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CROWD SENSING

Current series production vehicles already process a vast quantity of information. Much of the sensor data, such as data from a radar sensor, is distributed to and used by several systems in the vehicle. Reflecting the state of the art, the data is centrally processed to reduce its complexity and enable its efficient use. Premium vehicles, in particular, have many radar, laser, camera and other sensors. In addition to the distributed use of the data within the vehicle, it makes sense to share it with other road users. The data can supplement classic map data to provide the driver with a comprehensive picture of the road network. Automated driving also necessitates high data precision, as well as information about relevance and validity. Conventional navigation systems which are not cloud connected and only updated occasionally when the vehicle goes in for a service cannot deliver this.

In the future, therefore, data about the vehicle's environment from different traffic participants will be bundled (distributed perception and mapping). Sensor data won't just be collected for individual vehicles but also made available to all road users. Vehicles will communicate with each other and exchange data with other vehicles in their immediate envi-

Modern driver assistance systems support drivers in complex, hazardous and also monotonous driving situations. In manageable traffic conditions such as a traffic jam on the motorway some of today's systems are already assuming control of the vehicle. However, their horizon is restricted to the vehicle's direct environment. This is too limited for future driver assistance systems or autonomous driving. Additional details, such as information about geographical, topological, weather and road conditions, are necessary. They can be provided in the form of real-time infrastructure information in combination with digital map data from vehicles, describes Elektrobit.

The Car as a Sensor
Cooperative Perception and Learning for Automated Driving

ronments, **FIGURE 1**. Vehicle data will also be stored and evaluated in the cloud for purposes such as map optimisation when a section of road is surveyed. Many drivers are already participants in this process of indirect data collection because they make data available via their smartphones. One example for this is data on traffic jams used for traffic reports.

The quality of the information gained from the cloud depends, among other things, on the volume of data. The more vehicles there are providing information, the more precisely the road environment can be mapped. Traffic sign recognition is a good example of this. Even the latest navigation systems don't have informa-

tion on speed limits for all roads. They usually only have this information available for the main roads. They are also unable to provide information on short notice changes to maximum speed limits. This information gap in the digital map can be closed by a road sign recognition function in the front camera. However, the net recognition rate isn't ideal. And in poor weather and bad lighting conditions it is even lower. On the other hand, if a fleet of several hundreds of thousands of vehicles regularly send their data to a central cloud repository for evaluation, the net recognition rate improves vastly. This is called 'crowd sensing' and the sheer volume of data

provides a far more precise and up-to-date picture than the map provider's special survey vehicles. In addition to traffic sign data, information about the route that is relevant for transmission and drive strategies, especially in hybrid and electric vehicles, is needed. A proactive chassis, on the other hand, needs data on road conditions such as road surface wetness, iciness or friction coefficient. And additional information about curves, lanes and traffic routing is necessary for autonomous driving.

Map information has to be supplemented by metadata for highly automated and autonomous driving so that the vehicle can check the data's validity.

Today's maps don't include the age of the data or an ageing model, i.e. they don't provide information about how old data can be to be classified as reliable. All this information is necessary for autonomous vehicles because different features of a map age at a different rate. For example data on black ice sensed by the vehicle won't be valid after several hours or even minutes. In contrast, information about a tunnel will probably still be valid even after several years. So a suitable ageing model can draw conclusions about the validity of data on the basis of its age. Such a model is feature-specific, which means it deals with digital map features such as inclines, curves or traction individually.

FROM THE VEHICLE TO THE CLOUD

A modern, well-equipped vehicle generates several gigabytes of sensor data every minute. Not all of this data can be transferred due to limited network capacity, so the volume of data to be transferred has to be reduced. To achieve this, the sensor data is initially compared with the vehicle's existing map data in the cloud. For example, in the case of traffic sign recognition, the system checks whether the sign has an identical counterpart in the map mate-

rial. If it doesn't, the information is uploaded to the cloud.

Even if there is a data match, it might still makes sense to upload the information so that the map material can be validated. The decision on whether to transfer the data or not depends on the ageing model, the objective being to transfer as little data as possible and as much as necessary.

Once the relevant data is in the cloud repository it has to be pre-processed, grouped, sorted and interpreted. In the pre-processing stage obviously incorrect features are discarded. Then, the information on the individual map features is grouped. When 100 vehicles provide information on a specific road sign there will initially be 100 data records which will deviate slightly as regards the sign's precise location or the perceived maximum speed limit. Data mining is then used to establish whether the 100 data records all relate to exactly the same sign, where precisely it is located and what kind of a sign it is, **FIGURE 2**. Then a calculation is performed to see whether the feature can be assigned to existing map data. After that the system interprets the data to establish whether the sign is new or not, and whether the ageing model has to be adapted. This can happen, for instance, with variable message road signs.

FROM THE CLOUD TO THE ECU

When the information in the cloud has been analysed, it has to be transferred back to the vehicle. Various protocols are necessary for the transfer process. When incremental updates are made at relatively long time intervals, NDS (Navigation Data Standard) format is used. There are also several proprietary formats and the Open LR Standard for shorter-interval updates.

Data dissemination is modularised on different levels to separate fast-changing information from rarely updated information. This reduces bandwidth requirements during data transfer and simplifies the update process. At the same time, it ensures that the in-vehicle systems always have the latest information available. Combination with metadata for relevance also makes it possible to assess data reliability.

The information from the cloud is first of all integrated in the navigation system's map material. Then it has to be transferred to the relevant ECUs so that the assistance functions can use it. This is done with a transceiver mechanism. The data is transferred to the ECUs on the basis of a protocol such as the ADASIS protocol (Advanced Driver Assistance Systems Interface Specifications). The ADASIS Reconstructor receives the data sent by the ADASIS Provider (within the navigation system) and sorts it correctly into the ECU's data structure, **FIGURE 3**. The Reconstructor and Provider are components of EB's electronic horizon for anticipatory driving. The ADASIS protocol ensures that the various components which are necessary to generate and utilise the electronic horizon interact properly.

AUTHENTICITY AND DATA PROTECTION

The technical function of crowd sensing must comply with data protection legislation. So the sensor data from the vehicles is initially reduced and compressed, then anonymised, signed and encrypted before being transferred to the cloud.

Anonymity protects the drivers' privacy. After the anonymisation process it is necessary to ensure that consecutive information of the same type can be assigned to a sender in the cloud. For example, if the system receives the
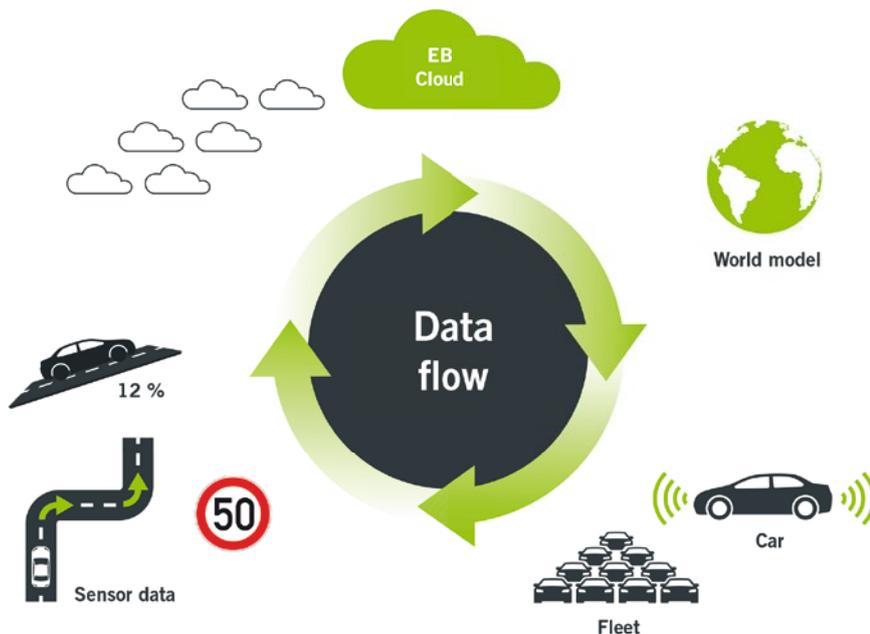

FIGURE 1 Many vehicles have sensors that record data on speed, incline, curves and other information that is stored in the cloud, this information is used to supplement map material, thereby providing a more comprehensive picture of the worldwide road network

FIGURE 2 Analysed data is integrated in the navigation's map material and made available for driver assistance features via a transceiver mechanism (provider / reconstructor)

message "vehicle stationary" several times within a short period of time, it has to know whether the information relates to one or several vehicles. If it is sent by several vehicles, it can be assumed that they are in a traffic jam. The vehicle's identity is irrelevant, as is the fact that different information types relate to one vehicle. However, there are some exceptions. For example, if the vehicle sends a technical defect message, it needs to be possible to be identified correctly by its manufacturer. So with all information, it is necessary to find a balance between anonymity and identification. The data is signed so that its authenticity and credibility can be assessed and verified. It is also encrypted for secure transmission with

standard encryption methods such as symmetric and asymmetric encryption.

SELF-LEARNING SYSTEMS

Many vehicle manufacturers already store sensor data in the cloud today. However, they are still having problems using it efficiently. Their analyses tend to focus on specific functions and are performed manually. In future, the data to be collected and evaluated will become increasingly complex. In order to exploit the potential of sensor data from an entire fleet of vehicles, it is therefore necessary to increase the degree of automation along the data processing chain. Suitable systems such as

those developed by Elektrobit cover the entire process from data mining and evaluation to data transfer and use. The vehicle manufacturers retain ownership of the data at all times.

We are still in the very early stages of vehicle sensor data use. Growth in the number of driver assistance functions in mid and lower price segment vehicles will cause the volume of analysable data to increase over the next few years. The technologies described allow data from the cloud to be used for both comfort and safety functions. Crowd sensing information provides a precise picture of the road network, which will be indispensable as the basis for automated driving.
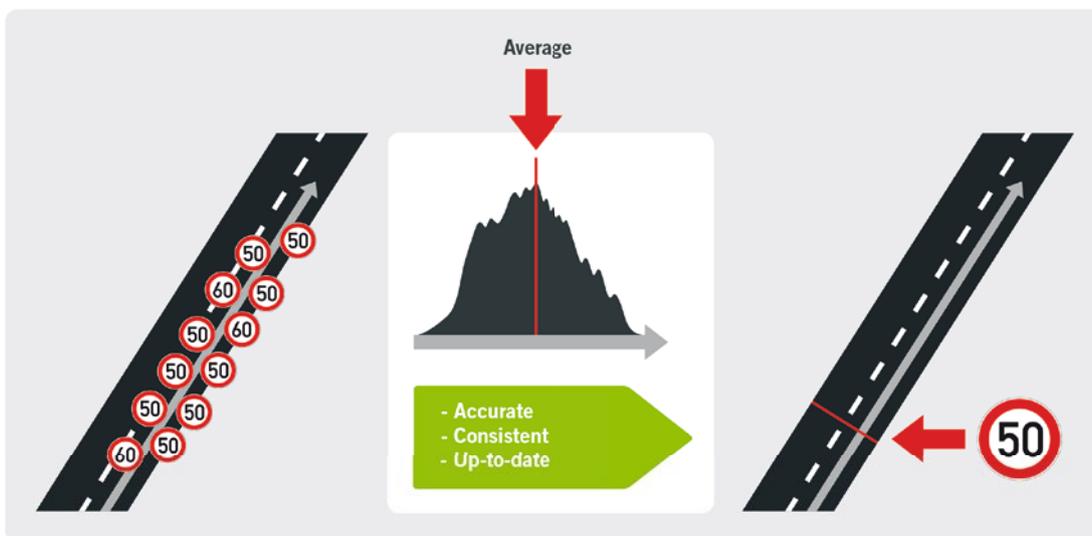

FIGURE 3 Several vehicles record and transfer data to the cloud about a specific road sign; these data records which vary in terms of exact location and perceived maximum speed limit, are then analysed by data mining; the objective is to update or verify existing sign information and to possibly include new road signs in the map material