Take-over Requests in Simulated Partially Autonomous Vehicles Considering Human Factors

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***Abstract*—In the development of autonomous vehicles, the main focus of sensor research has been in relation to environmental perception, and only minimal work has focused on the human-vehicle interaction perspective. However, human factors need to be considered to ensure the safe operation of partially autonomous vehicles. This study briefly introduces a design methodology for the take-over request (TOR) time in National Highway Traffic Safety Administration level 3 vehicles and compares four different TORs in a simulated environment based on human-in-the-loop experiments with various driving scenarios. A total of 30 drivers participated in the study, and quantitative/qualitative data obtained shows statistically significant differences between the four TOR thresholds. This study shows that the timing involved in takeover can be obtained using a performance-based approach considering human factors.**

***Index Terms*—Autonomous levels, autonomous vehicle, driver reaction time, driver behavior, human factor, human in the loop, takeover request.**

I. Introduction

AUTONOMOUS vehicles that rely on the use of sensors have been developed to improve driver safety and simultaneously enhance vehicle convenience. In the initial stages, autonomous vehicles were developed by the Defense Advanced Research Projects Agency using specific sensors such as those for parking, intersection and lane change navigation, and emergencies. However, the development of a concentrated sensor has now produced an improved Advanced Driver Assistance System (ADAS), and autonomous vehicles are now the subject of considerable research. However, when developing such a vehicle, it is necessary to consider not only high quality sensors but also the driver in relation to the human–vehicle interaction.

Autonomous vehicles rely on their detection ability, and by using sensors, it would be possible for a vehicle to be operated without consideration of driver characteristics such as driver reaction time, driver behavior, and driver states. However, research conducted in the 1970s showed that although the role of the driver can be taken over by automation, in addition to replacing the role of the driver, the car would also need to deliver a performance identical to that of the driver if it is to be trusted[1]. This ability would be particularly relevant during high traffic situations as all drivers operate their vehicles differently at such times, and even though they potentially receive the same information, their individual reaction abilities differ. Recently, automated vehicle risk has been determined in the U.S. by using naturalistic data [2], where different standards for incidents and unreported crashes complicated the comparison between currently published crash data and automated vehicle crash data. In this respect, it is essential to consider human–vehicle interactions [3].

In 2008, NHTSA defined the levels of autonomous vehicles by classifying the driving roles of the driver and the autonomous vehicle in [4, 5], i.e., Autonomous Level 0, 1, 2, 3 and 4. Autonomous Level 3 involves a considerable amount of interaction between the system and the driver, and if this does not adequately occur then neither the system nor the driver can react appropriately to external stimulus [6]. Therefore, this paper focuses on vehicles at Autonomous Level 3. The main human factor considered in this study is reaction time.

Reaction time refers to the time gap from initiation of a stimulus up to the instant before the intended reaction occurs, and this differs both between drivers and for drivers at different times. Reference [7] classifies reaction time into three parts: simple reaction time (SRT), detectable reaction time (DRT), and choice reaction time (CRT). SRT refers to the process occurring when the driver already knows the object is going to appear, DRT is when subjects have no previous knowledge of an object appearing, and CRT is the decision time involved

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