A DRIVER MODEL FOR VIRTUAL CONTROL SYSTEM DEVELOPMENT

Virtual road tests for the functional safeguarding and application of vehicle control systems place high demands on the driver model used. The driver model developed by Tesis Dynaware previously determines realistic targets and switches between open and closed loop control depending on the driving situation. It is a prime example of the development and preliminary adjustment of traction control systems for all-wheel drive vehicles at Magna Powertrain.

AUTHORS

DR. RER. NAT. RAINER FISCHER
is Project Manager for Driver Model Development at Tesis Dynaware GmbH in Munich (Germany).

DR.-ING. TORSTEN BUTZ
until September 2011 was Head of Product Development at Tesis Dynaware GmbH in Munich (Germany) .

DIPL.-MATH. MARTIN EHMANN
is Product Manager at Tesis Dynaware GmbH in Munich (Germany).

DIPL.-ING. MARIO VOCKENHUBER
is Development Engineer for Controlled Powertrain Systems at Magna Powertrain AG & Co. KG in Lannach (Austria).

THE PROBLEM

The consistent use of simulation methods at Magna Powertrain allows real road tests to be carried out more efficiently and better results for adjustment variants for traction control systems to be achieved according to customer specifications [1]. For this purpose, the simulation framework Dyna4 from Tesis Dynaware [2] provides models of vehicle, driver and environment which have high mapping quality but low computing time requirements and permit good virtual preliminary application of the all-wheel control units.

Tests based on driving tasks can be put together from any desired sequence of open- and closed-loop manoeuvres, iterative simulations and automated evaluations of the results. This allows variant calculations, controller verifications and virtual adjustments in function development and even control unit testing in Hardware-in-the-Loop (HiL) environments.

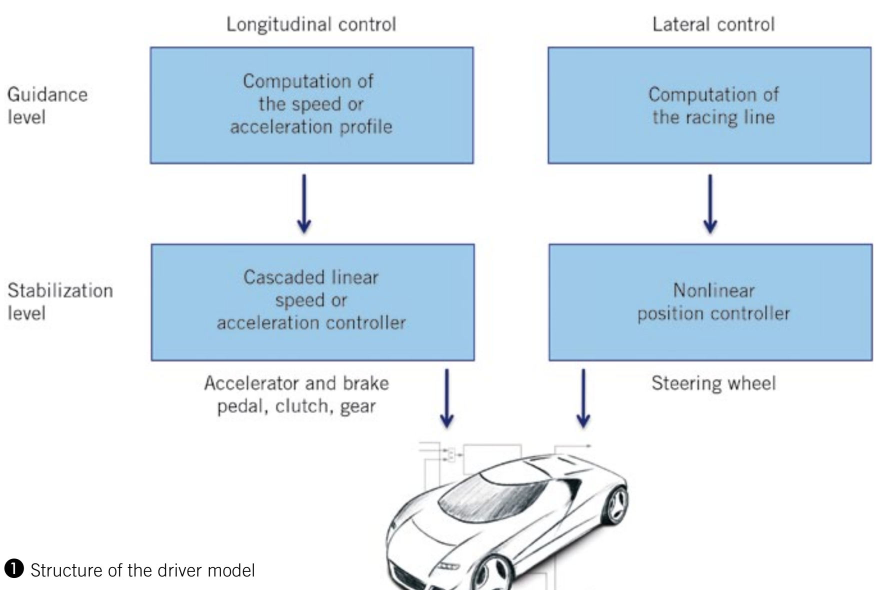
VIRTUAL TEST DRIVER

The implementation of virtual road tests places high demands on the driver model used. This must provide optimum setpoints for the test task in each case and ensure the longitudinal and lateral guidance of the virtual vehicle. The mapping of a wide range of plausible driver behaviours is achieved including realistic action of actuating variables and full use of the traction potential.

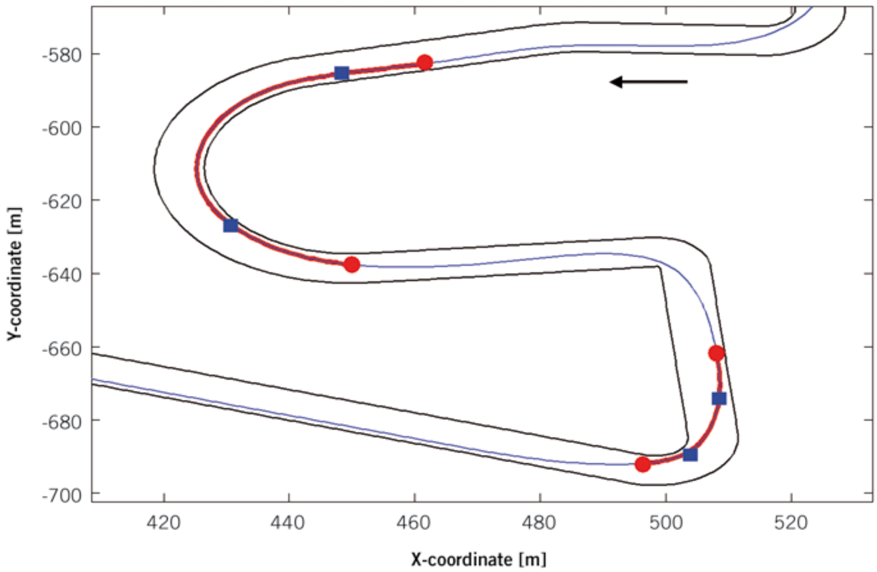
The Dyna4 test driver is a virtual driver model which can be universally used for a wide range of test scenarios ranging from standard and handling tests to extreme driving situations, the simulation of fuel consumption cycles, parking or realistic reactions to surrounding traffic. The modular structure, ❶, is based on the two-level model by Donges, which has been expanded to include a strict separation between longitudinal and lateral guidance and between setpoint calculation and actual control [3].

The specified course for lateral guidance is determined dynamically during the simulation or in a pre-processing step carried out beforehand. This is done via a heuristic method which uses the expert knowledge of test drivers to calculate approximations of time-optimal ideal lines for handling courses and mountain passes [4]. Curves and sequences of curves are identified and optimum trajectories with regard to the acceleration behaviour are computed. At very short computing times, this procedure provides good correspondence with trajectories actually driven and better results than the driver models of the competitors. Extreme driving situations such as those which are for example necessary for control system intervention on the part of an ESP control unit can be simulated in a reproducible way in the HiL test.

The non-linear position controller used for lateral control is based on the theory of non-linear system decoupling and control. Various driver types can be mapped by varying characteristic parameters such



❶ Structure of the driver model



❷ Phase subdivision for cornering on a handling course

as the distance for which the driver can see up ahead.

Depending on the driving situation, the control variables for the longitudinal guidance of the vehicle are determined by means of a cascaded speed or acceleration control which compensates for the non-linearities in engine and powertrain via inverse engine characteristic maps and gain scheduling controllers. The determination of realistic settings for the longitudinal guidance is described in the following section.

MANOEUVRE SUBDIVISION FOR THE LONGITUDINAL GUIDANCE OF THE VEHICLE

The specification of a target speed profile for longitudinal guidance is widespread in practise, but it is not suitable for a large number of applications. In particular when the friction coefficient is low, a pure speed control can lead to unrealistic braking and gear change operations in curves and thus stand in the way of the virtual adjustment of the traction control system to suit the human driver. The approach presented automatically carries out phase subdivision depending on the curve profile of the specified course. As with lateral guidance, curves and characteristic curve points such as the brake point and the end of the curve are identified. For each curve phase, either speed profiles or acceleration profiles for the driving controllers in question or open-loop setpoints are determined depending on the desired driver type.

By way of an example, the manoeuvres "braking" and "operation of the accelerator pedal followed by driving at a constant speed in curves" are outlined for the two curve sections marked, ❷:

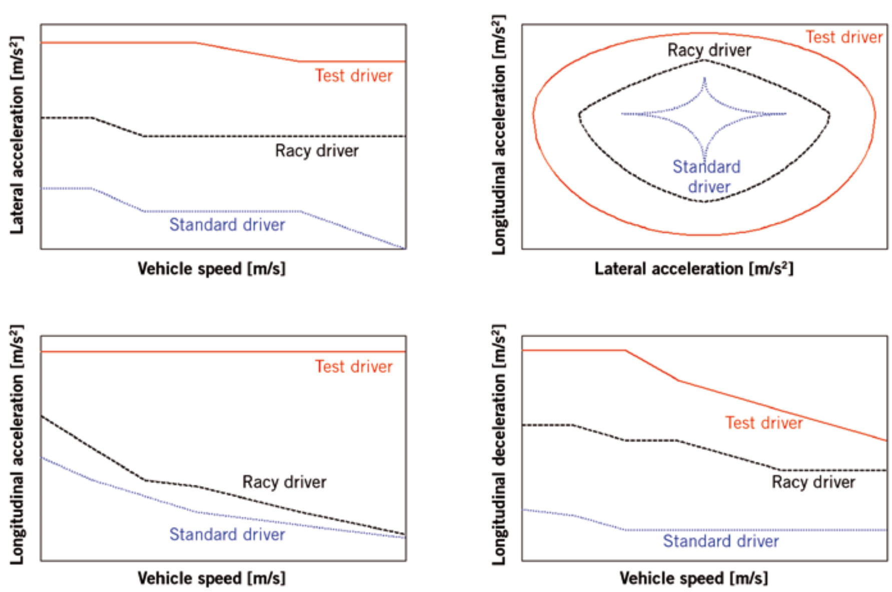
- The beginning of the brake phase (red circle) is determined from the specified end of the brake phase (blue square) and the acceleration limits typical for the driver. A deceleration controller is used for slowing down to the desired curve speed. At the end of this phase, the suitable gear for negotiating curves has been engaged.
- Braking and gear change operations are not permitted when driving at a constant speed. The curve speed is determined from the maximum curvature and the lateral acceleration limits typical for the driver.
- The beginning of the acceleration phase (blue square) is defined by falling below a lateral acceleration limit when driving at a constant speed. An acceleration controller is used for accelerating until the end of the curve is reached (red circle).

A suitable speed profile is used for the transition between the curves.

MODELLING DRIVER TYPES

Different driving styles are mainly mapped via three-dimensional g-g-v diagrams which reproduce the longitudinal and lateral acceleration limits of different driver types such as standard driver, racy driver or test driver depending on the driving speed, ❸. This also allows degressive acceleration processes and progressive braking processes etc. to be modelled.

The characteristic curves for the acceleration [5] reflect the fact that racy drivers and test drivers achieve much higher lateral and longitudinal accelerations than the average driver does. The longitudinal acceleration and the longitudinal delay tend to decrease as the speed increases,



❸ Speed and acceleration characteristics for average drivers, sporty drivers and test drivers with the precise reduction varying as a function of the driver type.

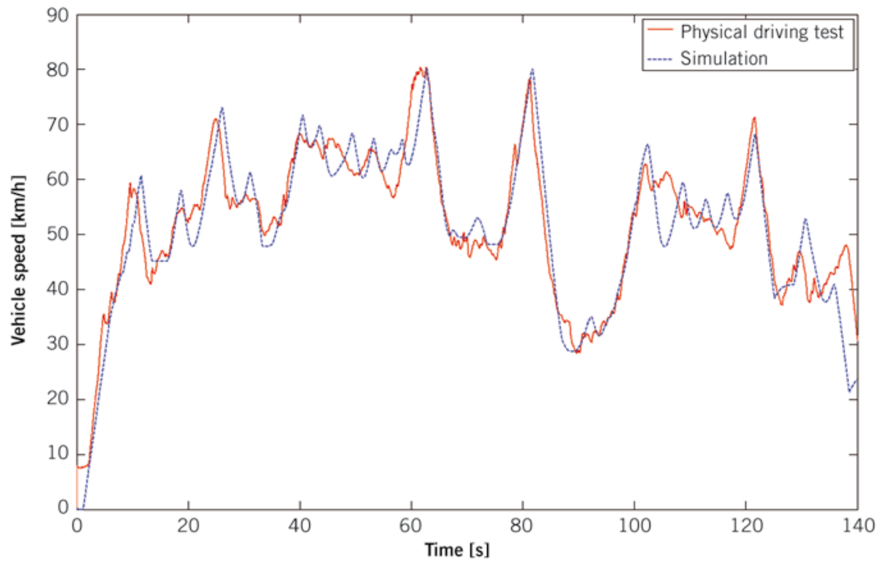
In addition, other characteristic parameters for the subdivision of manoeuvres are used to distinguish between different driving styles. Some examples of this are the end of the brake phase, which is later in the curve when the driving style is racy, the limitations on accelerator and brake pedal gradients as well as dead times at the transitions between phases.

ADJUSTMENT OF TRACTION CONTROL SYSTEMS

In the development of traction control systems at Magna Powertrain, virtual function development is becoming more and more important, and this also includes the reduction of CO_2 emissions [6]. To qualify for series production, the control algorithm has to fulfil a number of criteria from the fields of driving dynamics, traction, fuel consumption and system load. Different adjustment variants can be alternately tested for high and low friction values in the simulation, thus allowing adjustment to be carried out with a high confidence level. As a result of the humanoid model for the longitudinal guidance of the vehicle, even control logics which adapt to the driver behaviour can be tested realistically.

Low friction coefficient conditions are a particular challenge. Here the virtual driver has to achieve a stable driving behaviour even in extreme situations and is only permitted to operate the accelerator pedal and the brake in a moderate, targeted way when the vehicle goes into a skid. The driving speeds for a handling course largely show a correspondence between measurement and simulation, ❹. The phase-by-phase manoeuvre definition depicts the sensitive, dynamic behaviour of an experienced test driver in the operating states braking, load change and operation of the accelerator pedal followed by driving at a constant speed in curves.

Every time the control system is adjusted, the simulation allows the fuel consumption, the driving stability and the traction to be determined in a good correspondence with the test drive. The load on the powertrain results from the effects of the forces and torques on the mechanical components, such as the friction work occurring in the all-wheel clutch and the permanent torque in the axle transmission, which is equivalent to damage. Via suitable weighting, this is included in the total sample as a basis for the evaluation of the operational stability. Tool support from Dyna4 thus allows simulations to be carried out for a wide range of vehicle setups, the results of calculation and the quality of the adjustment variants to be evaluated and documented.



❹ Driving speed during test drive and simulation on a handling course

SUMMARY

The increasing number and complexity of mechatronic control systems in vehicles means that they can no longer be developed and adjusted without the assistance of simulation models and tools. A contribution to this is made by the driver model from Tesis Dynaware, which allows various driver types to be simulated. In the evaluation of traction control systems for all-wheel vehicles from Magna Powertrain, it was possible to successfully meet high demands such as that for control over the vehicle under low friction coefficient conditions. The results for the adjustment of all-wheel systems show good behaviour with regard to subjective evaluation by experienced test drivers and according to objective development criteria.

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