

In cars equipped with cruise control system, the speed of the car is controlled by the vehicle. The system takes control of the throttle to maintain the speed set by the driver. Once the driver depresses Brake/Clutch, the throttle control returns to the driver and the control is regained when the pre-set speed is reached.

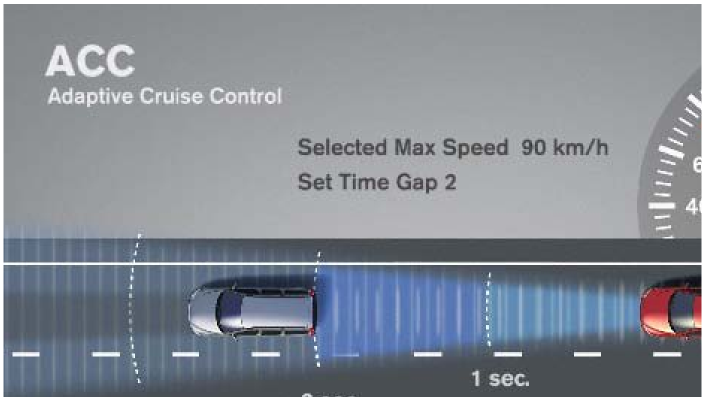


Image source: http://www.driveandstayalive.com

Speed control systems are useful for maintaining steady speeds in highways or in maintaining the legal speed limits on the road. The Adaptive Cruise Control systems use Radar/Laser sensors to allow cars to follow the vehicle moving ahead automatically which includes acceleration/deceleration as required.

Forward Collision Warning

This system uses Radar/Laser/Camera sensors to detect possible collision with the vehicle moving ahead, alerting the driver beforehand.. These systems can also be made to take control of the vehicle to avoid a crash in case of inaction from driver.

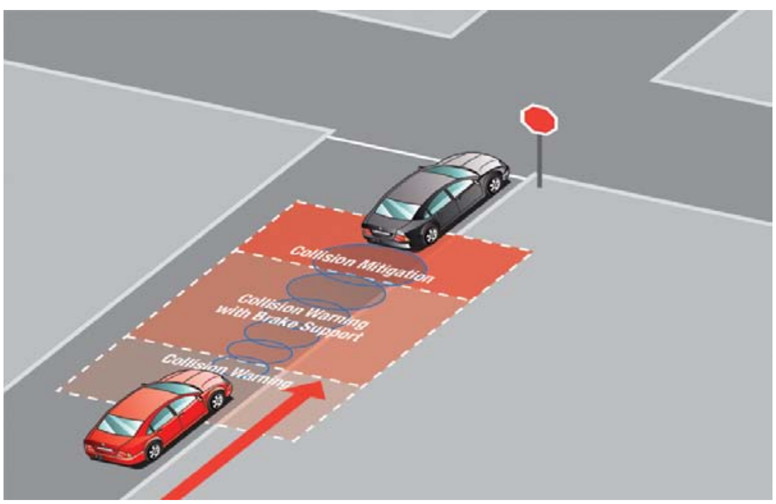


Image source: http://www.tc.gc.ca/

Upon detection of a possible collision, these systems can close the windows, tension the seat belts and proceed to light braking followed by full braking to bring the vehicle to a complete stop.

Pedestrian Detection

As the name suggests, these systems detects pedestrians crossing the road and alerts the driver of the same. The driver then takes necessary action to prevent a collision.

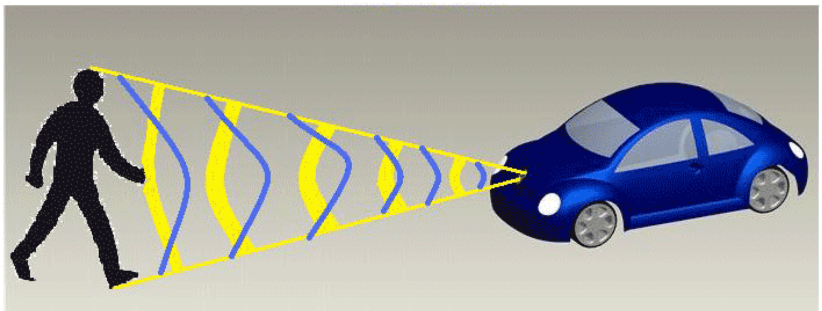


Image source: http://www.cvel.clemson.edu/

In a typical Pedestrian system, training is carried out to get a model of pedestrians and this model is used during detection of a pedestrian in an image frame. Training data is generated from the HOG features/descriptors which are commonly used for pedestrian detection.

Some of the factors affecting pedestrian detection are occlusion between pedestrian and any other kind of objects placed in the sight of the car.

Blind Spot Detection and Cross Traffic Alert

These systems have sensors that detect other vehicles/objects located on the side and rear of the vehicle. Warning is issued as soon as an object at a dangerous distance is detected by the sensors of the system. High tech RADAR system or multi sensing system with read camera can be used as sensor. The warning can be visual, audible or vibrating.

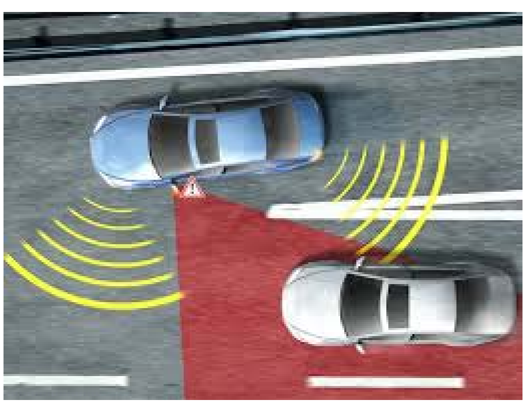


Image source: http://www.bosch-automotivetechnology.com/

The Cross traffic system alerts the driver of incoming traffic when navigating the car out of a parking space.

Driver Drowsiness Detection

Driver fatigue is a serious problem resulting in thousands of road accidents each year. Statistics suggests that around 20% of road accidents are due to driver's fatigue. The Driver Drowsiness Detection Systems detect the driver's fatigue and uses Vibration /Audio/Video signal to alert the driver.

Drowsiness systems can be classified into:

- Systems that analyzes the driving behavior by monitoring speed of vehicle, steering movement, Throttling, braking, Lane change patterns and gear changing.
- Systems which tracks drivers head and eye movements.
- System that collects the physiological data such as heart rate, pulse rate as well as the brain activity.

In each method, the collected/measured metrics is analyzed to conclude that a driver is drowsy.

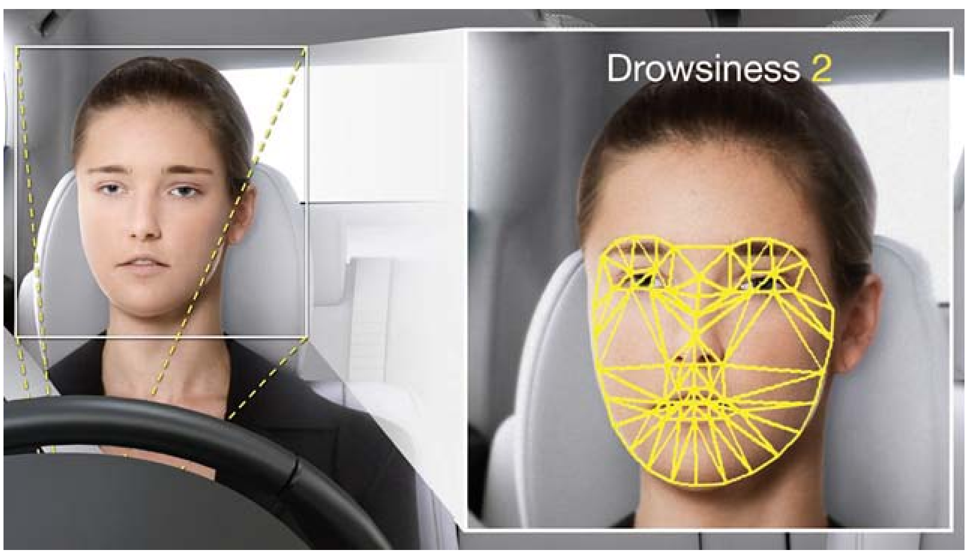


Image source: http://www.autoguide.com/

Adaptive Headlight System

Majority of the road accidents caused on road are at night and can be attributed to poor road visibility at night. This augmented by the fact that the standard headlights shine straight ahead irrespective of the direction of the car. Rather than the road, the sides of the road are illuminated at curves/bends.

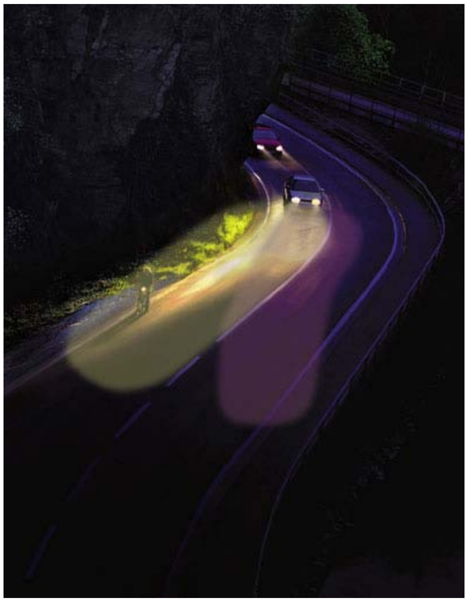


Image source: http://wikicars.org/

The adaptive headlight gets inputs from steering, speed and the elevation of the car and automatically adjusts the region to be illuminated as well as the amount of light needed. . In addition to providing better visibility of the road to the driver, also avoids blinding the drivers coming in the opposite direction.

Hardware and Software Requirements

As explained so-far, there are various features that have to be implemented as part of a complete ADAS system. For the actual realization of these use-cases, specific support in hardware and Support are required.

From the hardware point of view, integration of various sensor interfaces and video input sub-system is required. The sensor interfaces provide feedback to the main-core or dedicated cores for features like Collision Detection/Alert. Video input-sub system interfaces will have to acquire Images at a very high frame rate and then run the Pattern/object recognition algorithms on them. This typically requires interfaces such as LVDS, Serial or Parallel camera interfaces and also dedicated image sub-system modules inside the SoC to run the algorithms on the incoming Video Stream.

From the Software view-point, we first require appropriate firmware/device driver modules to handle the above mentioned hardware blocks. In addition to the firmware/device driver modules, we also require specific libraries related to 2-D Image Processing, Machine Learning, Object/Pattern Recognition and so on.

Given the above scenario, heterogeneous System-on-Chips are the ideal choice for the implementation of ADAS use-cases. Platforms containing Main Core for System Interface and User Interaction and additional/dedicated cores for handling the above mentioned operations will be ideal for realization of an ADAS System. At the same time, these dedicated cores should offer the following flexibility:

- Lesser power consumption when running the Object/Pattern Recognition, 2-D Vector Operations rather than the main Core
- Should perform maximum instructions/parallel execution engines if possible to speed up the processing of the algorithms
- Should have dedicated inter-core communication paths so as to reduce the over-all latency in invocation of the algorithms.

In the following sections, we will explore two such Heterogeneous SoC Platforms which can be utilized for development of ADAS based end products.

TI's TDA Family SOC

TDAx is Texas Instruments new family of SOC's optimized to meet the requirements of the leading driver assistance systems. The SOC integrates next Gen TI C66X DSP cores, Vision Acceleration Pac, ARM Cortex A15 core, IVA-HD core and Dual Cortex M4 cores. This SOC offers a mix of performance, low power and vision analytics processing for building the driver assistance systems.

Some of the key features/modules/components are -

- Video accelerators for decoding multiple video streams over Ethernet AVB network
- Graphics accelerator for rendering virtual views to enable 3D viewing experience
- Integration of peripherals such as multi-camera interfaces (parallel, serial), display, CAN, GigB Ethernet AVB
- Innovative Embedded Vision Engines (EVE's) which are part of Vision AccelerationPAC, offloads the vision analytics functionality from the main application processor
- Supports Front Camera, Park Assist and Radar Sensor Fusion technologies
- For Radar Sensor Fusion, capability to support Radar on dual ARM Cortex A15 and vision analytics on Vision AcclerationPac
- Supports 3 video input ports, each with two 16 bit sub-ports, provide 4-6 camera inputs needed for LVDS based surround view application

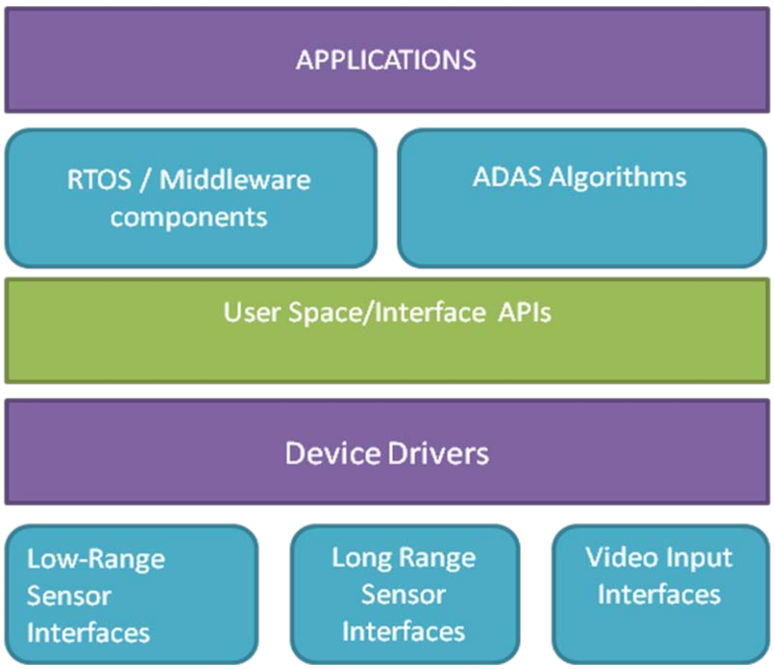
NVIDIA Tegra

The Tegra SOC integrates numerous specialized processors, including an energy efficient multi core ARM CPU, a powerful GPU and dedicated audio, video and image processors.

The newest Tegra processors support NVIDIA CUDA parallel processing architecture, brining super computing horse power into the car. For realizing Advanced Driver Assistance systems, rear-facing, side-facing and surround cameras can be processed in real time. Tegra SOC provides crystal clear video from car-mounted cameras which increases glancing ability.

ADAS Software Architecture

The Figure below shows typical ADAS software components.



At the lowest level, we will have all the Hardware Interfaces/blocks which are used to collect the data from the car surrounding. This includes short-range and long-range sensor interfaces. We will also require video input Interfaces to collect the video profile/data/view in front of the car and at the tail-end and rear of the car as well. In order to initialize and operate these hardware interfaces efficiently, we will require a Device Driver Layer which will be designed and developed in accordance with the RTOS environment used for the ADAS Product. Device drivers provide the hardware abstraction for the underlying Hardware/SOC while the Middleware components provide the higher level services above the drivers.

The core of ADAS is the layer which implements the vision algorithms. The building blocks work with other layers in the system in realizing the use-case. RTOS provides the necessary OS services for realizing real-time requirements. Majority of RTOS used in

ADAS are proprietary, while there are few available commercially and certified for safety critical applications (GHS, QNX, WIND-RIVER).

Summary: ADAS is a growing market and it will certainly change the way we drive in the coming years. There are a couple of Car OEMs/ODMs who are already providing initial solutions based on ADAS in existing or upcoming Car Models in the US and the Europe.

About Mistral:

Mistral has extensive experience in designing IVI and Radio Unit Software components and has worked with several Car OEMs/ODMs in building products for Car IVI and Radio Unit modules.

Mistral is a technology design and systems engineering company providing end-to-end solutions for product design and application deployment. Mistral is focused in two business domains: Product Engineering Services and Defense & Homeland Security. Mistral provides total solutions for a given requirement, which may include hardware design, embedded software development, systems integration and customized turnkey solutions. Mistral's strategic partnerships with leading technology companies help provide customers with a comprehensive package of end-to-end solutions.

Mistral's Product Engineering Services are delivered through a proven development process, designed for embedded product development. Mistral's hardware and software team works together in a seamless manner providing expert product designs covering board and FPGA Designs, BSP and Firmware developments, Embedded Application developments, integration of 3rd party solutions, testing & validation, product prototyping, production coordination and product sustenance services.