Driver Monitor and Feedback Dispatcher in SPARC

Johann Kelsch, Henning Mosebach, Frank Flemisch, Mark Vollrath

Abstract — **In context of the EU-project SPARC [1], a comprehensive driver support concept was developed. At first, the actual vehicle behaviour is compared with reference vehicle behaviour, generated by the virtual co-pilot [2]. In case of any deviation the driver will be supported depended on his current condition. With a 'Driver Monitor' the system determines to what extent the driver is involved into the actual vehicle guidance. This support is generated by a software module 'Feedback Dispatcher' and transmitted as multimodal feedback to the driver.**

Index Terms **— Driver activity, driver monitoring, feedback dispatcher, Assistant System, Highly automated driving, SPARC**

I. INTRODUCTION

In the SPARC-project two types of interfaces between driver and vehicle are used: 1) an electronically controlled system consisting of a combination of electric steering-wheel and set of pedals and 2) an advanced input device with a side-stick [3], [6]. To show the easy change from left- to right-hand steered vehicles, the pedal-set or pedal-box and the steering wheel can be dismounted and mounted again on the other side of the vehicle. The side-stick is installed in the middle of the passenger car and can be moved from the left to the right seat inside the truck.

The German Airspace Centre 'Deutsches Zentrum für Luft- und Raumfahrt (DLR)' is responsible for the interaction design between the human driver and the virtual co-pilot, using HMI components , sensor data and appropriate algorithms. When the driver is in his/her vehicle, the HMI is the single link with his/her vehicle. Without an adequate HMI an effective human-machine-interaction is not possible. Additionally, a good HMI contributes to the acceptance of the SPARC system. Therefore the HMI is a dedicated sub-project of SPARC.

Furthermore, for the correct functionality of the joint human-machine-system it is important to detect the activity or not-activity of the driver. In the case of driver inactivity the virtual co-pilot is capable to inform the driver about some danger, warn him or intervene in the vehicle guidance using force feedback of the feedback dispatcher and the HMI of the vehicle. Both modules (driver monitor and feedback dispatcher) are developed and integrated on SPARC-XCC as two separate software-modules. This paper describes their functionality and principles in a short way.

II. DRIVER MONITOR

The Driver Monitor's task is to observe the driver's activities at the HMI input devices. Based on the driver's activities to control the vehicle the software-algorithm calculates an index, which provides information of the current driver fitness for the Intelligent Switch and Feedback Dispatcher). The general functionality of Driver Monitor is shown in Figure 1.

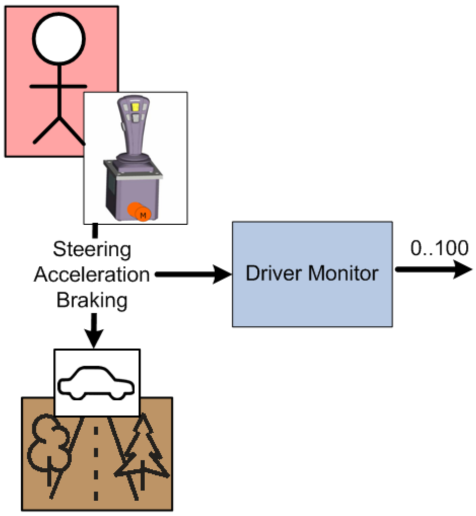


Figure 1: Principle and signal flow of Driver Monitor

The major control elements for vehicle guidance of actual position on the road and speed are acceleration-pedal, brake pedal and steering wheel. Signals like clutch and turn signals as well as secondary control activities like the operation of on board computer, radio, CD etc. were not included and unobserved first, since the attention to the driving is not present here and the driver is not active related to driving [4]. The information about acceleration (gas pedal value, % of the maximum way), brake pressure (in bar) and the steering wheel angle (in degrees) is simple to get over the vehicle CAN-bus and serves as basis for the driver activity index computations shown in Figure 2. The analys show that the vehicle speed is to be considered too. It can be obtained also over the vehicle CAN-bus.

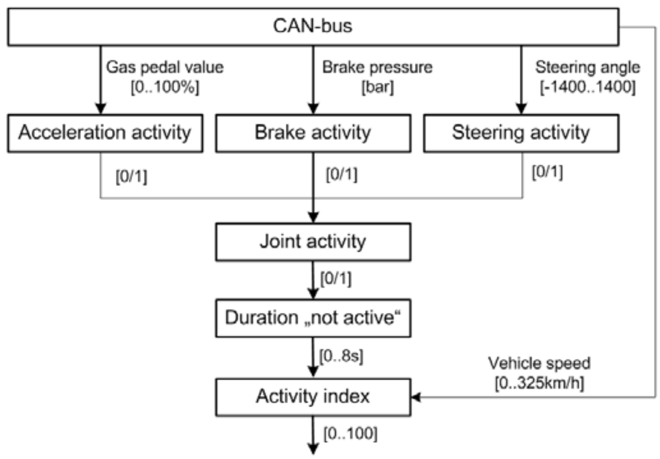


Figure 2: Algorithm for the computation of an activity index

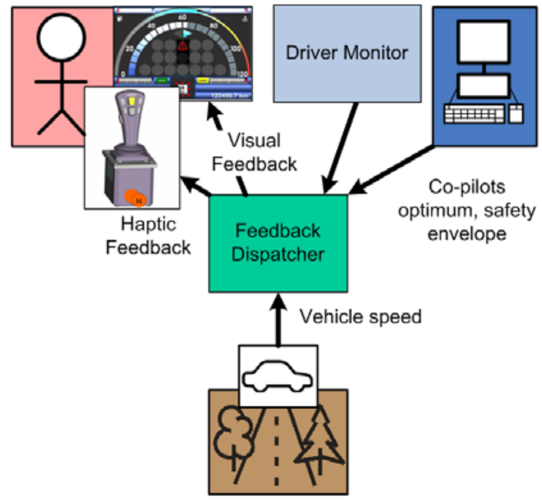


Figure 3: Principle and signal flow of feedback dispatcher

Development Process

In test runs with the DLR "ViewCar" comprehensive information about driver behavior, vehicle reactions and the surrounding traffic conditions were recorded [5]. The information necessary for the development of the algorithm came from CAN-bus every 100 ms. N = 15 test drivers (10 men and 5 woman, mean age = 31 years, sd = 6.6 years) drove a approx. one-hour test run on motorways, federal highways and highways, containing crossing roads, turning at crossings and/or u-turning maneuvers. These relatively short runs were accomplished in medium traffic density, so it can be assumed, that the drivers were awake and active. On this assumption calm and inactive conditions should occur relatively rarely.

Based on the test runs the mean frequency and duration of the inactivity as a function of vehicle speed and occurred events on the HMI-actuators (gas, brake pedal, steering wheel) was computed. Afterwards, this computation was applied in the algorithm development.

III. Feedback Dispatcher

The feedback dispatcher generates, based on the current traffic situation, feedback signals on different communication channels. The haptic channel is used in order to support the driver fast and directly. Different stick-forces and vibration patterns are applied to the stick, so that the driver can feel the co-pilot's reaction directly. For this reason most of the output signals of this application go directly to the side-stick via flexray communication. In addition, the visual channel is used in order to improve the understandability of the system (Figure 3). The signals for visual feedback also go to the relevant output device (primary display) via flexray communication. Input signals for the feedback dispatcher are co-pilot's optimum (motion vector), safety envelope, actual vehicle speed and driver monitor output. Using these signals the application decides which level of feedback is to be applied.

Development Process

The HMI interaction strategy itself is developed in a SPARC-specific test environment – virtual reality laboratory [7] [8] [9] and afterwards tested and optimized in SPARC-vehicles. The software architecture of the DLR test environment is quite similar to the other architectures within the SPARC project (VAL-HIL-environment, SPARC-vehicles) with the focus on guaranteeing the rapid exchangeability of functions (e.g. virtual sensor data fusion, virtual co-pilot-emulator etc.) The idea of the test scenarios is to integrate the hardware and software elements and to improve them with the aim of bringing the results gradually into the real world once the virtual sensors can be replaced by the sensors in the real vehicles.

Feedback Strategy

Feedback to the driver is necessary on the status of the virtual co-pilot in order to ensure that the driver can understand and trust the system. For example, if the driver's motion vector leads to change the lane, a visual or acoustic warning may be sufficient if the driver is awake and active. If he or she is sleepy and does not react to warning, a haptic feedback at the steering wheel or side-stick and/or a switching over to the safe motion vector from co-pilot is necessary.

The general feedback strategy is shown in Figure 4. At rising danger, like the e.g. unintentional leaving of the lane, an informing phase begins, followed by a warning and then intervening with the vehicle guidance in sequenceal order ($\mathbf{t_i}$, $\mathbf{t_w}$, $\mathbf{t_u}$). All happens at first on the haptic channel on the side-stick. Subsequently, on the visual channel it is indicated that the co-pilot intervened ($\mathbf{t_e}$). The direction of the intervening is graphically indicated on the primary display to provide an explanation for the driver.

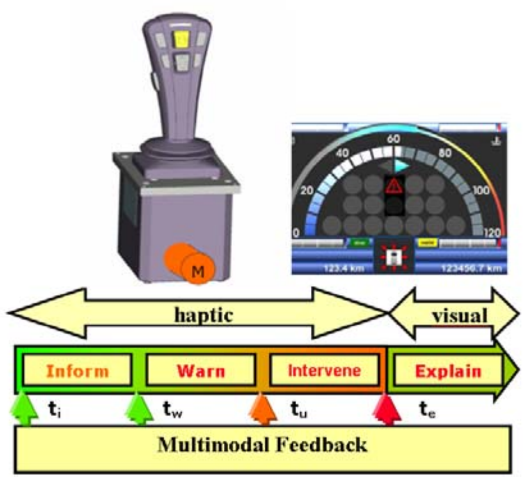


Figure 4: Timeline of the Feedback Strategy

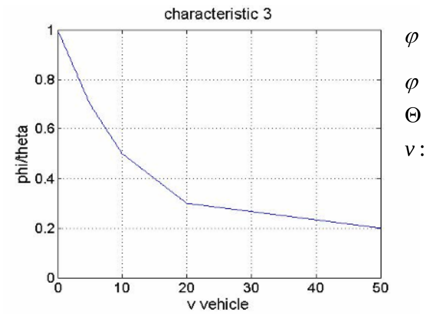
In the informing phase the driver feels a continuous force dependent on the co-pilot's optimum. This force 'guides' the driver and the vehicle on a safe way through the environment, but the driver is always able to correct this guidance. In the warning-phase, if e.g. the driver approaches the safety envelope border, he can feel a rising vibration. In the intervene-phase, the co-pilot takes over control and guides the vehicle exclusively. In this case the driver feels a vibration and can move the side-stick or steering wheel unhindered for correcting the occurred fault and in order to regain control over the vehicle again.

Side-stick parameterization

Contrary to steering wheels, which has over 1000 degrees deflection in each direction, a side-stick has only 20-25 degrees deflection in each direction [6]. Therefore it is necessary to consider strategies, which permit failure free and comfortable controlling of the vehicle at any time and regardless to this physical restriction.

Additionally to the development of driver monitor and feedback dispatcher DLR were designing the parameterization of the side-stick. A special attention was placed to speed dependency during the changing of stick angle. In principle, the faster a vehicle drives, the smaller steering angles on the wheel axle are needed. At the same time one would not like to do without the full 20-25 degrees stick deflection. This is handled with a nonlinear, speed-dependent translation between the stick deflection and the commanded steering angle.

In runs on the test track and empirical investigations the optimal speed-dependent translation for the current stick deflection to the actual steering angle was determined empirically. From several potential look-up-tables with the best handling one was selected and converted by a mathematical formula (Figure 5). Thus it could be ensured that the vehicle was stable and well controllable at the speeds up to 50km/h.



$$\varphi = \frac{\Theta}{0.1 * v + 1}$$

$\varphi : Steering - \text{coefficient}\,[\%]$

$\Theta : Stick - deflection\,[°]$

$v : Vehicle - speed\,[km/h]$

Figure 5: Look-Up-Table and mathematical formula for calculation of steering angle factor dependet on vehicle speed

IV. Conclusion

SPARC is still work in progress. So far we have implemented the concepts in prototype vehicles, and have first, positive data on the usage of the side-stick. First test runs on the closed-loop adaptive system based on a driver monitoring show positive results, but also hint that the overall complexity of the human machine system might grow if not controlled properly. Our next steps are usability tests in controlled environments, and, if permitted by funding, a re-engineering of the promising concepts described here.

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