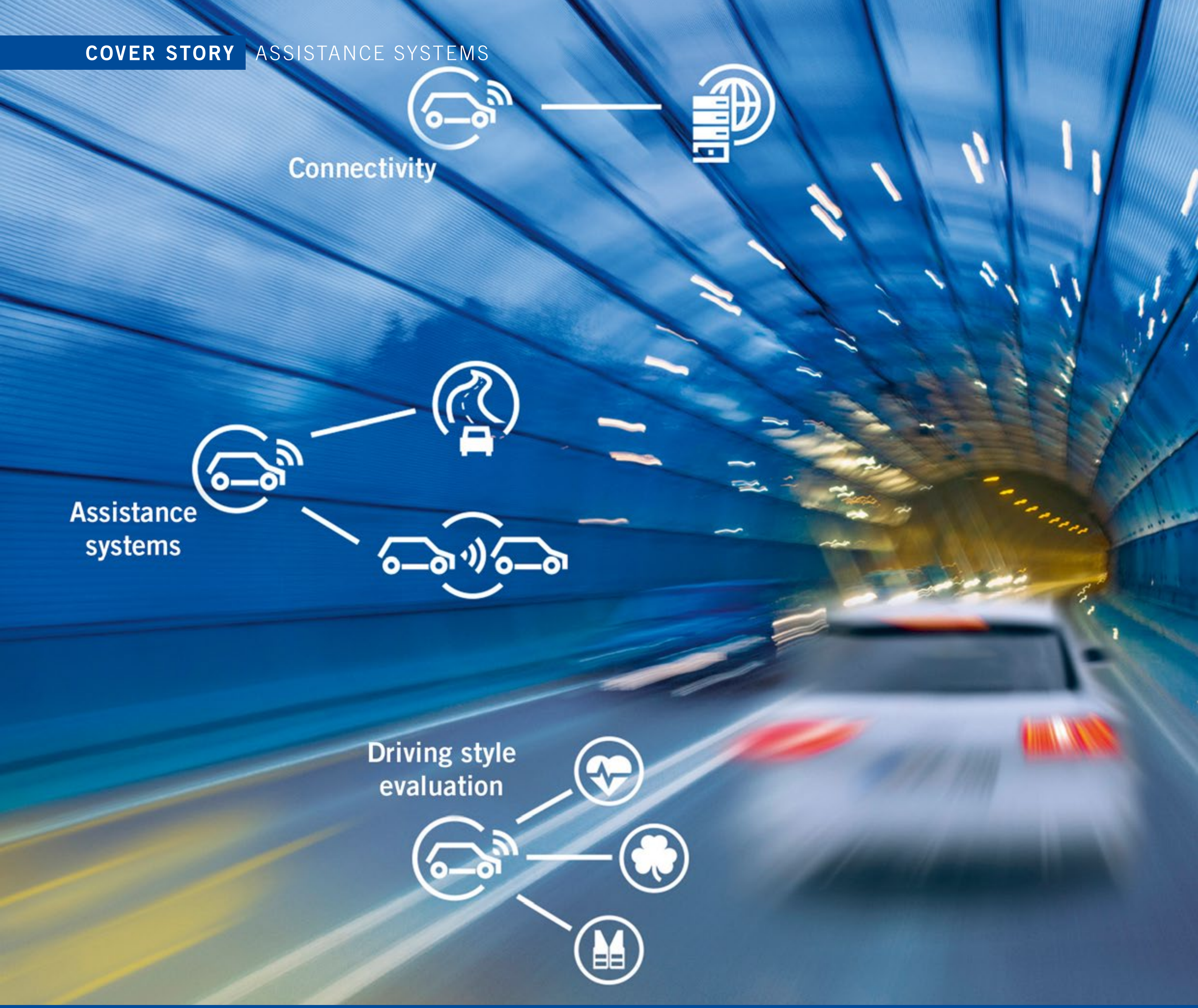

System Adaptation as Key Technology towards Automated Driving

Bertrandt has optimised the human-machine interaction on the basis of driver profiling. The result shows that the recognition of the environmental conditions of a vehicle and the adaptation of assistance systems to the driver are two important components of fully automated individual transport. In the future, driver adaptation will help to increase the acceptance of driver assistance systems and to make automated driving a fixed part of everyday life.

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STATUS QUO

Driver assistance systems should support the driver in longitudinal and lateral motion and provide safe and comfortable travelling. One of the most well-known systems is cruise control, which continuously controls the speed that has been set by the driver. A further development of this is Adaptive Cruise Control (ACC). In this system, radar sensors are used to detect a vehicle ahead and maintain a distance from it as selected by the driver. In most cases, oncoming traffic and stationary obstacles are excluded. By additionally using the evaluation of predictive route data, it is already possible today to adapt the vehicle's speed to the road topology and its geometry. This pioneering development enables the system to control the vehicle autonomously on bends and inclines even if route guidance is deactivated, thus making driving more efficient and reducing fuel consumption.

In addition to the road topography – bends, roundabouts, intersections, upward and downward gradients – speed restrictions are also recognised using map data and camera sensors. Accordingly, predictive ACC is able to react to roads ahead that have speed restrictions, thus enabling drivers to experience stress-free driving without the need to intervene. To allow a smooth and comfortable transition into different speed areas, which are defined by the road topography and speed limits, the system controls the ideal interaction between braking, acceleration, overrun and sailing phases, **FIGURE 1**.

However, when it comes to partially automated control of the vehicle, some drivers have the impression that they are relinquishing some of their own habits and feel misunderstood by the system. Studies – such as those by Forsa [1] or Puls Marktforschung [2] – have shown that drivers still prefer conventional driving over automated driving. Nevertheless, people have had an increasingly positive opinion of the development of autonomous vehicles over the past three years. In order to raise the level of acceptance of driver assistance systems and to gain the confidence of vehicle occupants, the driver should be integrated into the control process. For this purpose, the vehicle's environmental data and the driver's driving style are analysed to enable the assistance systems to be adapted to the behaviour of the driver. Intuitive interaction with the assistance system and its improved reaction to new situations ensure that the driver feels "understood" by the vehicle, and perceived reliability increases.

ADAPTATION OF THE DRIVER ASSISTANCE SYSTEM

For the adaptation of the driver assistance system, three aspects are taken into account: environmental detection and analysis, driving style analysis, and driver adaption.

The first step for the environmental detection and analysis takes place by using data fusion and "data enrichment". Enrichment has the function of bundling the quantity of environmental data and interlinking them logically in order to generate a higher information content (Smart Data). For example, radar, camera and acceleration sensors are used for this purpose. The different sensor signals are then used to derive road conditions and traffic information as well as the time of day and the time of year. As a result, the assistance system can, for example, increase the distance from the vehicle ahead when visibility is poor or reduce the speed on bends in snowy conditions, **FIGURE 2**.

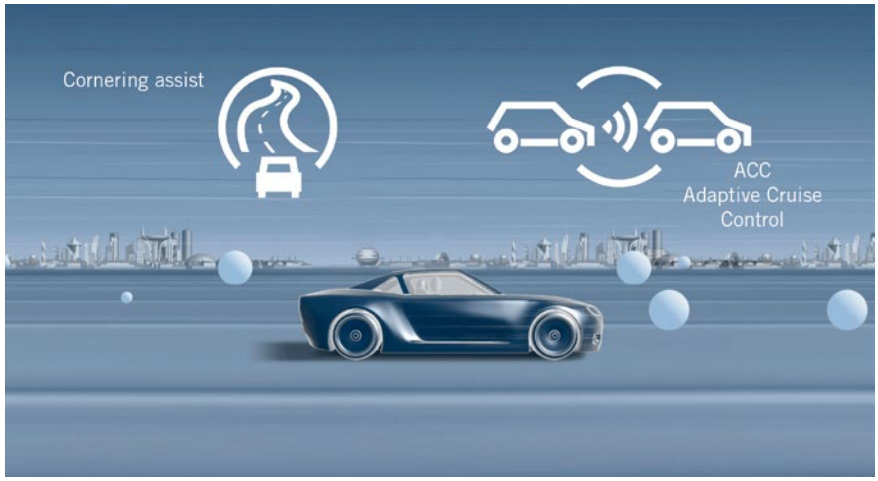

FIGURE 1 The further development and new development of driver assistance systems and the expansion of their areas of application represent an important step towards automated driving (© Bertrandt)

FIGURE 2 The three components of the adaptation of driver assistance system to the driver: driving style analysis – driver identification – environment recognition and evaluation (© Bertrandt)

The second part of the adaptation process involves driving style analysis. This makes it possible to characterise the driver through key attributes such as sportiness, safety awareness and energy efficiency. In order to continuously monitor the driving style, the behaviour of the driver in defined situations is observed. Various measured data are used for this purpose – for example, acceleration from a standstill, the average speed during unrestricted driving on a motorway with no speed limit, the average lateral acceleration when cornering and the curve of the distance maintained to the vehicle ahead.

The third part of driver adaption, with the aid of algorithms, the measured environment information and the analysed data of the driving style can be merged. From the combination and the interaction of the two areas, the driver assistance system can be adapted to the driver. The objective is to ensure that the driver assistance system always behaves in the way in which the driver himself would behave in different situations. As a result, the driver feels "understood", **FIGURE 3**.

Some of these analyses are carried out in real time in the vehicle to make sure that the system can react to new conditions at any time. In particular, it is possible to set threshold values for predefined situations, and when these threshold values are exceeded this is a strong indication of a certain driving style. Achieving a more detailed analysis of the personal driving style outside the situation and including environmental data will require processes from data mining and machine learning, and these demand considerable computing time. What is more, access to a large quantity of data from the past is necessary, which is why computation on typical control units is not possible.

Instead, transferring non-time-critical operations to a back end offers a number of advantages. For example, discriminant analysis can be used to determine those external factors that have the greatest influence on driving behaviour, and to do this individually for each driver. The basic driving behaviour can also be identified more precisely by using long-term recordings, even if the driver exhibits a different driving style for a short period. In a further step, cluster analyses allow the current driver to be compared with different driving styles in order to make predictions on his or her own behaviour in new situations – and to do this even if data are not yet available for this situation for the driver in question. For example, for a typically careful driver who drives his car in winter, the cornering speed in snowy conditions can be reduced more strongly than the average value of all drivers, **FIGURE 4**. The knowledge gained in this way forms a kind of long-term profile that describes the driver and which changes only very slowly. However, as the driving behaviour is influenced by the driver's current mental situation on a particular journey, this profile is combined in the vehicle with short-term observations which allow fast adaptation, **FIGURE 5**.

BACK END AND DATA SECURITY

As the current computing power of the ECUs in the vehicle is not sufficient for processing the data and for the different calculations of the algorithms, a modern vehicle architecture that also includes a powerful computing centre (back end) is required. First of all, the data are collected, fused and enriched, and certain time-critical calculations are performed. This information is collected and sent to the back end in order to carry out the time-consuming and non-time-critical calculations for the adaptation. The system remains fully functional in the vehicle at all times even without connection to a server. This requirement regarding functional security and reliability must already be taken into account when the system architecture is designed. Transferring data to a back end not only offers the advantages of increased performance capacity, compared to which the vehicle would soon reach its limits, but also the benefits of high availability and dynamic scaling. Scaling at the back end can be implemented much more quickly than in a vehicle in which all ECUs are installed. The keywords here are virtualisation and software extensions in full operation. A back end also includes properties of dynamic broadband adaptation, even going as far as geo-redundancy for high-availability systems. Elementary damage to the server infrastructure must also be taken into account in the design to ensure that systems in the vehicle can be reliably supplied with data. This will make sure that the data are available at all times and are protected against failure.

At the back end, automated analyses are performed by various algorithms in order to calculate a long-term profile for each driver. The combination of the separately created profiles generates swarm

FIGURE 3 Example of the visualisation of the vehicle status on the instrument panel, including current weather data and future situations, such as bends and speed limits; a special feature is the representation of the recognised driving style in the colours magenta (safety awareness), blue (sportiness) and yellow (energy efficiency) (© Bertrandt)

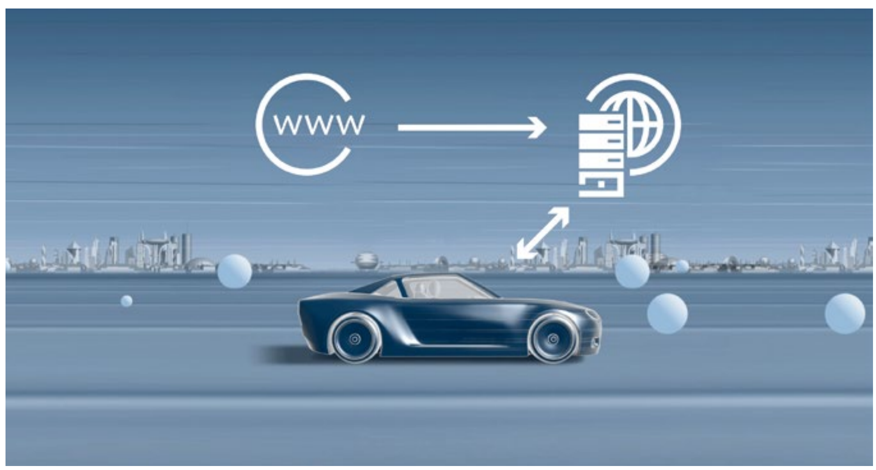

FIGURE 4 In order to further enrich the data from the vehicle at the backend, information from the world wide web is needed, for example traffic or weather information (© Bertrandt)

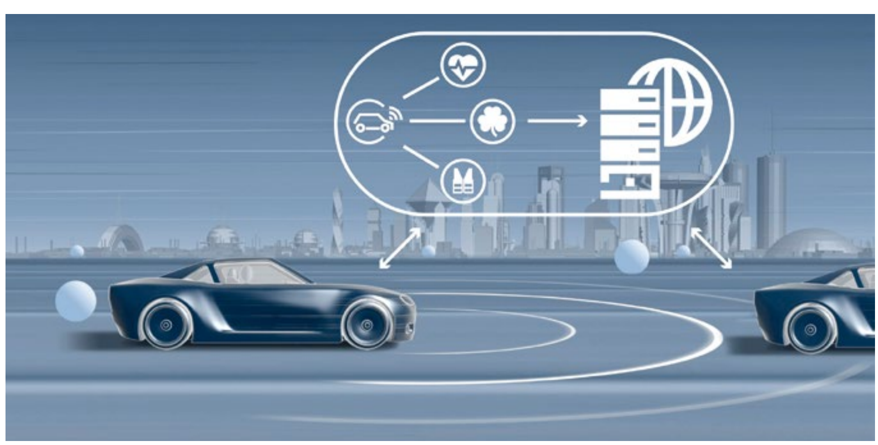

FIGURE 5 Sporty, safety-conscious or energy-efficient driving style? In order to define the individual driving style, the usual vehicle architecture is expanded with the addition of a back end on which non-time-critical calculations can be carried out (© Bertrandt)

intelligence that benefits each individual vehicle – in the end, especially the driver.

The IT structure behind the vehicle offers almost infinite possibilities to verify data and to allow the swarm intelligence to continue learning. For example, it is possible to synchronise data directly from the vehicle with weather data, traffic jam data and many other data. Then, for instance, the speed of all vehicles in a region can be temporarily reduced if the vehicles ahead are already moving particularly slowly and the weather report is warning that there is a risk of black ice.

In order to make the processing of "big data" manageable, filters in the vehicle, algorithms at the communications control unit and the back end can be used to enrich the data to generate "smart data". This process serves to optimise data traffic and security.

The aspect of data protection and data security plays a key role, as any hacking attack on the data connection between the vehicle and the back end must be prevented. Unauthorised access could allow the vehicle to be remotely controlled or could result in incorrect control or the theft of sensitive data. The aim is to avoid manipulation of the data by unauthorised persons thus raising confidence in the reliability of the data processing system. Achieving this aim will be supported by legal specifications, anonymisation in the vehicle, data management and data storage. For that reason, this subject must already be carefully considered at the start of the development process and decisions regarding the scope of functions and the risks involved must be taken.

ROAD TO AUTOMATED DRIVING

Bertrandt is currently carrying out a study in cooperation with a University of Applied Sciences. This study examines to what extent the self-assessment of drivers regarding their own driving style corresponds to an external assessment and to characteristic values of driving dynamics. With the aid of adaptation to the driver and the establishment of data security that this involves, it will be possible in the future to increase the acceptance of driver assistance systems in society. With this key technology, we are going a step further towards making automated driving a fixed part of everyday life in the future.

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