© Claas, Vector Informatik

Automated Data-driven Validation of the Diagnostic Implementation

Using automatically generated tests for the validation of diagnostic protocol implementation has been practiced for many years. This process is based on diagnostic description files from the automotive OEM. The ECU's diagnostic interface can be efficiently tested in a verifiable way, and this leads to an improvement in product quality. In addition, automated validation of diagnostic parameters and error codes is also possible – depending on how complete the diagnostic description is – as shown in a joint project by Claas and Vector.

AUTHORS

Dipl.-Ing. (FH) Nils Niedermark works as Development Engineer in the Development Electronic Integration Department at the Claas Self-propelled Harvesters GmbH in Harsewinkel (Germany).

Friedemann Löw, B. Sc. is Developer for the Automotive Diagnostics Product Line at the Vector Informatik GmbH in Stuttgart (Germany).

Dipl.-Inf. Simon Müller works as Product Manager for the Automotive Diagnostics Product Line at the Vector Informatik GmbH in Stuttgart (Germany).

TASKS

Claas, an agricultural machine manufacturer, describes the interrelationships between diagnostic parameters and ECU inputs and outputs in its diagnostic data. The description of error setting criteria is formally documented for new implementations. In the past, this information was used to perform manual tests, or test engineers implemented special test cases. However, it was still not possible to attain broad test coverage.

In cooperation with Vector, this information relating diagnostic parameters and ECU I/Os is being automatically linked to the existing network (communication matrix) and hardware description. Fully automated diagnostic implementation tests are generated and executed in a test environment based on existing specification data such as CDD (CANdela Diagnostic Data) or ODX (Open Diagnostic Data Exchange). Correct diagnostic hardware and software integration is tested by automated stimulation of the ECU environment. This is done by modifying signals in the bus simulation or driving specific hardware I/O. So it is possible to test the correct setting of diagnostic parameters, or generate error states and test for their proper memory storage.

AUTOMATED TEST GENERATION

To attain automated test generation and test execution of implementation tests, the diagnostic parameters and ECU I/O must be correlated to each other. Besides the diagnostic data (ODX, CDD), specification data that indirectly references diagnostics is also used. This might include network descriptions (dbc, arxml) or environment configurations such as the interface description of an HiL configuration. This system information can be used to stimulate and measure an ECU's inputs and outputs in a test environment.

Today, the interdependencies between the diagnostic and ECU environments are typically not described formally in the diagnostic data – if they are described at all, they are typically described in natural language. This generally makes it impossible to further process it by automated methods. Heuristics can be of help here and at least enable some use of this information for test automation. If additional detailed OEM-specific knowledge about the type and scope of the ECU I/O description exists, they can be used to derive tests of the diagnostic implementation. In particular, this enables automated diagnostic parameter tests and fault memory tests.

FAULT MEMORY TESTS

The structure and formal contents of the fault memory data are taken from the diagnostic data, such as the layout of the environment data from DIDs (Data Identifiers) and conditions for setting DTCs (Diagnostic Trouble Codes). The latter, however, usually exist in a non-formal description. If the diagnostic description can be interrelated to the ECU's periphery, then it is possible to test whether a DTC is stored correctly in fault memory and under the proper conditions. In addition, it is possible to validate DTC status transitions and proper clearing of DTCs.

The specific setting condition must be known for each DTC. This consists of at least the following:

- I/O type (input or output, network or sensor/actuator)
- I/O name (message name, channel name)
- error pattern (e.g. short circuit to ground).

The error pattern can often be derived directly from the standardised Failure Type Byte (FTB) of the DTC (SAE J2012). Depending on the error pattern, additional information might be needed: threshold values, setting times and information on error monitoring.

DIAGNOSTIC PARAMETER TESTS

Analogous to fault memory tests, diagnostic parameter tests need to know the relationship between diagnostic parameters and the ECU pins. A diagnostic value can be validated by comparing it to a:

- measured value at an ECU pin
- Bus signal
- CCP/XCP signal.

In addition to the I/O type and name, conversions are also necessary to enable comparisons – such as conversion of a resistance value at a sensor to a temperature value in the diagnostic parameter. The updating frequency of the diagnostic parameter or ECU output must also be considered. Furthermore, test values are needed for the I/O stimulation, because they are seldom documented in the diagnostic description, and suitable values generally cannot be derived from specification data.

For both fault memory tests and parameter tests there may be preconditions for the availability of a function to be tested. For instance, grinding the blades of a field chopper requires that the main drive is activated. These interdependencies must be known and considered at test execution.

GOALS AND IMPLEMENTATION AT CLAAS

At Claas, much of the data required for implementation tests are described formally. Therefore, the goal is to automate test generation and execution based on this information. To accomplish this, Claas uses the CANoe.DiVa tool from Vector. The I/O information in the diagnostic description (CDD) and from other sources is imported into CANoe.DiVa to parameterise a test generator. Afterwards, the generated implementation tests are automatically executed in the CANoe test environment that already exists for the ECU under test, **FIGURE 1**.

Claas manages all data relevant to the implementation tests in a development database. Since the data is also imported into the diagnostic description file, this file is usually sufficient to generate the parameter tests. Additional conversion information is only needed for I/O's which use different units in the diagnostic parameter than at the ECU pin. They are contributed in the form of a CANoe mapping that maps signal values to CANoe system variables via a conversion rule.

This data can be used to automatically parameterise and generate three different parameter tests:

- Input tests: The test environment stimulates a sensor pin of the ECU. The associated diagnostic parameter is read out, and it is compared to the value at the pin.
- Output tests: A diagnostic service (I/O Control) writes a new value to the ECU, which causes it to drive an actuator. Afterwards, the value at the output is measured and compared to the value of the written diagnostic parameter.

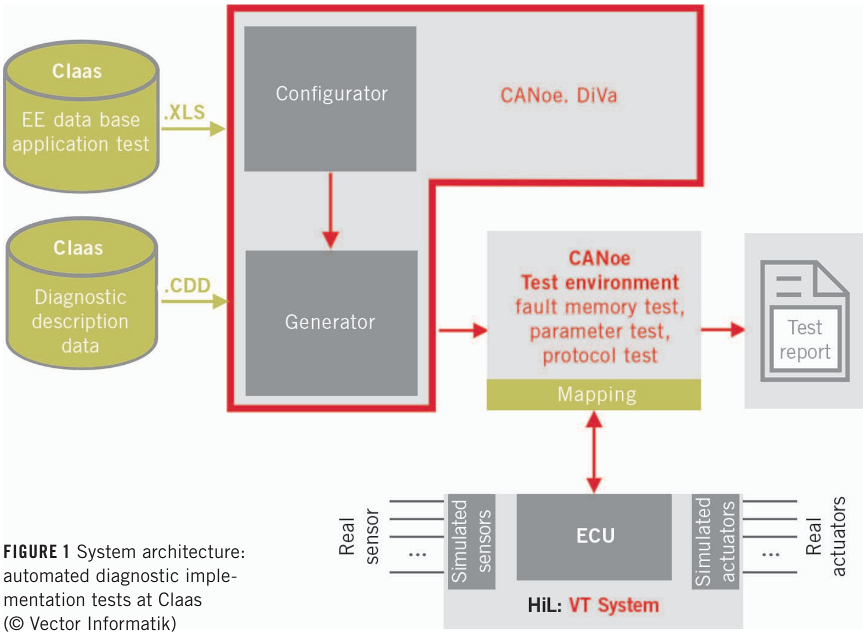

FIGURE 1 System architecture: automated diagnostic implementation tests at Claas (© Vector Informatik)

FIGURE 2 Test setup at Claas for measuring and stimulating voltages at ECU pins with the VT System from Vector (© Claas)

– Passive tests: Some signals cannot be controlled by a diagnostic service; rather they can only be read out. They are controlled solely in the ECU application bypassing the diagnostic layer. In this case, a test can be generated which reads the value at the diagnostic service and compares it to the value at the ECU input or output.

In contrast to parameter data, some of the data needed for fault memory tests at Claas do not exist fully in the diagnostic description. They are therefore exported from the development database as an Excel file and are read in for test parameterisation.

In the test derived from this data, the I/O of an ECU is stimulated to create an error situation. Afterwards, the test verifies whether the correct DTC was stored in fault memory. DTC status transitions and DTC environmental data stored for the error can also be verified by having the test correct the error situation, implement wait times and set the error state again. The fault memory tests are rounded out by checking the clearing of fault memory on different safety levels.

To measure and stimulate voltages and currents at the ECU pins, Claas uses a HiL system from Vector– the VT System, **FIGURE 2**. In order to automatically drive the VT System using the data of the diagnostic description and the development database, name conventions were defined for the VT System configuration.

INCREASING TEST COVERAGE

At Claas, diagnostics-capable ECUs are not only found in combine harvesters and tractors, but also in such machines as mowers and baling presses. In the largest Claas machines, up to 40 ECUs may be installed depending on equipment options. Implementation tests must be conducted for all of these model series. This verifies that the ECU modules can be controlled by the Claas Diagnostic System (CDS). The largest ECU installed by Claas has more than 75 I/Os, with up to 15 different machine functions implemented, depending on the installed machine options. Associated with these I/Os are over 200 DTCs that must be checked in testing.

Automating the generation and execution of more implementation tests reduces the effort required for validation of the ECUs tremendously. OEM-specific extension of the test tool at Claas enables greater test coverage by automated tests of fault memory and diagnostic parameters: from a previous 55 to 95 % currently. Claas has set a goal of subjecting all of its ECUs to automated implementation test with CANoe.DiVa.

The effort required for diagnostic tests of hardware I/O is high, despite automated test generation and test execution. Setting up the test environment is especially time-consuming. Depending on the specific ECU, it can be very complex to drive individual I/Os, and individual access must be implemented. By contrast, validating diagnostic parameters with reference to network signals can be implemented with low initial effort: The necessary infrastructure can be automatically generated by generating a remaining bus simulation from the communication matrix, which can then be used by the test.

SUMMARY AND OUTLOOK

Automated generation and execution of tests – such as those performed at Claas with the CANoe.DiVa tool from Vector – offer great potential for increasing depth of testing while reducing test effort. Currently, for full test coverage with CANoe.DiVa, some functionalities must still be manually configured at Claas, because no formal description is available that could be used for automated parameterisation. For instance, there are I/O’s whose control is very complex in parameter tests. Here, some preconditions in the ECU environment must be satisfied before it is possible to use the I/O as intended.

Similarly, there are also preconditions for some fault memory tests that need to be met before an error monitor becomes active and a DTC can then be recognised and stored in fault memory. The currently implemented tests can still be supplemented by further details such as testing of self-healing functionality, prioritisation of fault memory storage and to test different error situations that lead to the same DTC. The test solution will be continually developed further in these areas.

In the automotive industry, there is also a noticeable trend toward merging development data for electrical and electronic architectures. Databases and tools thereby obtain information, either directly or indirectly, that can be used to automatically test electrical installation and electronic integration with diagnostic software.

Further formalisation of data is associated with greater effort initially. Above all, formal description leads to a rewarding high optimisation potential for automated tests which is well worth the effort. Progress in standardisation (e.g. Autosar) and the integration and interoperability of development tools are leading to a wide variety of new approaches in the field of automated testability. CANoe.DiVa is following this trend and will make use of these new opportunities for deriving further automated tests of the diagnostic implementation.

The possibilities for automated, data-driven tests have hardly been exhausted, and this field will remain exciting.

REFERENCE

[1] Peti, P.; Timmerberg, A.; Pfeffer, T.; Müller, S.; Rätz, C.: Automatic validation of diagnostic services. In: ATZelektronik worldwide 3 (2008), No. 6, pp. 30-35