Analyze Large Quantities of Measurement Data Rationally and Flexibly

On test benches and in durability tests, automotive OEMs collect important information on the behavior of vehicle components under realistic conditions. However, in view of the enormous quantities of data that are generated and their complex interrelationships, it is often a time-consuming process to subsequently identify and analyze the relevant data sets. To accelerate the analysis of measurement data in testing its automatic transmissions, Daimler AG relies on automated data evaluation by the CANape measurement and calibration tool from Vector.

The development of automatic transmissions at Daimler began in the year 1960 with a 4-speed transmission, which would be considered a rather simple engineering design by today's standards. The rapid advancement of technological development is attributable to a wide variety of new requirements such as increased comfort needs, larger gear spreads, lower fuel consumption, more powerful engines, additional gears, etc. For example, the drive-off element was changed, planetary gears and torque converters were added, and in 1995 the first version with electro-hydraulic transmission control was launched.

The 7G-Tronic Plus automatic transmission represents a pinnacle of this development history. Designed in 2010, the 7G-Tronic Plus can handle torques of up to 1000 Nm and can be implemented in a broad range of vehicles: from the smallest rear-wheel drive vehicle of the C-class with a 4-cylinder engine to the high-performance models of AMG. The transmission is also used in the small variant of the Sprinter van. It attained a successful combination of the seemingly contradictory requirements of optimized fuel economy, driving fun and ride comfort, and in 2011 the transmission won the internal Daimler Environmental Leadership Award.

Automatic Transmission Requires Many Parameter Optimizations

The extremely broad implementation range in the different models requires optimal calibration of ECU parameters to achieve the desired driving behavior. The path to product maturity was accompanied by numerous test bench and in-vehicle durability runs. Measurement data accumulating from daily testing is saved on servers, where it is available to development and calibration engineers. The challenge in evaluating and analyzing these large quantities of measurement data is to identify those data sets in which

errors occurred, such as limit value violations or excessive thermal stresses. The errors of a poor gear shift operation, for example, expresses itself in typical vibration and jerky behavior, which is noticeable to the driver and passengers. Excessive thermal stresses associated with increased wear occurs when allowable friction values are exceeded during clutch operations.

Proven Analysis Process is Pushed to its Limits

The measurement data, which exists in various formats, comes from the CANape measurement and calibration tool and from other data loggers. Previously, it was evaluated in a method where the first step was to process it in an internal Daimler tool, and it was written to an Excel file **(Figure 1)**. Then, an Excel macro would generate a graphic overview on which the user could discern "trigger points" where errors occurred. Using these results, the relevant measurement files were loaded in CANape, and finally the analysis points were displayed there. This approach was not only tedious; it was also burdened by other disadvantages and limitations. The Excel tools work very slowly, which is all the more challenging with large volumes of data. Moreover, they also limit the maximum amount of data that can be processed, because the total number of lines in Excel tables is limited, and the program only offers limited graphic display options. Maintenance efforts for further development of the solution also had to be provided by Daimler.

Automated Evaluation by Data Mining

Since CANape is already widely used at Daimler – whether in calibrating ECUs, logging measurement data in test bench tests and durability tests, or for evaluation purposes – the managers there decided on an implementation strategy based on this Vector tool. The graphic display functions are optimally tailored for measurement data applications and – an important prerequisite – CANape offers the option of formulating company or project-specific evaluation algorithms using its internal programming language.

Calibration Tool as a Platform for Analysis and Graphics

To obtain a usable analysis tool as rapidly as possible, Daimler engaged Vector to implement the concept. Vector's task was to represent the evaluation algorithms Daimler wanted as CANape scripts and to graphically prepare the results. The data mining functionality in CANape is now used to analyze the measurement data of interest. In an analysis of results, the tool lets the user visualize the measurement file precisely at the location at which an error occurred **(Figure 2)**. CANape can be used as both the platform for executing the analyses and the platform for displaying the results. The size limitation has been overcome, and data volumes of up to 100 GByte can be processed effortlessly.

On the configuration side, the user selects the measurement data, chooses exactly what to study from a list of possible evaluations, e.g. upshifting or downshifting, and starts the analysis process **(Figure 3)**. After completing the evaluation, statistics are

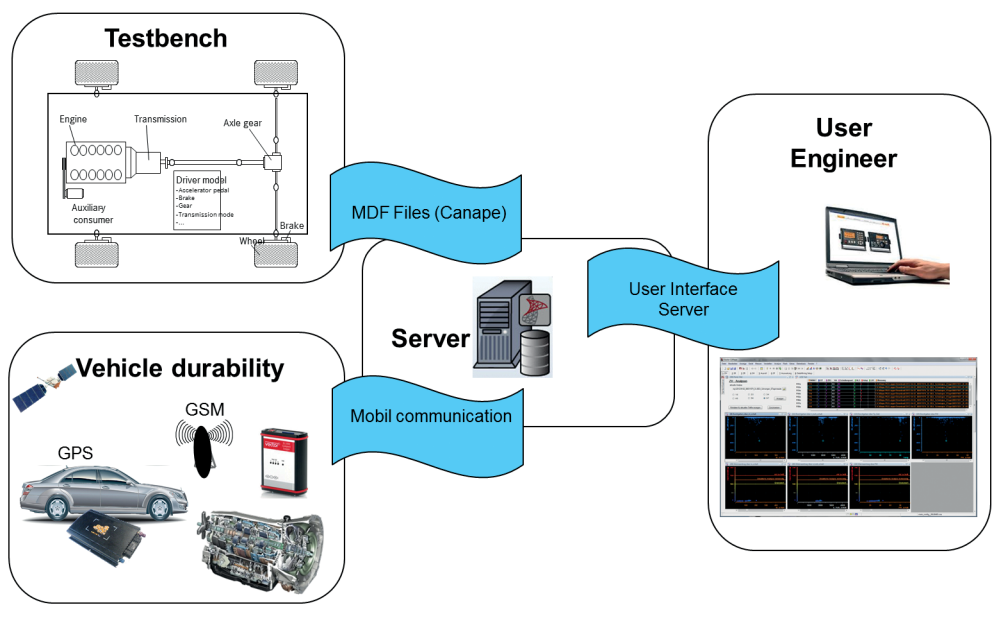

Figure 1:
The measurement data generated on test benches and in durability test vehicles are saved on the server and are available to calibration engineers for evaluation.

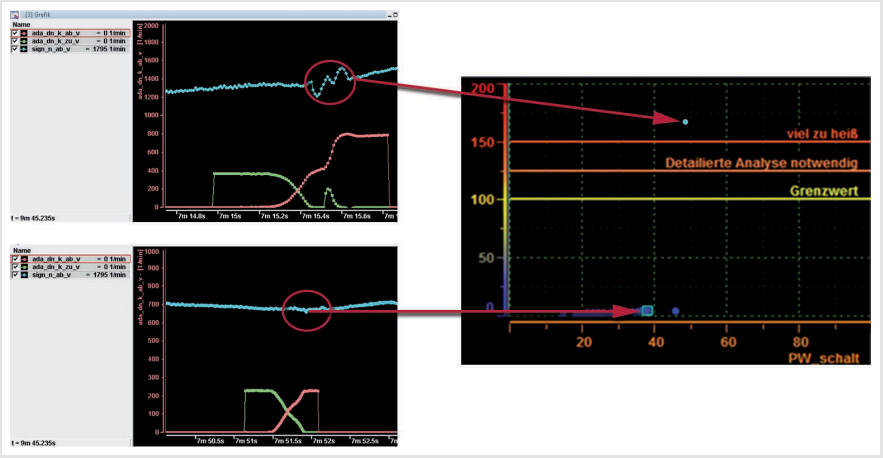

Figure 2:
Data mining functionality is used to identify poor and good gear shift operations in a 2-axis diagram. This lets you quickly detect any limit value violations.

generated which provide a summary of the analysis. They show, among other things, that a 1-2 shift occurred a total of around 1,200 times **(Figure 4)**. The heat entries can be displayed above other physical parameters in XY diagrams, for example. This results in dot clouds, where each point represents a shift operation. The user can then recognize points lying outside of value limits based on their position on the diagram. When a point is selected, the related measurement file is loaded, and the user can generally visualize the value over a time axis in a display diagram. The time segment in which this shift operation occurred is shown directly.

Since the window contents are time-synchronized in CANape, all other windows show the specific contents, e.g. torques or engine speeds, which exactly match the time point at which the selected data point was measured.

In the windows, it is not only possible to show signal responses, but also limit value lines, e.g. the maximum tolerance values for frictional work and frictional power. Points lying outside of the limits indicate limit violations and errors in the shift operation. This makes it easy to identify those gear shift operations that require closer examination.

Flexible Adaptation of the Measurement Data Evaluation

The data mining functions of CANape allow Daimler test and calibration engineers to essentially perform an entire analysis of all of the measurement data and to see whether limit values were violated, or if undesirable events occurred. This is an important step for developers to attain more efficient use of the existing data material, and in the end it lets them arrive at conclusions quicker and more precisely in determining whether a specific ECU software level fulfills the required maturity level.

The requirements for the analysis are subject to a continually changing dynamic. Scripts may be modified either by the end customer or by Vector as a service. If the language tools of CANape are

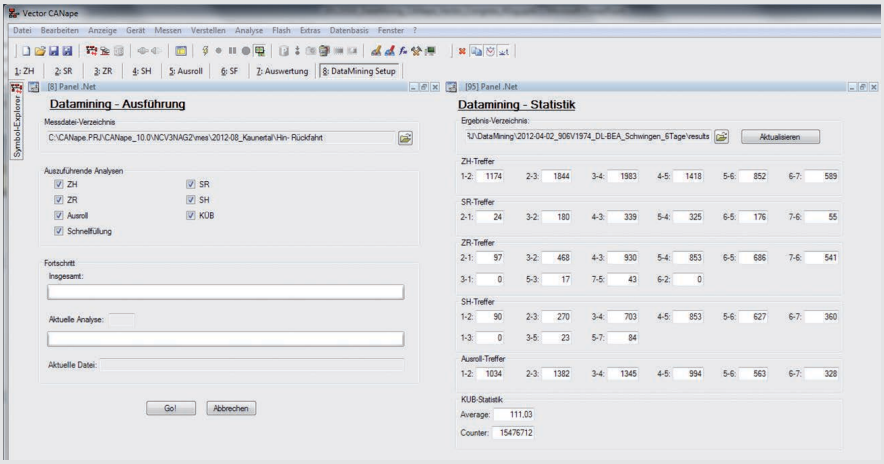

Figure 3:
Data Mining user interface of CANape that was customized to the individual requirements of Daimler engineers.

inadequate for any reason, other function libraries may be generated from C code or Simulink models, and then they can be used as DLLs in CANape. This makes it possible to implement any desired evaluations.

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All figures: Daimler AG

Links:
Daimler AG:
www.daimler.com

Vector Informatik GmbH:
www.vector.com

Product information CANape:
www.vector.com/vi_canape_en.html

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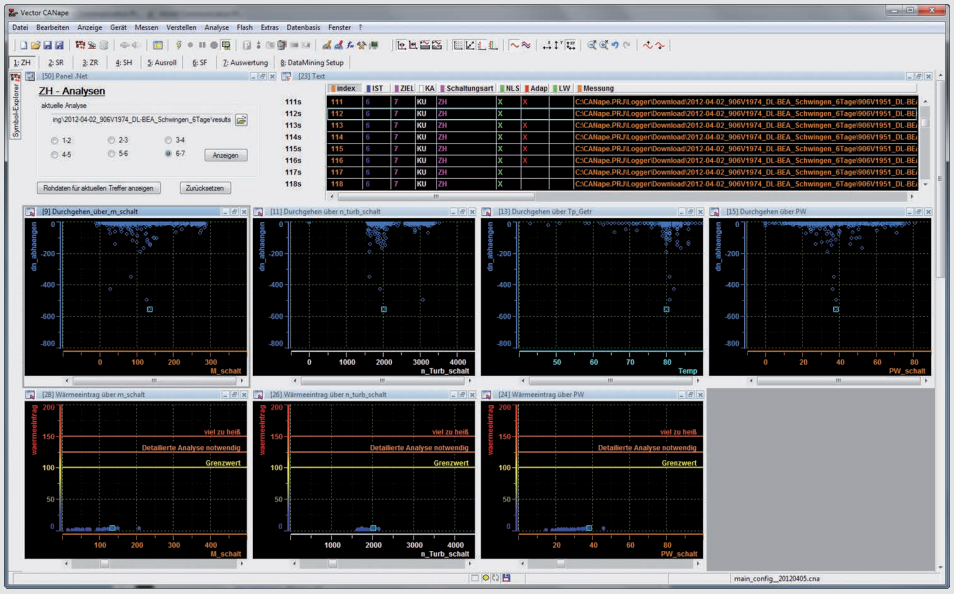

Figure 4:
Evaluation of traction upshift: initial assessments of the durability run can already be made based on information in the predefined display windows.