Current challenges in autonomous driving

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Abstract. Nowadays the automotive industry makes a quantum shift to a future, where the driver will have smaller and smaller role in driving his or her vehicle ending up being totally excluded. In this paper, we have investigated the different levels of driving automatization, the prospective effects of these new technologies on the environment and traffic safety, the importance of regulations and their current state, the moral aspects of introducing these technologies and the possible scenarios of deploying the autonomous vehicles. We have found that the self-driving technologies are facing many challenges: a) They must make decisions faster in very diverse conditions which can include many moral dilemmas as well; b) They have an important potential in reducing the environmental pollution by optimizing their routes, driving styles by communicating with other vehicles, infrastructures and their environment; c) There is a considerable gap between the self-drive technology level and the current regulations; fortunately, this gap shows a continuously decreasing trend; d) In case of many types of imminent accidents management there are many concerns about the ability of making the right decision. Considering that this field has an extraordinary speed of development, our study is up to date at the submission deadline. Self-driving technologies become increasingly sophisticated and technically accessible, and in some cases, they can be deployed for commercial vehicles as well. According to the current stage of research and development, it is still unclear how the self-driving technologies will be able to handle extreme and unexpected events including their moral aspects. Since most of the traffic accidents are caused by human error or omission, it is expected that the emergence of the autonomous technologies will reduce these accidents in their number and gravity, but the very few currently available test results have not been able to scientifically underpin this issue yet. The increasing trend in automation of vehicles will radically change the composition of car industry players, as mechatronics will not only be a complementary part of the automobile industry but an indispensable part of it. There is a reasonable expectation that automated cars will perform the same or better in all respects than their conventional counterparts. However, it seems that the current regulations do not keep up with the development of technology and sometimes hinder the development and testing of autonomous technologies.

1. Introduction

The first section in your paper

Autonomous vehicles are “such vehicles that are able to perceive their environment and to move on without any intervention of a human driver” [3], [10]. These vehicles are also known as driverless, self-driving, unmanned or robotic vehicles [3], [9].

In 2016, the Society of Automotive Engineers (SAE) International revised its terminology for autonomous vehicles originally released in 2014 and defined their levels as a function of their automation grade (figure 1). As the SAE conceived “these levels are descriptive rather than normative and technical rather than legal”. They do not denote any particular order of their market introduction.
Each level is described by a set of minimal capabilities of the vehicle and a certain vehicle can operate at different levels, depending on their activated automation features (Table 1). Autonomous vehicles have to be evaluated taking into account many aspects. Some of them studied in this article are presented in figure 2.

Figure 1. The six levels of automated cars

Figure 2. Main challenges of the automated vehicles

The main objectives of this work are all aimed at pointing out the current stage of autonomous vehicle’s development and identifying the most important challenges in this field.

2. Environmental and traffic safety benefits
New technologies can significantly reduce vehicle emissions by reducing fuel consumption [2]:

- according to the opinion of several experts, by optimizing the acceleration and braking actions of the driverless vehicle the fuel consumption can be drastically reduced, by up to 60%;
- as autonomous vehicles are able to communicate with each other and with their environment, they can be organized into platoons with controlled speed; this may result in a reduction of fuel consumption by 5-20%;
because of the advanced navigation system which uses car to car communication, further reductions in fuel consumption can be obtained by avoiding congestion zones, particularly in crowded urban traffic.

Table 1. Levels of driving automation [1, 3, 4, 9]

| SAE Level | Name                      | Description                                                                 | Control (steering, acceleration, deceleration) | Monitoring of driving environment, evaluation, and decision | Fall-back performance of dynamic driving task | System capability to manage different driving modes |
|-----------|---------------------------|------------------------------------------------------------------------------|-----------------------------------------------|----------------------------------------------------------|--------------------------------------------|--------------------------------------------------|
| 0         | There is not any automation | The human driver performs all driving tasks.                                 |                                               |                                                          |                                            |                                                  |
| 1         | Driver assistance         | The driver assistance system executes steering OR acceleration and braking operations, by using information about the driving environment. The human driver performs all remaining aspects of the dynamic driving task. The vehicle is fully under the driver’s control. |                                               |                                                          |                                            | Limited driving modes                           |
| 2         | Partial automation        | The driver assistance system undertakes both of steering and acceleration/braking operations, with the expectation that the human driver performs all remaining aspects of the dynamic driving task. |                                               |                                                          |                                            | Limited driving modes                           |
| 3         | Conditional automation    | An automated driving system performs all aspects of the dynamic driving task in certain driving modes. The human driver will respond appropriately to a request to intervene. |                                               |                                                          |                                            | Limited driving modes                           |
| 4         | High automation           | An automated driving system performs all aspects of the dynamic driving task in certain driving modes even if the human driver will do not respond appropriately to a request to intervene. |                                               |                                                          |                                            | Limited driving modes                           |
| 5         | Full automation           | An automated driving system performs all aspects of the dynamic driving task in all driving modes. |                                               |                                                          |                                            | Unlimited driving modes                         |
driving modes even if the human driver will do not respond appropriately to a request to intervene.

Human errors cause a significant part of traffic accidents. By excluding the driver as the weakest link, it is expected that the automated vehicles will travel more safely, reducing the number of accidents. However, it is also likely that new technologies will cause new types of accidents, especially in cases when the responsibility of driving is transferred from the human driver to the vehicle or vice versa. Further risks may appear because of the presence of conventional vehicles and driverless cars on the roads or because of the incompatibilities between the different autonomous technologies [8].

3. Legal Aspects of Autonomous Driving

In the pursuit to accomplish the fully automated driving, several technical issues have to be solved and the automotive industry seems to be up to this task [11].

As all revolutionary innovations, the technical developments in driverless vehicles are more advanced than the regulatory processes. Worldwide, the regulations regarding all aspects of the road traffic have as the main objective to provide the best road safety, so the autonomous cars must prove that they are safer or at least as safe as their predecessors. Consequently, the legal challenges are among the most critical issues, including the public policies, traffic code, technical standards, and tort law [11].

For example, steer-by-wire technologies have been available for a long time, but could not be integrated into the vehicles because the Convention on Road Traffic signed in Vienna in 1968 [7] stated that, in order to determine the path of the vehicle the steering system should contain a mechanical constraint between the steering wheel and the wheels.

This provision was only revised in 2005 when "Advancing technology, coupled with the wish to improve occupant safety by elimination of the mechanical steering column, and the production advantages associated with easier transfer of the steering control between left- and right-hand drive vehicles, has led to a review of the traditional approach and the Regulation is now amended to take account of the new technologies. Accordingly, it will now be possible to have steering systems in which there is not any positive mechanical connection between the steering control and the road wheels."

A further step was made 2017, when the beforehand mentioned decree was further amended, introducing the concept of autonomous steering system and opening the way for autonomous vehicles.

Also, the initial form of the Convention on Road Traffic contained a requirement that made the autonomous vehicles illegal in the signatory countries of the Convention. In the Article 8 of the Convention states that: (1) “Every moving vehicle or combination of vehicles shall have a driver”, (5) “Every driver shall at all times be able to control his vehicle”. In March 2014, this article was supplemented by (5bis) “Vehicle systems which influence the way vehicles are driven and are not in conformity with the aforementioned conditions of construction, fitting and utilization, shall be deemed to be in conformity with paragraph 5 of this Article and with paragraph 1 of Article 13, when such systems can be overridden or switched off by the driver”. With this modification, the presence of the driver is still mandatory, but the steering of the car can be carried out by an automatic system if the driver can take over it at any time. The amendment thus provides a legal framework for the (semi) autonomous vehicles.

4. Moral and ethical aspects

The self-driven vehicles must make good decisions even in extreme emergency situations. Is this always possible?

Imagine that a vehicle is approaching a pedestrian crossing, the traffic light is green for the car, but suddenly a pedestrian passes to the road. Although it is the rule that the designated pedestrian crossing place should be approached with extreme caution and the speed of the vehicle must be sufficiently low to be able to stop before the pedestrian crossing, if necessary, but the pedestrians can only cross the road if they are convinced that there is no risk. What is the right decision in this case?
Does the car swerve into the traffic from the opposite lane or in the roadside electric pylon, exposing the car owner to unforeseeable consequences? Is it a duty of the car to protect its owner at any cost? Would the dilemma change if not one but two people stepped on the road? Who is responsible for the consequences: the owner, the user or the computer programmer, who stays in his ergonomic chair some thousands of miles away and has no idea what happened? There is, however, a strong need to develop moral algorithms that can solve such situations according to acceptable moral norms.

5. Market
There is no doubt that the interest for driverless cars is increasing. According to a survey conducted by the Boston Consulting Group in 2015, 55% of potential car buyers said they would consider buying a semi-autonomous vehicle, while 44% said that they would consider buying a fully autonomous car [8]. Almost all the major automotive manufacturers are working on meeting this demand. According to the HIS, an international market research company, in 2020 the market share of the 4th and 5th level autonomous vehicles will be 0.004% (4,200 cars), which will increase in 2025 up to 0.5% (578,000 cars) and in 2030 it will reach 3.8% (4,503,000 cars) [5].

The trend of the market penetration of the semi- and fully automated passenger cars, estimated by IHS is shown in figure 3.

![Figure 3. Market penetration of automated vehicles][3], [5]

Autonomous vehicles are marketed following three scenarios: 1) traditional carmakers are integrating more and more automatic components into their products until the vehicle becomes fully autonomous, 2) new market players brake into the market with new concepts, 3) co-operation of traditional car manufacturers with new market players delivering a technology that allows the production of 3rd or 4th cars [3].

The optimistic scenario takes account of less restrictive safety regulation, more pork-barrels, appearance of new market players, the conservative one considers that the present condition will not change.

6. Conclusions
Autonomous technologies are becoming increasingly sophisticated and technically accessible, and in some cases, these can already be installed in commercial vehicles.

As several carmakers have announced that they will start the production of highly automated cars in 2017, it seems realistic that autonomous cars will make their appearance in developed countries in the
near future. We can estimate that in 2030 a significant number of driverless vehicles will travel on the roads.

According to today's research and development, it is unclear how these technologies will be able to handle extreme and unexpected events.

There is a concern over the development of several different technologies that will result very different products, which in some situations will not be able to work together and communicate with each other. There are trends that rely solely on the signs of sensors in the car, others need infrastructure improvements that help decision making.

As the cause of most traffic accidents is human error or omission, it is anticipated that the emergence of autonomous technologies will reduce the number of car accidents. There is not enough statistical data to sustain this statement yet.

The increasing trend of automatization level of cars will radically change the composition of car industry players, as with the rise in automation levels, mechatronics will be not only an additional part of the automobile industry but also an indispensable and integral part of it.

There is a reasonable expectation that automated cars will perform the same or better in all aspects than their conventional counterparts. However, it seems that the current regulations do not keep up with the development of technologies and sometimes hinder the development and testing of autonomous technologies.

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