The diagnostic information valuation method in servicing tractors

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Abstract. The objective of the article was to develop a method of evaluating diagnostic information basing on the existing systems of agricultural tractors diagnostic used in authorized service centers, which will improve of the quality of the evaluation process. Initially, available tractor diagnostic systems were identified in order to gather information about individual diagnostic signals. Following that, the information was verified by empirical evidence concerning a given failure. Thus, the work presents an original evaluation method of the information obtained from the agricultural tractor diagnostic. Obtaining diagnostic information generates certain costs, hence, it is necessary to rationalize and make the processes efficient. Further part of the thesis contains a description and logical verification of the developed method using empirical database. Finally, we presented the method's application for evaluating diagnostic information obtained from the tractor computer diagnostic, in order to examine its effectiveness and for a final verification. The described method of validating diagnostic information creates new cognitive and pragmatic possibilities.

1 Review of the literature

Tractors are complex technical objects which structure consists not only of mechanical elements but also electronic, IT and mechatronic ones. A complex structure of modern tractors raises efficiency of their exploitation measured by cost reduction connected with performing some field works and the ones performed in farms. Electronic and IT modules installed in tractors make it possible to optimise work of mechanical units under given environmental conditions. Such activities increase also tractor reliability decreasing simultaneously effects of a negative influence of machine work on environment.

Tractor work conditions are also special. They are characterised by seasonality which is determined by a specific agrotechnical period during which machine usability necessary to perform certain works is required. The time of the beginning of those works, their finishing time and applied technologies depend mainly on atmospheric conditions. Therefore it is crucial for technical service to be prepared in a wider range and assortment than it is in fact required [1].

Contemporary tractors are equipped with modern drive units fitted with microprocessor control systems, multirange, stepless gears and hydraulic systems as well as board computers for continual machine diagnostics [2-7]. In agriculture, it is crucial for individual treatments (ploughing, fertilisation, sowing etc.) to be performed in a strictly determined period, called an agrotechnical period [8]. It is connected with continuous sustaining condition of machine efficiency by using authorised technical service centres having spare

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parts, sufficiently staffed stands and equipped with computer software for repairing tractors [9-14]. Actions planned in such a manner related to tractor servicing and their state-of-the-art structure made it possible to increase machine efficiency and simultaneously to reduce exploitation costs [15].

The presented above tendencies in automation and diagnostics of working modules and elements of tractors are not free from flaws. Broader application of automation in tractors leads definitely to an increase in controlling their working parameters and enables a prompt reaction in emergencies. However, flawed information gained from one or a few sensors installed in certain tractor units may be the reason for making incorrect decisions by technical service or unnecessary tractor downtime e.g. during higher intensity of field works.

A crucial element of an efficient tractor automatic control system and diagnostic functioning is to provide a proper manner of transmission and prioritisation of sent information between particular drivers and sensors as well as between a central driver of diagnostic management and an external receiver (at a vehicle diagnostic station, in a producer's data base etc.).

In such a context it is advisable to develop a data valuation method obtained during tractor diagnostics regarding assumed criteria e.g. minimum repair time of certain tractor units or a minimum cost connected with a vehicle downtime in a service station. A developed method may be applied to support and optimise decision making processes in diagnosing, servicing and exploiting tractors.

2 The aim of the article

The aim of the article is to develop the method enabling valuation of diagnostic information and its verification on the example of tractors.

3 Method

The article is of a methodical character and as a result of it a universal method of valuation diagnostic information in servicing processes of tractors has been developed.

The information was obtained from tractor construction documentation and technological documentation of their servicing. Following its analysis, enriched with own practical experiments, there was created the knowledge base of a process structure, its objects, relations with environment and problems with functioning which are going to be a base for the developed method.

An integral part of the developed method was to create a data base of actual damage and diagnostic information.

In order to obtain that, observations and surveys were conducted. They involved identification of actual damage and diagnostic information about it. The criterion of tractor selection for the research was their share in a general number of tractors exploiting in agriculture. Five tractor makes were selected to the research: Valtra, John Deere, New Holland, Zetor and Massey Ferguson which according to AgriTrac data 2005-2015 account for more than 50% of the market share of the new machine market.

The tractors which were investigated had either experienced a failure or their malfunction had been discovered during scheduled servicing. In case of a failure, a tractor was delivered to a service station in which a malfunction was found during servicing by a diagnostic system. Information about damage is visible on a board computer as a failure code or only after connecting an external computer with software compatible with a serviced tractor. A failure code or oral information is a signal which generates a string of variants of possible failures. Unfortunately, a few variants of failures are often assigned to one signal. In such a case, a person performing diagnostics needs to make a decision which variant is to be checked as first. Such machines after removing a malfunction will have

work parameters of particular units the same or very similar to values before a failure has occurred. The diagnostic process of a tractor is presented in Fig. 1.

Fig. 1. A scheme of tractor diagnostics (own work).

4 Mathematical model of the method

In order to create the base of possible damage variants gained from one signal it is essential to collect proper data. The collected information was recorded using a relation in which one signal S , is a set of information variants n_w of a proper quantity (1):

$$S = \{n_w\} \tag{1}$$

where: S – a single diagnostic signal,
 n_w – a number of possible information variants.

From a gained diagnostic signal it is possible to generate a certain set of information n_w with a determined probability of occurring each of it.

Such an empirical system with a set of probable variants of its realisation being information in technical diagnostics can be described using information entropy.

The examples of information entropy application are included in the following works (Rzeźnik and Molińska, 2003; Ludwikowski, 2008; Bennington and Cummane, 1998; Dowdy et al., 2004; Hellwing, 1998), among the others.

The statistical information theory describes information entropy taking into account probability of event occurrence (information variants). The theory is applied to machine diagnostics as during diagnostic tests a machine generates a certain amount of information which should be used during recognition of its technical condition. The source of diagnostic information possible to be obtained is the knowledge about a machine structure, experience stemming from exploitation of that type of machines as well as a properly conducted interview with an operator. The information collected in such a manner may be used to diversify probability of damage occurrence of machine parts. In order to calculate an amount of lacking diagnostic information (information entropy) one uses the statistical information theory. It is mainly used during valuating logical experiment efficiency.

Applying the described scheme of valuating information, at the beginning a set of possible damage variants obtained from a certain signal on the basis of data from repairing

documentation and data from diagnostic computer systems was created. At that stage of the method formulation it was assumed that the occurrence of each information variant generated by a certain signal was equally probable.

On the basis of the set of information variants developed in such a manner, the amount of lacking information – thus information entropy of each signal occurrence – was calculated. The equation of Shannon structural information theory was used to assess the amount of lacking information – information entropy at the same probability.

Servicing documentation and also computer diagnostic systems do not include all possible variants of a malfunction as in the case of a printed version it would be too unclear to include all information and in the case of computer diagnostic systems waiting time for complete diagnostics would be very long. Producers included the most common damage variants in the documents. However, as practice shows, there happens to be tractor models in which failures are different than the ones described by a producer. It may result from negligence at design or production stages. Therefore in order to create more precise sets, there was conducted empirical research among workers of authorised tractor service stations selected to the analysis of makes in the doctoral dissertation and of a possible malfunction to occur. Damage variants which had not been investigated before and were added by workers enabled creation of a more precise and more numerous information set. The amount of information entropy for a given signal in which damage variants of parts or units pointed by service workers were added varies. Their values were determined on the basis of service cards of damage being the reason for an investigated malfunction.

Following an analysis of service cards and included data, information variant probability was differentiated and information entropy was calculated using a statistical information theory equation.

The conducted analysis shows that it is possible to determine numerically the amount of lacking diagnostic information (information entropy) using the information theory. Additionally, due to providing a machine operator with a proper training or protecting properly wire connectors it is possible to reduce the amount of lacking diagnostic information necessary to be gained by instrumental diagnostic methods. It will increase efficiency of a tractor servicing process not only in terms of diagnostics.

Such enriched instrumental diagnostic information will help to eliminate the most unreliable spots and to check them as first and only when verification is positive, a service worker will proceed to control particular variants arranged according to probability of their occurrence. The least probable variants and the ones which occurrence depends on faulty machine operation by an operator will be eliminated from the variant list and their probability will be assigned in an even proportion to remaining variants. Final results are obtained calculating information entropy for variants which have been left after eliminating the most fallible ones.

While developing the mathematical model of valuating diagnostic information in servicing tractors, information theory and practical realisation of servicing processes were used.

As a result, the logical model describing that exploitation area was described which its logical correctness and practical utility required to be checked.

5 Logical verification of the method

The logical verification of the developed method requires checking whether a diagnostic information value obtained from it is pertinent to actual damage.

The research was performed for 100 tractors in which a signal was a malfunction of a rear power take-off (PTO) during diagnostics using a diagnostic computer system. Following selection and division of data three possible signals were obtained informing

about damage of a rear power take-off where each of them contained information about a few variants of damage.

Table 1 presents the verification of the above method. The results of all stages are presented in one table.

Table 1. Comparison of lacking diagnostic information (information entropy) for a rear power take-off.

l.p.	Signal type	Lack of possibility to start a rear power take-off	Lack of possibility to stop a rear power take-off	Lack of possibility to change the number of rotations of a rear power take-off
	The manner of obtaining information			
1.	on the basis of repairing documentation and information from diagnostic computer systems	2.32	2.00	0.00
2.	from item 1 extended by information from employees of service stations	2.81	2.32	1.00
3.	on the basis of actual repairing cards	2.55	2.01	0.81
4.	after eliminating damage variants possible to be averted	1.96	1.00	0.00

On the basis of the data presented in the table it can be observed that the biggest information entropy occurs when all variants are equally probable and they include possible damage given by mechanics of authorised service stations whereas after eliminating variants likely to be averted we need the least information necessary to diagnose damage of a rear power take-off.

On the basis of the obtained data we can develop a list of recommendations for the order in which particular damage should be localized. In case of a failure to start a rear power take-off, the following diagnostic checks are recommended:

- damp or soiled wire connections,
- damage of an automation switch in a service console,
- damage of a switch in a rear wing,
- damage of a rotation sensor,
- damage of a rotation valve 1000,
- damage of a rotation valve 540,
- damage of clutch disks.

Other recommendations regard a sequence of diagnostic checks in identifying the reason for the lack of possibility to disconnect a rear power take-off. They include:

- damp or soiled wire connections,
- damage of a switch in a rear wing,
- damage of an automation switch in a service console,
- the number of journal rotations is flawed,
- damage of a rotation sensor.

Whereas for a signal about no possibility to change the number of rotations of a rear power take-off firstly we check whether connections of wires are not damp or soiled and then we check whether a switch of speed selection has not been damaged.

6 Summary

The logical verification of the developed method confirmed that numerical valuation of diagnostic information value results logically from technical condition of an assessed unit. The base for proper functioning of the developed method is to create a pertinent variant set for a particular signal and a proper verification of the most unreliable parts of a tested tractor unit. All of the above allow a hypothesis to be formulated that the method can be also applied to other units of a tractor.

After a positive verification of the diagnostic information valuation method, it has been applied to a few other signals obtained during tractor computer diagnostics in order to check its practical usefulness.

References

1. P. Rybacki, *Agricultural machines servicing quality assessment system*, (Wyd. Uniwersytetu Przyrodniczego w Poznaniu, 2012)
2. S. Juściński, W. Piekarski, *Agricultural Engineering*, **2(100)**, 57-65, (2008)
3. S. Juściński, M. Szczepaniak, *Eksplatacja i Niezawodność*, **2(38)**, 45-52, (2008)
4. T. Pokusa, *Logistyczna obsługa i lojalność klienta jako orientacje rynkowe*, (Wyd. Instytut Śląski, 2001)
5. A. Skrobacki, A. Ekielski, *Pojazdy i ciągniki rolnicze*, (Wyd. Wieś Jutra, 2006)
6. P. Rybacki, C. Rzeźnik, K. Durczak, *TROL*, **2**, (2011)
7. L. Dwiliński, *IBMER*, **7**, 7-36, (1973)
8. L. Dwiliński, *Rocznik Nauk Rol.*, **69(C2)**, 25-28, (1972)
9. M. Ciesielski, *Logistyka w praktyce-studium przypadków*, (Wyd. Akademii Ekonomicznej, 2002)
10. D. Kempny, *Logistyczna obsługa klienta*, (Wyd. Ekonomiczne, 2001)
11. S. Juściński, W. Piekarski, *Eksplatacja i Niezawodność*, **2(38)**, 25-33, (2008)
12. S. Juściński, W. Piekarski, *Agricultural Engineering*, **8(117)**, 23-30, (2009)
13. J. Banasiak, *Agrotechnologia*, (PWN, 1999)
14. S. Juściński, M. Szczepaniak, *Agricultural Engineering*, **2(100)**, 67-74, (2008)
15. Z. Grześ, *Agricultural Engineering*, **2(100)**, 37-42, (2008)

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