Cooperative vehicle automation: Safety aspects and control software architecture

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Abstract

Automated vehicles are designed to take over all or part of the driver's task, in order to safely and comfortably navigate through road traffic. Automated vehicles, however, are limited by the line-of-sight characteristics of the on-board sensors, e.g., radar, lidar, and camera. To overcome this limitation, wireless inter-vehicle communication can be employed, which not only provides information of vehicles beyond the line-of-sight, but also provides information that cannot be retrieved otherwise. This allows for implementation of collaborative behavior, which can significantly increase traffic throughput and decrease fuel consumption. The resulting vehicles are often referred to as "cooperative automated vehicles", whereas non-communicating automated vehicles are usually (but not necessarily correctly) termed "autonomous vehicles".

To classify the various types of vehicle automation, the Society of Automotive Engineers has defined six automation levels, according to increasing functionality of the automation system and, correspondingly, a decreasing role of the diver [1]. In this classification scheme, level 1 automation, characterized by automation of either the longitudinal or the lateral vehicle motion, still requires the driver to be alert and to be able to take over the driving task at any time, thus implying only moderate requirements regarding reliability of the automation hard- and software. By means of an example of cooperative automation, in particular short-distance vehicle following by means of cooperative adaptive cruise control (CACC)[2], it is however shown that even for level 1 systems, stringent reliability requirements may apply, since the driver is unable to serve as a fallback option in case of system failures.

CACC, which is also the basis for truck platooning, is only concerned with automation of the longitudinal vehicle motion. As a next step, cooperative automation can be extended to also involve lateral motion, thus yielding cooperative automated maneuvering, involving, e.g., automated gap making and subsequent merging into a platoon. A layered architecture for this type of automation applications, consisting of an operational, a tactical, and a strategic layer, is presented. This architecture builds upon the decomposition of traffic scenarios into maneuver primitives, which are initiated by a so-called interaction protocol. The practical application of this approach is illustrated by a brief overview of the Grand Cooperative Driving Challenge (GCDC), which was held in 2016 in The Netherlands [3]. As such, a first step is made towards a common automation framework, which is considered essential to establish true cooperation among different types and brands of vehicles.

References

[1] *Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles*, SAE standard J3016, Std., Sep. 2016.

[2] J. Ploeg, E. Semsar-Kazerooni, G. Lijster, N. van de Wouw, and H. Nijmeijer, "Graceful degradation of cooperative adaptive cruise control," *IEEE Trans. Intell. Transp. Syst.*, vol. 16, no. 1, pp. 488–497, Feb. 2015.

[3] C. Englund, L. Chen, J. Ploeg, E. Semsar-Kazerooni, A. Voronov, H. Hoang Bengtsson, and J. Didoff, "The Grand Cooperative Driving Challenge (GCDC) 2016 – Boosting the introduction of cooperative automated vehicles," *IEEE Wireless Commun.*, vol. 23, no. 4, pp. 146–152, Aug. 2016.

About the speaker

Jeroen Ploeg received the M.Sc. degree in mechanical engineering from Delft University of Technology, Delft, The Netherlands, in 1988 and the Ph.D. degree in mechanical engineering on the control of vehicle platoons from Eindhoven University of Technology, Eindhoven, The Netherlands, in 2014.

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