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Autonomous Driving – A Bird's Eye View

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How it all started?

Over decades, assisted and autonomous driving has been envisioned as the future of automotive vehicles. Since the very beginning, mitigating the number of road accidents that involve human error has been the driving force behind its development. To achieve this objective, the automotive industry[1] has pursued investigations and demonstrations at several occasions over test vehicles. Despite these efforts, its maturity in terms of safety has been undermined due to several factors. These include the level of precision in the information perceived by the deployed sensors and the lack of computation power to execute sophisticated camera based detection algorithms at the same time applying sensor fusion techniques on the information perceived from various sensors.

A development platform

In the last years, there has been a tremendous progress in this direction. One reason behind this is the fact that industry has pioneered the art of acquiring precise information by fusing data available from different sensors namely camera, radar, lidar, ultrasonic, Inertial Measuring Unit and Global Positioning System[2]. The fused information is encapsulated in the form of an environmental model perceived by the vehicle, which includes the information concerning free space, lanes, traffic regulation and moving objects. Essentially, the environmental model serves as a platform that allows us to realize different functions for Advanced Driver Assisted System (ADAS) also termed as *system*. Taking this into account, DriveCore Compute is a hardware solution developed by Visteon promising sufficient bandwidth and the computation power to process the information from multiple sensors, applicable for achieving different levels of autonomous driving.

Speaking a common language

Autonomous driving demonstrates a typical scenario of a human-machine interaction under which the driving tasks are shared between the driver and the system. Hence, its development can be misleading unless a common terminology is established within the industry. Thus, leading to the precise definition of the boundary in terms of responsibility shared between the human and the system. The Society of Automation Engineers (SAE) has unfolded this problem by classifying autonomous driving into different levels (0-5) summarized in Table 1.

A perspective from an ADAS function

At this point, it is clear that the vehicle is equipped with different sensors that contribute to the environmental model. Let us understand this from a perspective of an ADAS function. To illustrate this aspect, an Automated Lane Change (ALC) is presented as an example. To execute an ALC, the ALC as a

[1] Includes OEM, Tier 1 and Tier 2 suppliers.
[2] Combined with HD map information.

Table 1: SAE levels for autonomous driving.

SAE Level	**Name**	**Narrative Definition**	**Execution of Steering and Acceleration-Deceleration**	**Monitoring of Driving Environment**	**Fallback Performance of Dynamic Task**	**System Capability (Driving Modes)**	**ADAS Functions**
Human driver monitors the driving environment							
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a	–
1	Driver Assistance	the *driving node*-specific execution by a driver assistance system of either steering or acceleration-deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes	Lane Keeping Assist, Blind Spot Monitoring
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration-deceleration using information about driving environment and with the expectation that the *human driver* perform all the remaining aspects of *dynamic driving task*	System	Human driver	Human driver	Some driving modes	Adaptive Cruise Control, Lane Centering Control, Automated Lane Change
Automated driving system ("system") monitors the driving environment							
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	System	Human driver	Some driving modes	Highway Co-pilot, Traffic Jam Co-pilot, Valet Parking
4	High Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	System	Some driving modes	Highway Pilot, Traffic Jam Pilot
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	All driving modes	Intelligent drive

system needs to ensure that there is no moving objects in the blind spot. Not only that, the ALC must evaluate the time to collision for each moving object that may appear in the blind spot while target vehicle is transitioning to the adjacent lane.
From here on, the things get more interesting, the ALC utilizes the environmental model to procure information for moving objects specifically (lateral and longitudinal) position and velocity relative to the target vehicle. Since individual sensors either cannot detect position and velocity or the detection itself is not sufficiently accurate. This is where sensor fusion comes into picture allowing us to improve the accuracy of the perceived information. Table 2 provides a brief overview of the aforementioned discussion.

Edge Case – Closing Speed

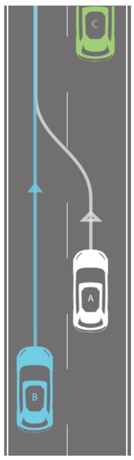
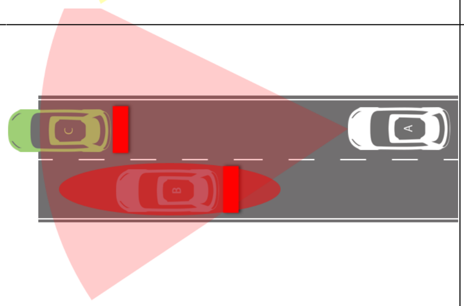
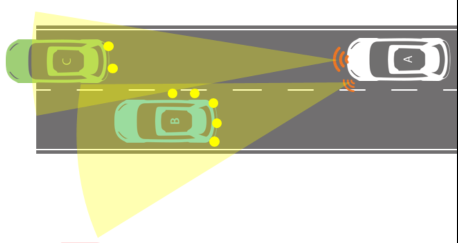
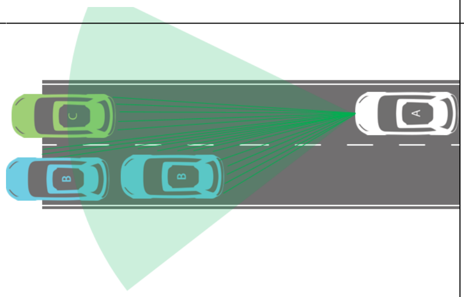
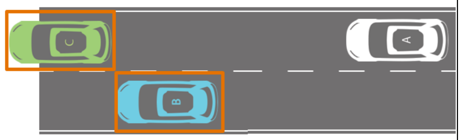


Figure 1: A driver-initiated automated lane change performed by the ego-vehicle (A) with fast approaching vehicle (B) in the adjacent lane.

Every ADAS function consists of numerous situations that are critical from a safety standpoint. One situation concerns the lane change initiated by the driver of the ego-vehicle (vehicle-A) which is most likely to happen when a slow vehicle (vehicle-C) is encountered in the ego-lane. However, whenever lane change is implemented the system must take into account for an approaching vehicle (vehicle-B) that may appear in the adjacent lane as depicted in Figure 1. Next, it becomes essential to quantify so that the situation is handled appropriately. This can be achieved for instance in terms of the closing speed that accounts for the relative speeds between vehicle-A and vehicle-B allowing comfort braking[3] for vehicle-B at the same time maintaining a safe distance from vehicle-A as prescribed by the traffic rules.
The closing speed can be used as a parameter to depict the sensor requirement for instance, Delphi SRR 2 and Continental ASR510 with detection range 75 m and 200 m yield the closing speed of 25.6 Km/h and 97 Km/h, respectively.

[3]As recommended by ISO 22179 standard.

Table 2: Position and velocity accuracy of different sensors and their fusion.

Sensor	Camera 	Radar 	Lidar 	Sensor Fusion 
Longitudinal Position	Inaccurate	Accurate	Accurate	Accurate
Lateral Position	Accurate	Inaccurate	Accurate	Accurate
Velocity	n/a	Accurate	n/a	Accurate

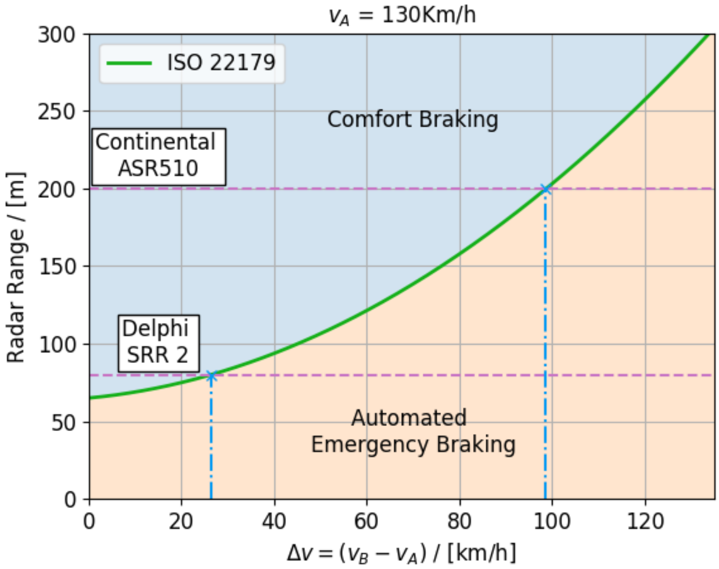


Figure 2: Closing speed (Δv) variations with regard to range depicted by the radar sensor for a certain vehicle-A speed, v_A = 130 Km/h corresponding to different braking profiles – (1) Comfort Braking, (2) Braking as per ISO 22179 standard, (3) Automated Emergency Braking.

Closing Remarks

Being up there in the market for several years now, the autonomous driving – in reference to higher SAE levels – is still an uncharted territory for a large portion of the automotive industry. Having said that, the market trend clearly states that the ADAS is currently and shall persist for the upcoming future, the force driving the automotive industry.