Driverless vehicles, artificial and human "intelligences": Which interactions?

Antoine Lafay,
director of research and innovation on autonomous vehicles, Valeo,
&
Guillaume Devauchelle,
vice-president Innovation and Scientific Development, Valeo

Abstract:
The complex relation between people and driving extends beyond the mere use of a technological object. The introduction of artificial intelligence opens unprecedented perspectives and raises, again, questions about the understanding and acceptability of a new technology. The gradual rollout of driverless vehicles is described along with the current state-of-the-art techniques being implemented; the prospects for this trend are analyzed; and the issues to be addressed, pointed out. The challenges are, of course, technological; but it will also be necessary to reinvent a new mobility. How will the time be used that is now perceived to be wasted on the uninteresting task of driving in current traffic conditions?

Let us face it: it is not easy to accept to be driven by someone else. So, what about being driven by a computer? "Driverless" or "autonomous" cars have aroused much enthusiasm and as much inconsistency. This lively debate has encompassed topics as varied as technological feasability, ethics, the law, acceptability, and the impact in urban areas, on infrastructures and on energy… not to mention all the topics that have slipped my mind. The reason for these reactions hinges on the key place of "mobility" in our lives, which are always "on the move". We have all experienced, each in his/her own way but intensely so, the loss of this mobility during the COVID-19 pandemic. For transportation by car however, the why and what of a trip cannot be grappled without coming to grips with the how, namely: the action of driving. Let us steer away from the importance of mobility with its many systemic dimensions and focus on driving itself.[1]

Engineers are rationally attracted to the idea of a vehicle that can make extremely complicated decisions in real time and might potentially save lives. However the imagination, subjectivity, pleasure of driving, fascination with speed, style, and relation to vehicles… all this reaches far beyond mere rationality.

A "robocar" is not something new. According to the highway code, a driver has to exercise control over his/her vehicle. That statement dates from the days of the horse and carriage. A horse was not to come back to the stable alone, since this implied that it could make a decision and follow an itinerary on its own. Driving was shared between a person and an animal, both of whom, following a long learning process, continually interacted.

The mechanization of traction probably gave drivers the impression that they alone controlled the situation once they had learned how the machine reacted — a machine with actions designed to be perfectly predictable. This control was, of course, far from perfect. Over time, more and more features have come in between the driver and the road. We have forgotten this, but those who like vintage cars know what it is like to drive or brake without "assistance" or a synchronized gearbox.

The introduction of electronics approximately thirty years ago altered this setup while sparking reactions. Electronics has its own "logic" — the software that takes the driver's place, especially

[1] This article has been translated from French by Noal Mellott (Omaha Beach, France). All websites were consulted in March 2021.

under extreme conditions. We need but recall the comparisons between braking distances with and without ABS.[2] A champion behind the wheel does better than the first generations of ABS, but not everyone is all the time a driver in top shape. The benefits of ABS are now widely accepted. Current performance has reached the point that the use of electronics has been restricted or forbidden in car races. So, everyone now trusts electronics with driving a vehicle under conditions of maximal risk. Several features now exist, their names acronyms (*e.g.*, ESP and EBA, respectively: electronic stability program for improving traction and emergency brake assistance), and many of them mandatory.

The automobile industry modestly enough presents these applications as advanced driver-assistance systems (ADAS), but the facts are that electronics is now managing the steering and braking of vehicles under critical conditions in the driver's stead. More recently, governors, these devices that regulate the vehicle's speed depending on the situation, sparked similar reactions but are now accepted. No one would describe a vehicle as being autonomous because it has adaptive cruise control (ACC) or a device for centering it in a lane of traffic. Beyond any doubt, such a vehicle, had it existed twenty years ago, would have been called "autonomous". So, when talking about "autonomous vehicles", we must precisely state what is meant.

The rollout of autonomous vehicles

We are observing a massive, rapid rollout of systems of driver-assistance in ordinary vehicles and, at the same time, the development of a few driverless vehicles.

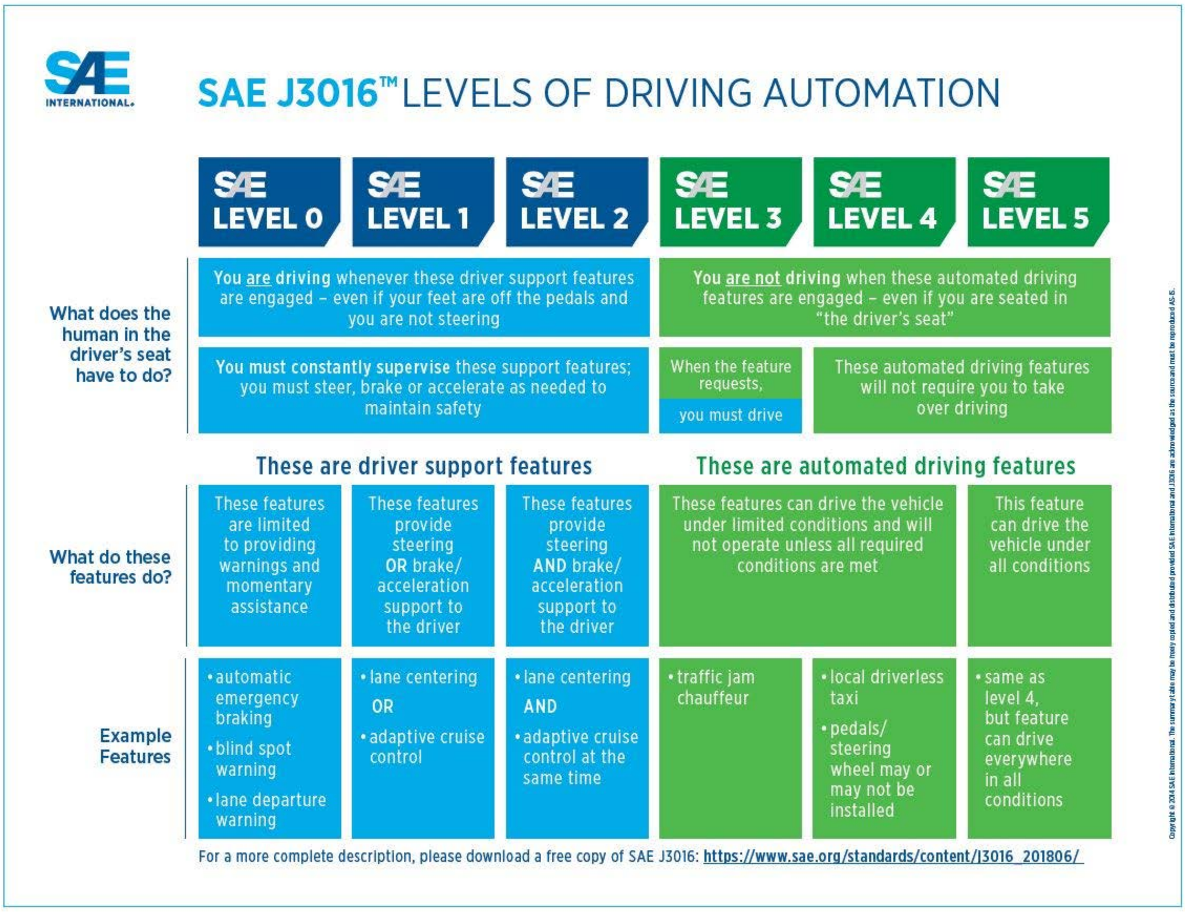

Figure 1: Levels of driving automation

Source: https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic

[2] ABS (anti-lock braking system, from the German *antiblockiersystem*) for keeping the wheels from locking during braking, as happens if the brake is not pumped but, instead, held down.

The specifications of SAE International have defined six "*levels of driving automation*" (*cf*. Figure 1). Beyond the zero-level of no automation (except for warning signals), the first two levels cover "*driver support features*". Besides steering or brake acceleration support, vehicles of the first level allow for longitudinal control (lane-centering or adaptive cruise control); and those of the second level, for longitudinal and lateral control (both steering and brake acceleration support and both lane-centering and cruise control). On these two levels, the driver is still in charge, and "*must constantly supervise these support features*". The focus is on alerting drivers and making them attentive, since they have but a few seconds to take back control over steering when necessary. The priority at these two levels is to avoid thinking that the system works better than it does. Systems on the second level are not robust enough to guarantee safe driving in all situations.

Starting on level 3, we can talk about "autonomous vehicles", since the installed system takes over steering and replaces the driver, who may temporarily not pay attention to driving. On level 4, drivers can permanently pay no heed; and on level 5, vehicles will have neither steering wheels nor pedals. Autonomous vehicles at the fourth level will be integrated in fleets linked to an infrastructure and an "operator" in a command center. The phrase "driverless vehicle" is, therefore, improper since these vehicles will depend on a third party. A precise formulation would be "vehicle without an onboard driver". Artificial intelligence (AI) will be embedded both on board the vehicle for local decisions and, too, in the infrastructure.

Levels 1 and 2 have been attained, even for low-end cars. A major step toward the third level has just been made. The United Nations has adopted a regulation authorizing third-level vehicles equipped with an automated lane-keeping system (ALKS). This allows for a rollout (of top-end models at the start) as of 2021 by all major automakers. Fourth-level systems are now undergoing tests (*e.g.*, robotic vehicles for taxis or shuttles, and automated parking systems) in private or public experiments (such as EVRA in France).

Underlying the general concept of an autonomous vehicle are three markets with different approaches:

- The private vehicle market with an incremental approach. Vehicles on this market will have many features: traffic sign recognition, adaptive cruise control, blind spot monitors, emergency braking, lane centering, automatic parking or assisted driving in traffic jams. These features, which will help or even replace the driver for some of the most technical or tedious tasks, should improve safety.
- The public transportation market with a much more direct approach for introducing robotized, driverless taxis and shuttles. Public transit operators and the managers of public transportation fleets will acquire and operate these vehicles. Factors related to costs or to the integration of these vehicles in a fleet will not weigh as heavily. However the criterion of availability will have to be maximized in order to guarantee a public service and recover costs.
- The freight market with an approach combining autonomous driving and supply chain logistics. The first robots for last-mile deliveries have evolved out of the automated guided vehicles (AGVs) now being used in factories and warehouses. They will rely on automobile technology to make deliveries in urban, but their radius of activity will be enlarged as their assignments become more complex.

Artificial intelligence: Analyzing, understanding and interacting with the environment

Vehicles are being equipped with more and more sensors (thermographic cameras, radar, ultrasounds) for detecting events (even beyond human perception) and producing a large volume of data that will have to be processed.

In the usual algorithmic chain (*cf*. Figure 2), bricks are needed for:

- the detection and classification of objects in the environment,
- localization,
- the prediction of movements in the environment,
- planning trajectories, and
- control and monitoring.

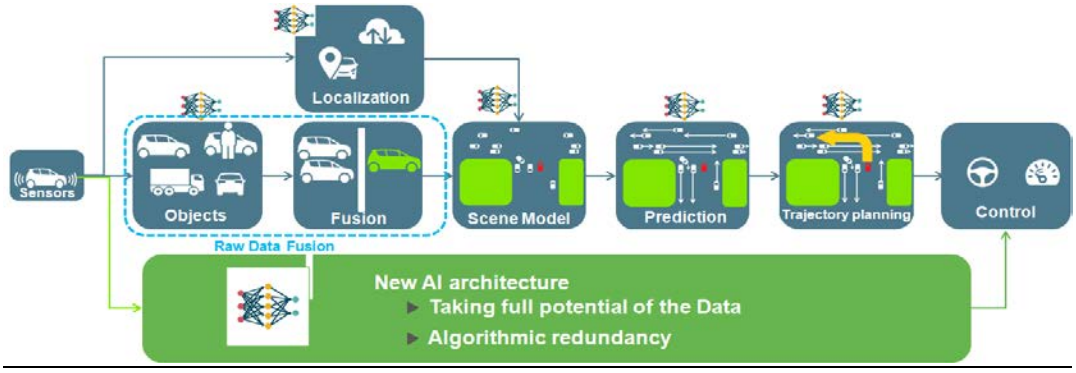

Figure 2: Bricks for the architecture for AI assisted driving

The surge of AI

To solve the mighty challenge of perception and decision-making, AI is being intensely deployed for the automation of motor vehicles. It is proving to be indispensable for improving performance and finding solutions to problems that had been deemed unsolvable.

In autonomous cars, AI is already being used to handle problems related to “perception”. Detection algorithms based on deep learning have been significantly improved. The graph (*cf*. Figure 3) illustrates the trend in visual recognition error rates in the classification of images. As we see, the introduction of neural network software has increased the results of classificatory operations to a level above that of human beings. This type of algorithm is being used in cameras on board mass-produced vehicles and on (lidar, radar or sonar) sensors. The second step will be to apply deep learning to the other bricks (data processing, prediction, planning and monitoring).

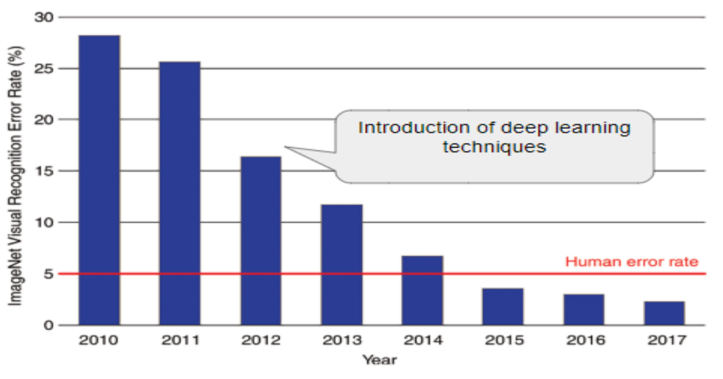

Figure 3: The decline from 2010 to 2017 in visual recognition error rates of images from the Imagenet data set.

Meanwhile, new forms of architecture are arising thanks to neural network technology. During the Consumer Electronics Show in 2018, Valeo demonstrated an "end-to-end" architecture, which consisted of directly using big data to generate final commands. For example, one neural network directly predicted lateral control from an image; and another, longitudinal control. This process is like human reflexes, which have evolved from the reptilian brain.

Four challenges

Although AI offers incredible opportunities for developing new features, many a problem still has to be addressed in order to reap the full benefits. Let us look at four challenges yet to be taken up:

- DEEP-LEARNING ALGORITHMS.[3] Deep learning is a recent, fast evolving field of science with a very rapid transfer of knowledge from research to industry. The link between research and industry is essential. A major advantage of deep learning is its ability to adapt the principles and architecture from one application to another. Unlike conventional algorithms, which require specific developments for each application, deep-learning algorithms can be transferred from application to application. Even though use cases are not exactly the same between the automobile industry and aviation, many of the principles and algorithms of the one can be shared with the other. Adaptation results from the data sets used to train the algorithms.
- DATA. The fuel for the learning algorithms is big data. To train and validate algorithms, it is necessary to have a large volume of data representative of all cases under study. Millions of kilometers are scoured to collect these data, but the data collected amount to nothing if they are not annotated. Besides an environment propitious to data collection, a method has to be devised for selecting and annotating hundreds of thousands of images containing relevant information. For this, the automobile industry has a major advantage: its ability to roll out systems on a large scale and regularly recuperate data from them (as PSA, Renault and Valeo do in the Moove Program). To increase the quantity of data, synthetic data are used. Simulators of multiphysical environments generate a wide range of scenarios, in particular for testing limit conditions — the rare, extreme or dangerous cases for which it is hard to obtain data from real-life situations.
- COMPUTING POWER. The exploding production of data requires, at the R&D level, working out solutions for a "data lake" and installing computers for processing all relevant data and, therefore, training machines to learn neural network models. Furthermore, the data for autonomous systems have to be processed in real time. As a consequence, algorithms for optimization are necessary, as are hardware improvements for boosting computing power, saving energy and handling the conditions for embedded objects. Dozens of calculators coming from different suppliers now share control over various features in a vehicle. The architecture is evolving toward much more powerful "domain controllers" for managing various features.
- EXPLICABILITY AND VALIDATION. Besides their performance, it is necessary to demonstrate that algorithms are robust and reliable in use. Deep learning alone does not suffice. New architectures are being developed (such as MobilEye's RSS: Responsibility-Sensitive Safety). Deep learning algorithms and conventional "deterministic" algorithms should be used redundantly, with points for crossing them and making predictions so as to explain the decisions that result. In France, this is the theme of Julien Chiaroni's challenge "*security, reliability and certification of systems that use artificial intelligence: AI with confidence*".[4] Cybersecurity is obviously part of this theme.

[3] To take up this challenge, PSA, Safran and Valeo have supported the chair "Automated driving, Drive for All" in the Robotics Laboratory of École des Mines.

[4] https://www.gouvernement.fr/grand-defi-securiser-certifier-et-fiabiliser-les-systemes-fondes-sur-l-intelligence-artificielle

Prospects

AI's scope of application is vast, ranging from perception to collective intelligence. It involves interactions between human and artificial intelligence at all levels. For perception (the five human senses) and detection, relevant information can best be obtained by combining and merging data sets. Sensors and cameras enable us to see farther and better, and have a much stabler view than the human eye. Other devices, using infrared, help us obtain a better perception of the environment in difficult circumstances, such as driving at night or in fog. Does this mean that we can let the "instruments" drive us, as in aviation? That is not the intention!

Essential elements are missing for us to better understand the context, the analyses made and the predictions of trajectories. AI can now predict the intentions of a pedestrian on a sidewalk, but is quite incapable of doing so for a crowd. Nor is it easy for AI to detect an aggressively driven vehicle that should be let to pass even if one has priority. Visual contact is still very important for making difficult decisions. Beyond the immediate environment, we need to better understand the global context. We are now used to receiving information from the radio, GPS and traffic applications. AI will be providing ever more relevant information that we will be unable to do without. 5G will enable a form of remote control over vehicles.

At the level of reflexes, of the reptilian brain, end-to-end AI could be much more reactive while making a "cool", unemotive analysis. Who has not instinctively closed his eyes when a danger looms, thus depriving himself of precious information? AI can now be used to analyze the driver's actual ability to execute tasks properly. Sensors for detecting, for example, alertness or stress are becoming mandatory. We are not always the best judge of our ability to take the wheel. At this point, questions of ethics obviously crop up.

The only limitation on the possibilities offered by the cloud for globally optimizing the transportation of people and of freight and for providing various services is our imagination.

Moving up to a more philosophical level, we cannot reduce the issue to driving alone. In a flow of traffic, it is not enough to spin a "cocoon" around a vehicle and its occupants. The machine must take over certain tasks without making people feel like prisoners or wards. The occupants must not only feel safe but also comfortable and relaxed. "Mobility" has become so important in modern society that the time devoted to it cannot simply be a period in between two other "profitable" periods. It, too, must be profitable. The simplest solution would be to create, in driverless cars, the conditions for a sedentary tranquillity "like at home"; but this would deprive occupants of the pleasure of traveling, of escaping, of the need for new experiences. It is apparently necessary for tasks to be shared, a hybrid activity in which people would retain only what is positive in a trip without the aggravating drawbacks of driving in the modern world. This is an ultimate challenge for AI.

The rising market in advanced driver-assistance systems (ADAS) is laying the conditions for a gradual appropriation of new technology and a massive financing of research on automated driving and AI. This silent revolution is under way.

Let us not forget, however, that "emotion" stems from the old French word *motion* (movement). There is no mobility without emotion — and not just etymologically speaking! Intelligence, whether human or artificial, is not everything.