The two main research branches in intelligent vehicles field are Advanced Driver Assistance Systems (ADAS) [1] and autonomous driving [2]. ADAS generally work on predefined environment and limited scenarios such as highway driving, low speed driving, night driving etc. In such situations this systems have sufficiently high performance and the main features that allow their large diffusion and that have enabled commercialization in this years are the low cost, the small size and the easy integration into the vehicle.

Autonomous vehicle, on the other hand, should be ready to work over all-scenarios, all-terrain and all-weather conditions, but nowadays autonomous vehicle are used in protected and structured environments or military applications [3], [4]. Generally many differences between ADAS and autonomous vehicles, both hardware and software features, are related on cost and integration: ADAS are embedded into vehicles and might be low cost; on the other hand usually are not heavy limitations on cost and integration related to autonomous vehicles. Obviously, the main difference is the presence/absence of the driver. Otherwise, most of the undelying ideas are shared, such as perception, planning, actuation needed in this kind of systems.

A. Advanced DAS

The driver assistance systems can be divided in basic and advanced: in basic DAS, such as Antilock Braking System (ABS), Electronic Stability Program (ESP), etc., is possible to remove the driver from the loop because of the low level intervention. Most of these systems are activated without driver authorization in case of emergency.

Advanced DAS (ADAS), on the contrary, like Lane Departure Warning (LDW), Lane Keeping Assistance (LKA), Adaptive Cruise Control (ACC), involve complex sensing and actuation and are generally limited by cost issues, moreover their applicability is limited to specific scenarios and the driver needs to supervise them. Even if the integration of recent ADAS technology might be sufficient to drive a vehicle without human intervention, such as for example an ACC+LKA system, driver supervision is needed since incorrect behaviors are possible; in these cases, if the systems is fault-aware, ADAS switches off and fall back to manual driving warning the driver; otherwise, the driver needs to override the automatic function.

An ADAS can interact both with the vehicle, and with the driver, by short or long term intervention.

In short term intervention the system recovers from a dangerous situation and quickly switches off; in this case the ADAS control is automatically triggered. An example of this possible scenario is a LDW system that corrects or informs the driver of the imminent lane departure. In long term intervention, the main problem occurs when the automation ends: if the driver is not kept in charge of the driving action, frequently triggering his attention, might be distracted and the recovery from an automation to a manual driving can be difficult, leading to a potentially dangerous situation.

B. Cooperative Driving

Different levels of automation are possible between manual driving and fully autonomous vehicle as shown in figure 1.

In high levels the vehicle proposes not only suggestions or corrections, typical behavior of short term automation, but solutions to the driver via various feedbacks. Due to these different interaction levels, even different HMIs have to be employed.
The first step after manual driving consists in assisted driving, where the vehicle only issues suggestions to the driver. Semi automated systems involve only a short intervention on actuators to correct and recover from potentially dangerous situations. In highly automated level the vehicle can make manoeuvres and holds the control even for long time in specific scenarios. The last step is the fully autonomous driving.

The higher is the level of automation the higher is the level of interaction in car-driver relationship. In case of highly automated level for example, the car and driver meet at manouvrering level. An example of this level can be LKA+ACC: the vehicle is able to keep a safe speed and a correct distance to the vehicle ahead, and follows the road. It involves lateral and longitudinal control with full autonomy in a specific and limited scenario, highway environment in this case.

Except for the first level, conflicts are possible and an arbitration is needed to solve these situations. The conflicts can be related to different approach at the same task or to an opposite interpretation of the perception, or even to a misunderstanding, or to a fault. Conflicts may happen at different levels: navigation level, manœuvre level, or control level.

In the semi automated level conflicts between driver and vehicle are at a low level, the control level. In this case conflicts can be solved giving the driver the possibility to override the vehicle.

In the highly automated level conflicts can happen at manœuvre level. At this level it is not possible to distinguish between unsafe driver or vehicle fault, the conflict can thus be solved only at different intervention levels: the vehicle will never follow behavior that are considered unsafe, while the driver can override the system at a lower level (control level). Different HMIs are thus mandatory for this conflict solving implementation.

Finally in the fully automated level conflicts can occur at navigation level and the resolution strategy is analogous to the previous one.

In conclusion, for ground vehicle, conflicts are solved in different ways depending on the level of occurrence.

II. BRAiVE: A TESTBED VEHICLE

VisLab is undertaking highly innovative research within its ERC-founded European project, whose topic is the development of an open standard for the perception and decision subsystems of intelligent vehicles. The subject, gathering the attention of car industries all over the world, was first outlined in 2006 by the German Research Foundation under the name of “Cognitive Automobiles”. Currently, many commercial vehicles include sophisticated control devices like ABS, ESP, and others. These control equipments have been independently developed by car manufacturers and suppliers. Generally, they also act independently, and are singularly tuned. Nevertheless, new methods to improve overall performance are currently under development, exploiting communication and cooperation of these devices: the recently introduced Unified Chassis Control (UCC) is an example. The deployment of the UCC in the mass market, requires to adapt and rethink all control subsystems to provide communication, data fusion, and an overall tuning: namely to integrate all of them together. From the car manufacturers and suppliers point of view, the introduction of the UCC requires the redesign of each single block (ABS, ESP, ...) meaning an additional financial effort, besides the obvious delay in reaching the market. Had a complete UCC architecture been
4 cameras are used to recognize obstacles, vehicles, pedestrians, and traffic signs. Autonomous driving is actuated by sending commands to the X-by-wire system.

16 laser beams are used to localize the vehicle in front during the autonomous queue driving. 1 multiplane laserscanner detect vehicles in front even with heavy rain or fog.

1 single plane laserscanner detect vehicles and obstacles in the back. 2 single-plane laserscanners localize approaching vehicles and obstacles.

Lateral vision for parking aid and merging crossing traffic. 1 camera in each rearview mirror detects vehicles in the blind spot.

2 back cameras help during parking manoeuvres. 2 cameras on lateral mirrors for rear view sensing, and a camera stereo pair placed above the licence plate for back sensing. BRAiVE mounts also 3 single plane laserscanners, 2 frontal installed in the front bumper edges and 1 looking back mounted in central position. A multiplane laserscanner and a LIDAR device with 16 laser beams are installed in frontal position.

A DGPS and IMU provide to BRAiVE position and inertial measurements. The BRAiVE's control system is implemented via CAN messages, the drive-by-wire system control gas, brake and steering.

The HMI suite can be configured in 3 different setup: a development setting composed by a touchscreen monitor, a keyboard and a touchpad installed inside the vehicle passenger armrest, to ease the development and debug of the

Fig. 2. The VisLab’s testbed vehicle BRAiVE.

defined well in advance with respect to the development of each single block, its implementation would have been straightforward, less costly, and would have reached the market earlier. Perception and decision modules are in an earlier development stage than control ones: the advanced driver assistance systems that are currently available on the market are only basic ones (Lane Departure Warning, Blind Spot Monitoring, Automatic Cruise Control, Collision Mitigation), independently developed by different car manufacturers and suppliers. The state of the art of advanced driver assistance systems, in fact, has not yet defined a complete architecture that would allow fusion of all these basic blocks and benefit from their integration. The availability of such architecture would allow to define a standard module interface so that the following research efforts could be more focused in providing modular systems, already engineered to fit into this architecture.

To develop these new concepts VisLab has equipped a new testbed vehicle called BRAiVE, short for brain drive. The aim of this vehicle is to be a demonstrator for ADAS and autonomous driving as well as a laboratory vehicle. The specifications for this task are very different, ADAS are related to low cost and small sensors with a deep integration and specific HMI's while autonomous driving involves redundant sensing, 360° sensor coverage and an appropriate actuation systems, in this case cost and integration are less important.

BRAiVE, as shown in figure 2 features a all-round vision coverage thanks to 4 frontal cameras (2 NIR graylevel, 2 color), 2 lateral cameras for lateral sensing, 2 cameras on lateral mirrors for rear view sensing, and a camera stereo pair placed above the licence plate for back sensing. BRAiVE mounts also 3 single plane laserscanners, 2 frontal installed in the front bumper edges and 1 looking back mounted in central position. A multiplane laserscanner and a LIDAR device with 16 laser beams are installed in frontal position.

A DGPS and IMU provide to BRAiVE position and inertial measurements.

The BRAiVE's control system is implemented via CAN messages, the drive-by-wire system control gas, brake and steering.

The HMI suite can be configured in 3 different setup: a development setting composed by a touchscreen monitor, a keyboard and a touchpad installed inside the vehicle passenger armrest, to ease the development and debug of the
application. A testing configuration to deeply test the functionalities that are in a final stage, composed by a small touchscreen monitor and a reconfigurable 3-button keyboard to switch on and off the functionalities. Finally a demo configuration used to demonstrate BRAiVE capabilities with two monitor for the passenger seated in the back.

The processing system is composed by 4 PC placed inside the trunk.

The current BRAiVE capabilities belongs to VisLab previous experiences with ADAS and autonomous vehicles. All the functionalities developed are or will be ported on BRAiVE hardware. Lane departure warning, adaptive cruise control, lane keeping assistant, vehicle detection, obstacle and lane detection [5], parking slot detection, pedestrian detection, high beam assistant, medium and short range obstacle detector [6], blind spot monitor and traffic sign recognition [7] are only some of the vehicle capabilities.

In conclusion a higher level of automation is going to be investigated in the next future, this automation level is related to ADAS system that will be implemented, and this will lead to the realization of a completely autonomous vehicle. Specific installation are needed to test different level of interaction between car and driver and cooperative driving and this is one of the main goal of this testbed vehicle.

REFERENCES


