

Application of intelligent analysis to identify defective vehicle components

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Abstract. The article shows the possibility of using intelligent analysis in a vehicle service when assessing the vehicle reliability. It was hypothesized that the use of association rules in diagnostics can increase the speed of repairs and the quality of customer service, allowing to identify the nodes that are highly likely to be faulty at the same time. For this, a knowledge base was built from the patterns obtained by applying association rules to the vehicle failure statistics. An application was implemented, which, on its basis, issues recommendations to the repair worker to check certain nodes based on the already identified defective nodes entered into the program. The proposed technique, together with the developed software tool, will optimize the diagnostic processes.

1 Introduction

The development of technics and technology leads to the fact that it is becoming more and more difficult to provide the consumer with the trouble-free operation of his vehicles. The increasing complexity of the vehicle design associated with the use of new engine types (electric energy and hydrogen cells), the transition to fuel alternative types (biofuels, compressed and liquefied natural gas), its intellectualization, leading to an increase in the share of electrics and electronics, impose new requirements for the specialists' qualifications for the detection and diagnosis of malfunctions. One of the factors to ensure the vehicle competitiveness, especially during the warranty period under the manufacturer's responsibility, is to increase customer loyalty. At the operational stage, this is achieved by high-quality service. The main task in the event of a vehicle breakdown is to find all defective units as quickly and accurately as possible, since one of the ways to improve operational reliability is to reduce the repair time. Since diagnostics is associated with the processing of information large amounts, tools to quickly identify complex interconnections through multivariate analysis are needed.

2 Theory: methods used in the analysis of vehicle reliability

Diagnostics and troubleshooting are one of the most important issues in organizing high-quality and fast maintenance and repair of technical systems and vehicles, in particular. To improve these technological processes, it is necessary to first determine the most critical

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units and the sequence of their check. A vehicle is a complex union of elements that interact and interconnect, therefore, it is necessary to search and apply methods and techniques that take into account the mutual influence of vehicle units and parts on each other when one of them fails.

Common methods for analyzing system reliability are failure tree analysis [1], logical-probabilistic method [2-3], failure mode and effect analysis [4], multivariate failure analysis [5-6], fuzzy logic [7], finding of failure distribution functions [8], instrumental diagnostics methods [9-10], for example, based on vibration level measurement [11-12]. However, limitations of the first three methods are the lack of deep systemic knowledge about the design and ongoing processes of the system under consideration. Other methods do not allow to take into account the mutual influence of adjacent parts. In this sense, machine learning methods will remove some of the limitations. In addition, extracting hidden knowledge from the available historical data on the phenomena and processes under consideration, it will be possible to discover non-trivial dependencies that are difficult to identify and analyze even for experts. Machine learning techniques have become an important part of data mining engineering research. They have evolved into powerful tools for developing efficient and accurate solutions to many data-driven decision making and optimization problems [13-15].

Association rules are one of the machine learning methods. It allows to identify common sets of objects in a large collection [16]. Association rules have previously been successfully used to predict customer purchases, help diagnose diseases, analyze and predict telecommunications equipment failures, analyze web page visits [17], and identify factors that affect the likelihood and severity of road traffic accidents [18]. The main advantage of association rules is such a form of calculations results presentation, which is easy for human perception and is available for interpretation by programming languages [19]. It was hypothesized that the use of association rules in vehicle diagnostics can improve the level of customer service, allowing to determine the nodes that are highly likely to be faulty at the same time. Thus, the purpose of the study was to develop a mechanism for helping vehicle service repair workers to make decisions when diagnosing failures in the form of recommendations for monitoring the state of "interconnected" nodes based on already detected defective parts.

3 Results: development of a tool for identifying defective vehicle units

3.1 Building a knowledge base using association rules

To achieve goal to be sought, a method of building a knowledge base using association rules was chosen, which is based on an apriori algorithm capable of processing a significant amount of information in a reasonable time, and as a language for creation - C # application, which in this case is optimal for rapid development complex applications for Windows. To apply the apriori algorithm, we used the Deductor Studio environment - a platform for creating complete analytical solutions. Software development was carried out using the Visual Studio IDE, a Microsoft product that is widely used for developing programs in C #, and has a free Community version for scientific research, educational projects, and open source projects.

The algorithm of the developed decision support mechanism is as follows: an array of records about faulty vehicle units in a file with the extension .xls (MS Excel format) or .odt (LibreOffice format) is used as the initial data for identification. Each entry must contain the following information: (1) Document number (complaint / work order); (2) VIN (engine number); (3) Group of parts; (4) Subgroup of parts; (5) Detail.

The document number is not unique, as it can be repeated in different service centers. Likewise, the engine number can also appear several times, since each vehicle can call in different service centers of the service network. Therefore, the concatenation of the "document number" and "engine number" fields is used as the transaction number. The combination of the fields "group of parts", "subgroup of parts" and "part" allows to uniquely identify the defective part.

This file is imported into the Deductor Studio project, where dependencies are displayed using the "Association Rules" handler. It indicates which parts fail at the same time (Fig. 1). For each rule, such objective significance measures are calculated as support (the frequency of parts' combination occurrence in the data array) and confidence (the probability that the rule will turn out to be true), as well as an subjective measure - lift (characterizes the significance of the rule in the form of the strength of the connection between the part- antecedent and detail-consequent) [20].

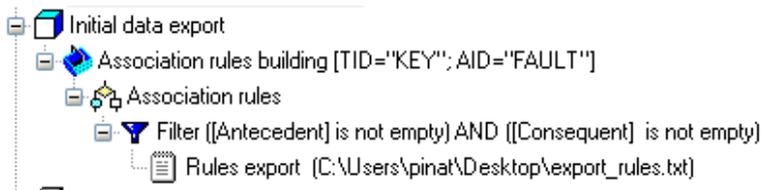


Fig. 1. Built script in Deductor Studio project

As a result of processing complaints data using Deductor Studio, potentially useful rules were derived. They exceed the specified minimum threshold of support and confidence (Table 1). Since the importance of the lift is large, it can be concluded that there is a strong direct connection between the antecedent and the consequent.

Table 1. Obtained meaningful association rules

Rule number	Antecedent, group	Antecedent, subgroup	Antecedent, detail	Confidence	Lift
	Consequent, group	Consequent, subgroup	Consequent, detail		
1	Brake system	Front working brake and brake drum	Pad	76,9	52,5
	Front axle	Front axle and steering knuckle	Support bearing disc		
2	Front axle	Front axle and steering knuckle	Support bearing disc	41,7	52,5
	Brake system	Front working brake and brake drum	Pad		
3	Brake system	Bypass brake valve	Dual-magister valve	26	9,8
	Devices	Oil pressure sensor	Sensor		
4	Devices	Tyre pressure sensor	Pressure sensor	21,2	8
	Devices	Pressure sensor	Sensor		
5	Electrical equipment	Generator	Relay-regulator	41,7	28,8
	Devices	VK403B	Reversing light switch		
6	Cooling system	Fan and its drive	Electromagnetic clutch engagement sensor	26,6	17,2
	Cooling system	Thermostat	Thermostat		

3.2 Developing an application that makes recommendations for checking nodes

The file with the resulting association rules is passed to experts or workers using the application. For example, an updated version of the association rules can be sent out regularly by email.

When launching the developed application, it is proposed to select the imported file (Fig. 2).

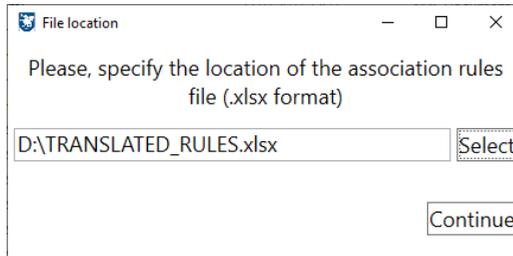


Fig. 2. File with association rules selection form

After adding already identified defective parts, a list of units recommended for inspection is displayed (Fig. 3). For greater convenience, the details proposed for verification are sorted in descending order of the association rules confidence.

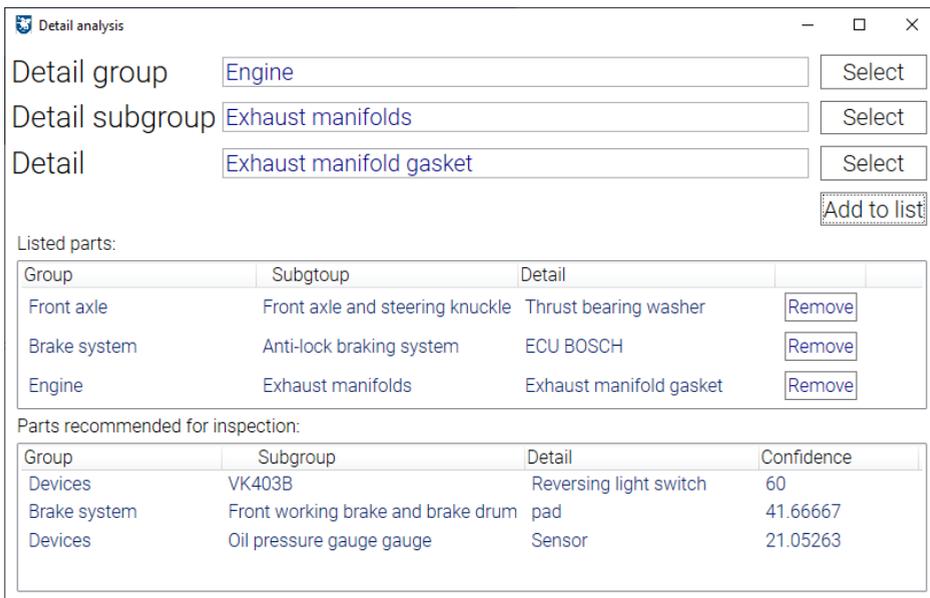


Fig. 3. The main form of the running application

The application is written using Windows Presentation Foundation (WPF), which allows flexible customization of the visual interface (Fig. 4), as well as the use of the data binding mechanism, which breaks the "hard" connection between the interface and the logic of its execution. In case of significant improvements or integration of an existing application into a package with extended functionality, project development will be much easier.

The architecture of the application is based on the construction of the Model-View-ViewModel (MVVM) pattern - a design pattern focused on modern development platforms, including WPF (Fig. 5). Model includes the logic of working with data and the description

of fundamental data. A View is a graphical interface focused on presenting data. ViewModel is a layer between data and a graphical interface that contains application logic. Using MVVM in conjunction with the freeware dependency injection library Autofac will also make it much easier to modify and extend the program in the future.

Dependency injection is the process of providing an external dependency to a software component, when an object instructs an external, dedicated general mechanism to build the dependencies it needs. The source code of the application can be downloaded from the link [21].

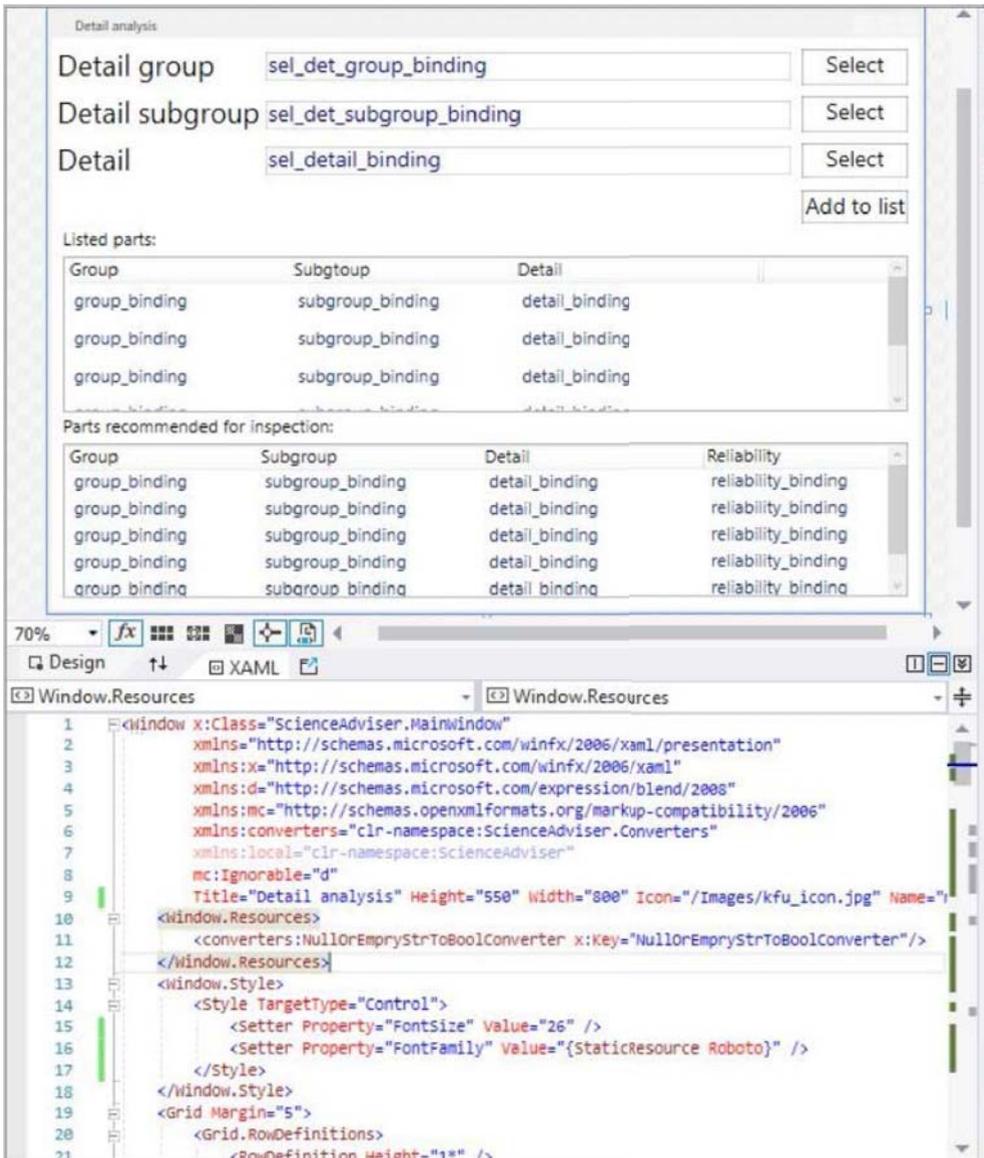


Fig. 4. The application main form in edit mode in Visual Studio

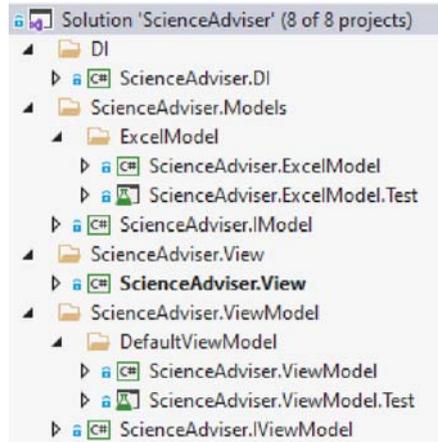


Fig. 5. Project library hierarchy in Visual Studio

Thus, due to the use of modern approaches to software design in project development, the application has the potential for development. The proposed mechanism can subsequently be implemented as a website or mobile application. Also relevant for the project's development is the implementation of the possibility of constant automated updating of the association rules base due to new data arrays from complaints or work order.

Conclusion

The increasing complexity of the vehicle design poses new challenges for the vehicle manufacturer's branded service system in the form of ensuring timely and high-quality maintenance and repair. The study shows that the use of association rules as one of the data mining methods and the introduction of an application developed on their basis in the branded service system will not only improve the efficiency and quality of repair work, but also ensure the reliability of vehicle operation. When diagnosing a vehicle received for maintenance and repair, the employee, in case of identifying any defective part, receives a list of components generated by the application that must be checked. In addition, rule-based recommendations with high support for the supply chain in the form of a list of parts with the least resource (in particular, non-conforming manufacturer) can be developed, and suppliers or manufacturers of such parts can be identified.

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