Ontology-based Knowledge Representation for an Automotive Off-board Diagnostic System

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Abstract: An approach for an ontology based automotive off-board diagnostic system is presented. This approach enables the realization of knowledge-based diagnostic concepts and facilitates the integration of automotive data and processes. On basis of the diagnostic framework GT-DART two knowledge based applications are developed: A workshop application and an authoring simulation application.

1 Introduction

In the last decades the extensive use of computer technology enabled the development of highly sophisticated automotive concepts with new features and functions. Inevitably the number and the complexity of electronic devices and lines of code in automobiles are growing [Ch09].

These complexities induce an increased failure potential. As a result, intelligent methods of diagnostics became more and more important. In this paper we propose the use of an ontology for representing the knowledge of an off-board automotive diagnostic system. This approach enables the realization of knowledge-based diagnostic concepts and facilitates the integration of automotive data and processes.

2 State of the Art

The model-based approach uses detailed models of the according system. Different types of models can be used, e.g. a component-based or a functional model which describe the vehicle by a hierarchical aggregation of its components or functions. Usually such a model is received as a result of a so called FMEA (Failure Mode and Effects Analysis).

When performing a diagnosis, the diagnostic system compares the observed vehicle behavior with the underlying model. For example in the model-based diagnosis by the general diagnosis engine (GDE) [KW87] the existence of a faulty component leads to inconsistency between the observed behavior of the system and the expected behavior described by the model. This is used to identify possible faults.

The major drawback of model-based diagnosis that limits their practical application is that models require detailed knowledge about device operations and the connectivity of the system. Thus, model-based diagnosis is poorly scalable and models of complex systems tend to increase complexity too.

On the other hand the application of the model-based design pattern results in the generation of a structured data basis for the diagnostic application. This allows handling of data by computer since it is machine readable.

The symptom based approach relies on the acquisition and formalization of expert knowledge. In so called expert interviews relevant diagnostics aspects are identified and rated. The method focuses diagnostic knowledge on component and on system level. This approach is not very efficient to identify unknown failures. Therefore, this approach is often combined with early-warning systems to detect problems in the field. Due to the scalability of the approach it is possible to increase diagnostic coverage during the development cycle of the vehicle step by step.

An example for the model-based approach is described in [Hag13]. A variant of the symptom-based approach is described in [Han13].

3 Methods

Existing automotive diagnostic systems are often characterized by a heterogeneous, interweaved tool landscape with incompatible, proprietary data structures. To alleviate these constraints we propose an approach based on a description logic (DL) system for the modeling of automotive data and processes. A DL-system provides a sound and formal basis for the construction of knowledge bases. Furthermore it enables the use of standardized inference services like consistency checking or instance classification for recognition and interpretation tasks [NM08].

3.1 Knowledge Representation

The domain knowledge is defined according to the *Methontology* approach [GFC04]. The result is a list of terms and relations which are structured in a subsumption hierarchy. It is represented in the so called terminology box (TBox) of the knowledge base. The TBox of the presented system includes concepts and roles to organize knowledge about automobile components and functions, diagnostic trouble codes (DTCs), symptoms, causes and solutions as well as descriptions [SSS09]. The TBox is defined once during the development process and is not vehicle specific. Figure 1 depicts the schema of the developed diagnostic ontology.

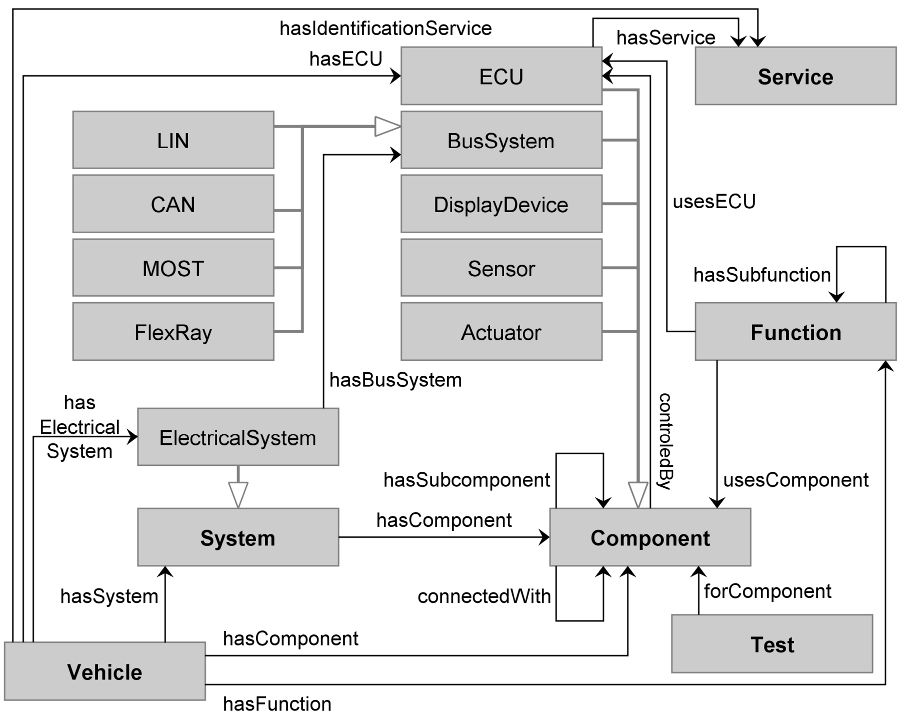

Figure 1: Diagnostic ontology (detail)

3.2 Design of Diagnostic Applications

To design a diagnostic application for a current vehicle it is necessary to include factual knowledge about this vehicle by defining names (individuals) in the so called assertional box (ABox). Depending on the application, further information is represented in the ABox, e.g. the workshop case model of a workshop application. A description of this model, which is used for the failure recognition process, is described in section 4. Using reasoning algorithms on ABox and TBox implicit existing information is made explicit. In the workshop case these algorithms are used to identify causes and solutions of the vehicle's failures.

The objective of this approach is to provide a sound and formal basis for knowledge engineering and enable the application standardized inference services for dedicated diagnostic applications.

4 Results

Prototypical ontology-based diagnostic applications are realized on basis of the Gigatronik Diagnosis and Reporting Toolsuite GT-DART [SS06]. Due to modular client-server architecture and strict separation of program logic (model) and representation (view) the GT-DART framework can be operated on a variety of workshop devices. This enables the realization of diagnostic applications on personal computers, tablets, smartphones as fat or thin client applications. Furthermore the two-layered knowledge model of GT-DART allows the design of knowledge based diagnostic applications.

4.1 Ontology-based Approach with GT-DART

In the first layer car-relevant knowledge is represented. This layer contains knowledge from the development process as well as knowledge from experience. Development knowledge is structured knowledge, e.g. ODX[1]-data which is represented in a XML structure. Knowledge from experience is unstructured knowledge, e.g. the feedback of a workshop employee regarding a workshop case or the result of a log file analysis.

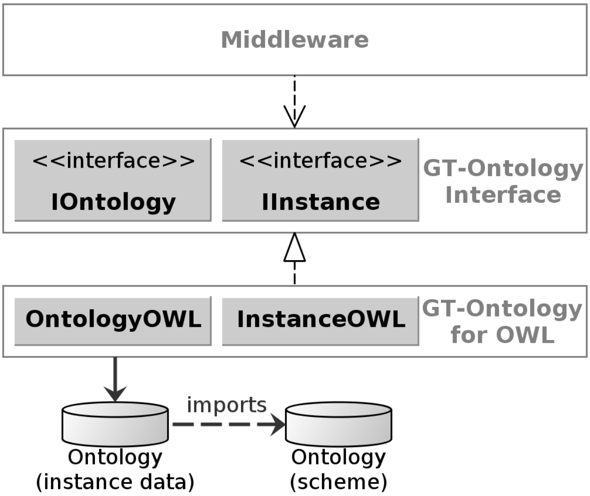

Figure 2: Architecture of GT-DART ontology module

In the second layer process knowledge, e.g. details of the workshop process, is represented. The ontology associates car relevant knowledge with process knowledge and enables its use in a diagnostic application. To realize the knowledge based approach the diagnostic framework GT-DART has been extended by an ontology module. The module realizes an abstract layer to handle ontologies and provides an ontology query language (figure 2). GT-DART applications using this ontology interface are independent of the ontology implementation. At present GT-DART frameworks supports OWL2 / SWRL implementations. On basis of the presented approach two applications have been developed: A workshop application and an authoring simulation application.

[1] Open Diagnostic Data Exchange (ODX) is a standard for diagnostic data (ISO 22901-1).

4.2 Workshop Application

Objective of the GT-DART workshop application is the recognition of failures and failure causes of a vehicle. The diagnostic relevant information about a vehicle is represented in the so called workshop case in the ABox. There are three main aspects to concretize a workshop case: Information about the vehicle's context, information about the vehicle's DTCs and information about the vehicle symptoms. The process chain of the workshop application starts with the acquisition of the vehicle context. This includes information about the manufacturer, model, year of construction and the vehicle's kilometers traveled. This information is used to load the concrete vehicle's ABox. In a second step the workshop employee selects one or more electronic control units (ECU) to read out the current DTCs of the vehicle. In a following step the workshop employee has the opportunity to select one or more symptoms, e.g. noise from right front. In a fourth step a reasoning algorithm is used to determine possible causes. For each cause the solution is presented. Furthermore the workshop employee can navigate through documents that are associated with the current workshop case, e.g. wiring diagrams of the vehicle.

4.3 Authoring Simulation Application

The GT-DART authoring simulation application facilitates the management of diagnostic knowledge. Aside from adding and editing data, an authoring process includes the examination of existing information. Diagnostic knowledge is not only to be treated in a static manner but also within the context of individual workshop cases. Hence a manager of diagnostic knowledge would expect an opportunity to visualize the modeled diagnostic knowledge as well as to simulate arbitrary scenarios in order to revise the computed diagnosis. As a preceding analysis pointed out existing tools are insufficient for this indispensable activity of the authoring process. To fill this gap a simulation application was developed. Beside of some essential functions as browsing and comparing data, it also enables the user to interactively simulate customizable diagnostic scenarios. Figure 3 shows the user interface of the simulation application: On the left side the user is able to compose arbitrary combinations of DTC and symptom states. Following each modification of the scenario, the result is immediately displayed on the right.

The result set of the simulation application equals the result of the workshop application. However it is enriched by additional information indicating how the result was computed, for example why a given failure cause was detected as relevant while another one was ruled out. This facilitates the user to interactively test any desired scenario and get an instant response. This can be used for troubleshooting, for example by reenacting the situation of a faulty diagnosis before and after the supposed correction

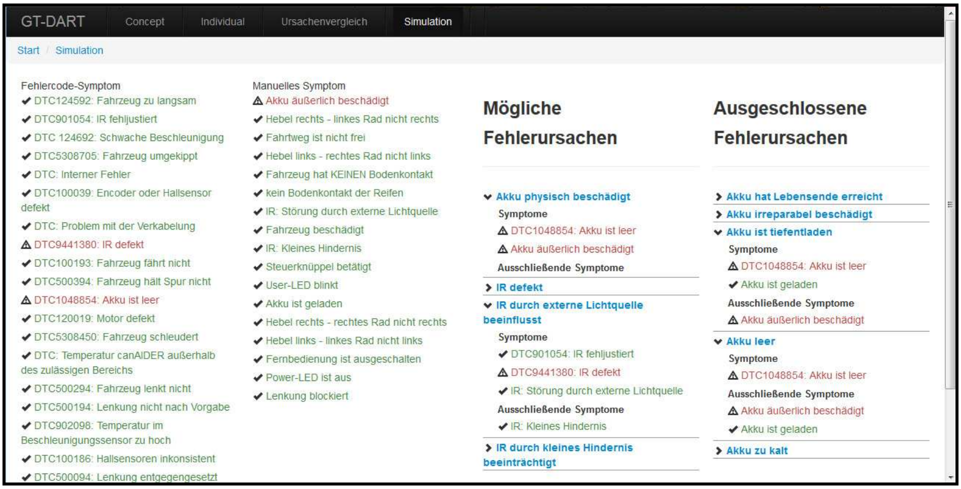

Figure 3: Simulation of a workshop case with GT-DART authoring simulation application

5 Conclusion

An approach for an ontology based automotive off-board diagnostic system has been presented. This approach enables the realization of knowledge-based diagnostic concepts and facilitates the integration of automotive data and processes. On basis of the diagnostic framework GT-DART two knowledge based applications have been developed: A workshop application and an authoring simulation application.

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