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Alleviating driver misuse with proactive level 2 ADAS

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At partial automation or SAE level 2 automation, it is the driver who is the sole responsible and they are required to monitor both the automated driving system and the road ahead for any objects or events, responding appropriately and regaining manual control when needed. However, the current advanced driver assistance systems (ADAS) enable reducing the driver workload, while increasing the risk of driver disengagement. To guarantee a certain level of engagement, driver monitoring systems (DMS) are applied. These solutions are reactionary to driver misuse (not holding the steering wheel or not looking at the road ahead) and not fully reliable. Moreover, the consequent safety oncost of these DMS seems justified for achieving compliance with the regulations and reaching top ranking in safety assessment. The objective of this paper is to point out some limitations of the existing technologies and to propose new design guidelines to improve the safety of level-2 ADAS functions.

An ADAS level 2 functions can be defined as an assistance intended to reduce the driver workload with no possibility of disengagement. Proactive ADAS are proposed to maintain the driver with a certain level of situation awareness and staying actively in the loop. Active lane-centering assistance (aLCA) is a proactive lane-centering assistance that provides support only when the driver applies torque to the steering, similarly than power steering delivering hand torque assistance upon driver input. Conversely, when the vehicle is centered in the lane and the driver applies no torque, no guidance torque is provided. The steering system is operated in manual mode. Hence, the driver is not tempted to take his/her hands off the steering wheel reducing the risk of misuse. In this way, the UNECE Regulation 79 can be fulfilled without additional cost related to DMS sensors such as hands-off detection. In the case of hands-free drive with deactivated aLCA, lane keeping assistance (LKA) remains present to prevent lane departure like in manual driving. Fig. 1 shows the driver activity (steering power) as an indicator of engagement. Significantly less power is required when aLCA is activated than during manual operation indicating lower driver workload but higher than with lane centering assistance (LCA) because of greater engagement.

The concept of a haptic shared control (HSC) has received significant attention due the anticipated benefits on safety for partial automation levels. Providing an interactive environment to the driver with the steering system, where manual and automated inputs can coexist alleviates the risk of disengagement. Two configurations are considered for HSC at the operational level of the steering system:

- Blended control, is based on the idea that the driver and the automation can apply commands to the same actuator independently. The automation is a feedback loop of the steering system displacement in which a manual torque input is seen as an external disturbance to be rejected. Blended control consists in modulating the angle controller impedance to enable driver intervention.
- Impedance and admittance control, benefits from the superposition of the reference signal of the human to that of the automation. Admittance control is the appropriate configuration for a steering system because of the available torque sensor .

Most vehicle in the market use blended control. Fig. 2 illustrates the tracking performance based on the weighting of steering control. The first generation of LCA was characterized by relatively high override torque threshold and high path tracking performance. Driver engagement has been improved in the newer second generation by lowering the override hand torque threshold and enabling shared control at the cost of lower path tracking performance. This traded nature along with the relative complexity of managing mode transitions while ensuring stability and good steering feel represents the major limitations of the level-2 ADAS functions developed with the blended control scheme.

In contrast, the admittance control has the advantage that the inner position control loop is purposefully made stiff so as to ensure high tracking performance in the absence of interaction. Conversely, the outer torque control loop is naturally closed in the presence of interaction.

The admittance control is appropriate for hands-free lane centering function because it enables the driver to intervene while keeping high path tracking performance at the same time. For partially automated operation, aLCA is recommended to guarantee driver engagement. The following human-centered design rules for ADAS level-2 function are required to guarantee driver engagement:

1. The steering guidance from the ADAS is triggered only following a driver action.
2. The steering guidance from the ADAS is interrupted only when the vehicle is in a safe condition.
3. The use of a haptic feedback is to be prioritized over other senses.
4. Visual and audio cues should be limited to a minimum.

By applying these rules, safer and more intuitive level-2 ADAS functions can be developed.

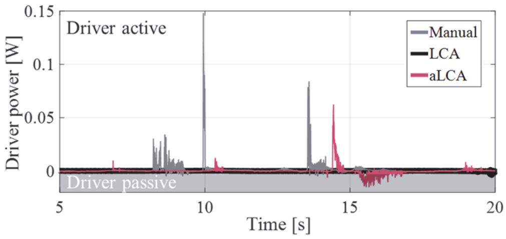

Fig. 1 Performance of aLCA on a straight road, measured on a test vehicle using a rack assist power steering system wit admittance control type haptic shared control: comparison of driver activity when driving in manual mode with LCA and with aLCA

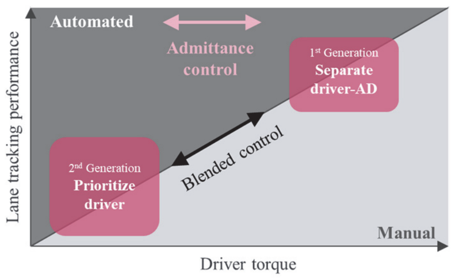

Fig. 2 Schematic representation of tracking performance of HSC control schemes in first and second generation