INTEGRATED CONCEPT FOR MANEUVER-BASED DRIVER ASSISTANCE

Can a vehicle in normal day-to-day traffic situations be conducted without continuous stabilization inputs but almost exclusively by maneuver commands? The Institute of Automotive Engineering (FZD) and the Institute of Ergonomics (IAD) of Technische Universität Darmstadt are exploring this question. To answer it, a simulation in IPG CarMaker and Matlab/Simulink is used during the DFG funded Conduct-by-Wire research project.

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CONTINUOUS AND EVENT-DISCRETE VEHICLE GUIDANCE

The conventional vehicle guidance task can be described in the form of three cascading control loops [1]: The navigation task encompasses route planning and possibly required modifications. The trajectory guidance task as a subordinate control loop includes the situation-dependent configuration of the route through the selection of suitable driving maneuvers and associated trajectories. They provide the command variables for the stabilization task that means the minimization of the difference of actual and required trajectories. It accounts for the major portion of the driver-vehicle interaction in conventional vehicle guidance and consists of continuous stabilizing inputs by means of the steering wheel and the pedals.

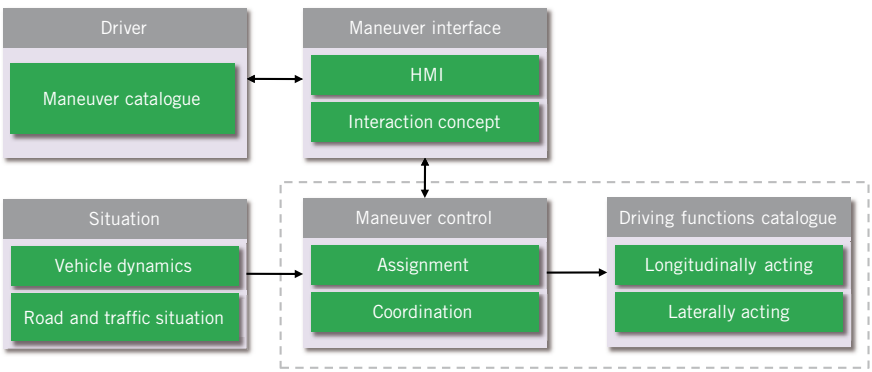
The Conduct-by-Wire approach of TU Darmstadt consists of elevating the conventional driver-vehicle interaction from the stabilization level to the guidance level. The continuous stabilization action for manual implementation of maneuvers and trajectories planned at the guidance level is replaced by event-discrete communication via a novel type of maneuver interface. By means of maneuver inputs the driver delegates the task of configuring and stabilizing the trajectories to the vehicle, influences the execution of maneuvers by parameterizations as appropriate and, if necessary, can still make stabilizing interventions.

The term maneuver interface stands for both the design of the human-machine interface and the associated interaction concept. This cooperative approach [2] relieves the driver of the stabilization task, integrates the driver, in addition to the automatic environment interpretation, as a decision-maker, continues – unlike autonomous vehicle guidance concepts – to require maneuver and route decisions and thus continues to hold the driver directly responsible in conformance to the 1968 Vienna Convention on Road Traffic.

MANEUVER COMMANDS AND EXECUTING FUNCTIONS

The maneuver commands [3] communicated by means of the maneuver interface are interpreted on the part of the vehicle by a maneuver control unit designed as a state machine and allocated to so-called driving functions for execution, ❶. The catalogue of driving functions consists of elementary, interlinkable and either longitudinally or laterally acting functions such as velocity control, preparing for reach into gap, target braking, obstacle avoidance inside lane markers, lane changes, turning and much more. At any given time exactly one pair of a longitudinally and a laterally acting driving function is active. The superordinate maneuver control unit is responsible for their selection, activation, deactivation and parameterization.

The modular structure of the functions catalogue accounts for the fact that the same maneuver command requires different executing functions, depending on the situation. A lane change, for example, may be ordered from congested into free-flowing traffic, from free-flowing traffic into a follow-on situation or into a situation in which no suitable target gap is available yet. While the driver would order the consistently identical “lane change” maneuver in this case, various functions, which



❶ Architecture overview with maneuver control and catalogue of driving functions

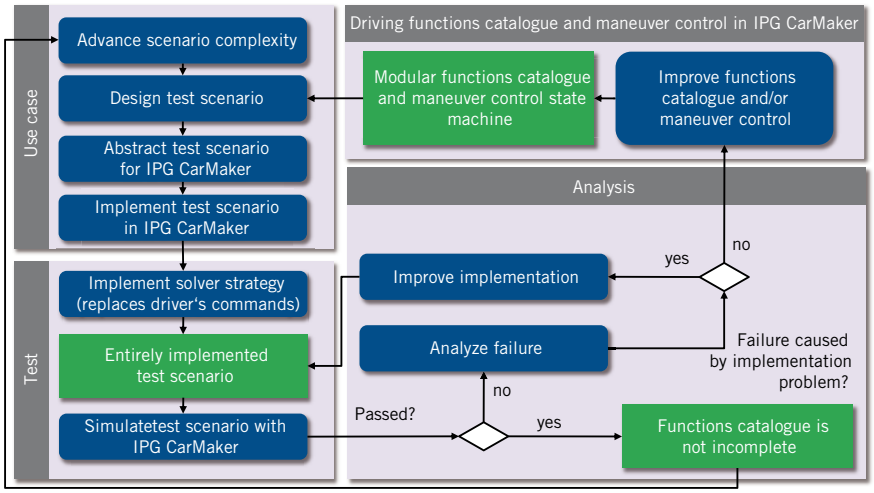
may even change within one maneuver, in the longitudinal and the lateral dimensions are involved. Due to the dimensional separation and elementary interlinkability of its components the functions catalogue is also capable of handling complex traffic scenarios on the one hand, on the other hand it remains compact and flexible with respect to extensions and adaptations.

FUNCTIONS DEVELOPMENT FOR CONDUCT-BY-WIRE

One of the major demands made on the functions catalogue and transition controlling set of rules is completeness that means the suitability for use in any type of traffic situation. Since it is from a logical perspective not permissible to draw the conclusion of suitability in any type of scenario from a successfully completed series of traffic scenarios, the functions development process follows a falsification approach: In keeping with good scientific practice the task is to disprove the universal hypothesis of a completeness of the existing functions catalogue and the associated set of rules. Or to put it in other words: the aim is to search for a traffic situation which cannot be handled with the scope of available functions.

The functions are developed using IPG CarMaker and Matlab/Simulink from MathWorks. In addition to a parameter-based multi-body vehicle model, a sophisticated driver model plus a road model that is extended in the project, CarMaker offers the possibility to integrate Simulink-based controllers and to let the simulated vehicle model interact with static and dynamic environmental objects in so-called TestRuns. From the project perspective, CarMaker represents the ideal environment for automated testing of the driving functions that have been developed plus their associated function transitions.

❷ shows the associated iterative development process. Starting at the top right-hand side, the respective current development state of the functions catalogue and the maneuver control are tested in relevant test scenarios, which for the simulation are reduced to the required details and then implemented as a simulation case. Each test case has a solution strategy in the form of simulated event- or route-dependent driver inputs.



❷ Iterative development process with simulation aid

The combination of the test case and solution strategy results in a test course that can be simulated and that is either passed or failed. A successful completion does not allow the conclusion to be drawn that the functions catalogue and set of rules are complete. It merely does not prove that they are incomplete and results in increasing the complexity of the scenarios or the selection of a new scenario for the next test. In the event of a failed test scenario a check is required to determine whether the failure was caused by an insufficiently implemented function or by the lack of a driving function or a function transition.

POSITIVE RESULTS

An initial functions catalogue presented in [4] has already proven its viability in simulation in relevant extra-urban traffic scenarios. Show stopper scenarios for maneuver-based driving could not be identified in this regard to date and the positive results of initial acceptance investigations [5] encourage the pursuit of further detailing of this concept.

In work that is currently underway the functions catalogue and the implementation of the functions using the methodology described are systematically being tested and extended in application cases of increasing complexity and, following a design example [6], a human-machine interface is being developed which meets the demands of maneuver-based vehicle guidance.

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