Use of Facial Expressions to Improve the Social Acceptance of Level 4 and 5 Automated Driving System Equipped Vehicles

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***Abstract*—According to the World Health Organization (WHO), more than one million people die yearly from car accidents. At the same time, between 20 and 50 million people suffer non-fatal injuries, which can also lead to permanent disabilities. Recently, vehicles equipped with SAE level 3, 4, and 5 Automated Driving System (ADS) have become one of the hottest topics in the automotive industry. In fact, their main expected benefit is that they could significantly reduce the number of road accidents. Their actual success will depend on how people react to their introduction: considering that the absence of the steering wheel and pedals is possible for levels 4 and 5, will people trust these advanced forms of driving automation? In this regard, the authors of this paper have proposed two different ideas. The first, which can be implemented during the proactive phase, consists in calibrating the driving algorithm of the vehicle based on the volunteers' reaction to simulations of common driving situations. The second, which can be implemented during the reactive phase, consists in dynamically adapting the driving style of the vehicle based on the average feeling inside the vehicle. Both of these ideas could help improve social acceptance and facilitate the transition to vehicles equipped with SAE level 4 and 5 ADS.**

***Index Terms*—Autonomous driving, Consumer behavior, Emotion recognition, Neural networks, Sociology**

I. Introduction

The entire automotive industry is going through a period of intense change arriving on multiple fronts. In this sense, one of the hottest topics is Autonomous Vehicles (AVs). In this sense, someone may wonder what can be considered an AV. Citing the SAE J3016 standard [1], there are six increasing levels of driving automation ranging from 0 (No Driving Automation) to 5 (Full Driving Automation). In particular:

- For SAE levels 0, 1, and 2, there must always be an active human driver who can be assisted to a greater or lesser extent with automated functions such as lane departure warning (level 0), lane detection (level 1), and lane detection with active cruise control (level 2).
- For SAE levels 3, 4, and 5, autonomous driving will always be the primary one, but if in levels 3 and 4 it will work only in particular cases, in level 5 it will instead be completely autonomous and functional in all situations. An example for level 3 can be a traffic jam chauffeur, while an example for level 4 can be a local driverless taxi.

Having seen the SAE levels, it may be difficult to assign a strict definition for the terms Autonomous Vehicle or Self-Driving as they are too general and equivocal. For this reason, in the latest iteration of the J3016 standard, the J3016:2021, they have been deprecated along with other equally imprecise and confusing terms [1]. For describing a vehicle with driving automation capability, the suggested alternative terms are ”Level [1 or 2] driving automation system-equipped vehicle” or ”Level [3, 4, or 5] ADS-equipped vehicle”, where ADS is the acronym for Automated Driving System.

Until a year ago, it was possible to market vehicles with a maximum SAE level of 2. At the end of 2021, the German Federal Motor Transport Authority (KBA) allowed the Mercedes-Benz group to market its level 3 ADS-equipped vehicle [2], which complies with the UN Regulation 157 (UN-R157) standard [3].

A question that could be posed is the following: will people trust these advanced forms of driving automation? It is a question that is not easy to answer but can have important consequences. Some obstacles to people's trust in them are the following:

- People may simply be reluctant to innovation [4] [5] [6] [7]. As for ADS-equipped vehicles, people seem to have a

Fig. 1. A screenshot of one of the scenarios set in the suburban setting used to calibrate the driving algorithm based on passengers' reaction.

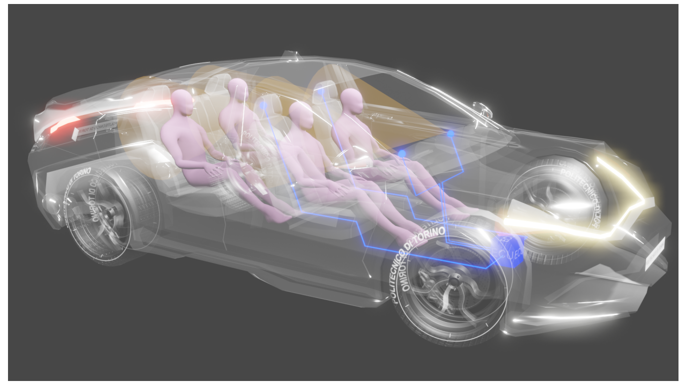

Fig. 2. A possible implementation of the proposed idea [14]. Cameras could be used to detect the presence of passengers in order to perform first face detection and then facial expression recognition.

better attitude towards them, but some resistance to their introduction remains [8].

- People expect these types of vehicles to be safer than traditional ones and that this is adequately verified. In this regard, a recent study followed the concept of risk tolerance in industrial safety strategy to research how much, for people, ADS-equipped vehicles should be safer than human-driven vehicles. The results showed that for the *tolerable risk* criterion, respondents expect these to be at least four to five times safer, while for the *broadly acceptable risk* criterion, they expect traffic risk to be at least two orders of magnitude lower than the currently estimated [9].
- For several years already, there have been difficulties in managing criminal liability arising from damage caused by advanced forms of driving automation [10]. This, too, can be a brake in their trust and adoption.

Such resistance can be a problem. In fact, if people do not trust these technologies, there would not be:

- A potential return to cover the costs incurred for the research and implementation of these systems.
- A reasonable safety improvement, as expected to bring.

Therefore, new technologies and new methods to improve the social acceptance of such advanced forms of driving automation are essential for the answer to the question posed above to be affirmative.

II. Methodology

From 2019 to today, we have proposed two ideas that could potentially improve it. This could be particularly useful for SAE levels 4, and 5 since the pedals and steering wheel are not needed on the vehicle. Their absence can limit complete confidence in ADS-equipped vehicles. New methodologies to influence their driving style transparently can be a valuable tool, especially in the transition phase.

In this sense, our first proposal consists in calibrating the driving algorithm based on passengers' reactions [11]. A feasibility analysis was then carried out through the use of 3D scenarios depicting some realistic cases of the trajectory of ADS-equipped vehicles. Specifically, such scenarios represented a right turn in an urban setting and a curve in a suburban setting. A frame of one of these is depicted in Fig. 1. They contained the following variables:

- The curve or turn was more or less strict.
- Presence or absence of cars coming from the other direction.
- Presence or absence of obstacles that required the vehicle to change its trajectory suddenly.

These scenarios were subsequently shown to testers with the intent of capturing their reaction. To demonstrate the feasibility of the idea, we trained and tested multiple Neural Networks (NNs) for facial expression recognition. In particular, we compared a Deep model [12] with a Shallow one [13]. This comparison focused on the results obtained by the two networks by testing different preprocessing techniques and hyperparameters. The best performing NN was then used to analyze the facial expressions of the volunteers in a laboratory setting to determine their potential preferred calibrations. The results suggested that the volunteers prefer calibrations in which the behavior of the car seems more natural and conveys calm and confidence.

Instead, the second proposal always concerns the monitoring of the passengers' facial expressions, but with the aim of adapting the driving style based on the average feeling inside the vehicle [14] [15].

In particular, for the vehicle, we have proposed the following behaviors:

- It will adopt a careful driving style if the people in the car feel sadness or fear, also coming to a stop if these negative feelings persist for a certain length of time.
- It will adopt a sporty driving style if the people on board are happy or surprised.
- Finally, it will adopt a balanced driving style if the people on board are neutral.

Unlike the first proposal, this second is a reactive technique, and both can be complementary.

Figure 2 shows how the proposal can be implemented. This can be done by using cameras aimed at passengers' faces and performing both face detection and facial expression recognition. By carrying out these operations on board via a dedicated Electronic Control Unit (ECU), potential privacy problems can be avoided.

III. Conclusions

Both previously proposed projects aim to improve the social acceptance of ADS-equipped vehicles. The results show that facial expressions can be useful both for calibration (proactive phase) and for changing the driving style (reactive phase). In the future, their joint use could therefore be a useful way to facilitate the transition towards SAE level 4 and 5 ADS-equipped vehicles. Authors of the paper are planning to improve these projects by resorting to other facial information, such as direction of the gaze and the frequency of opening and closing of the eyes.

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