Nonconventional Technologies Review
Romania, March, 2017

TAKING DECISIONS IN THE DIAGNOSTIC INTELLIGENT SYSTEMS ON THE BASIS INFORMATION FROM AN ARTIFICIAL NEURAL NETWORK

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ABSTRACT: This paper presents a method to control an operation process of a complex technical object, with the use of trivalent diagnostic information. Also, a general diagram of the complex technical object was presented, and its internal structure was described. A diagnostic analysis was conducted, as a result of which sets of the functional elements of the object and its diagnostic signals were determined. Also, the methodology of the diagnostic examination of the technical system was presented. The result was a functional and diagnostic model, which constituted the basis for initial diagnostic information, which is provided by the sets of information concerning the elements of the basic modules and their output signals. The theoretical results obtained in the present study were verified in practice on the example of a complex and reparable technical object. It belongs to the group of technical equipment for which a short time of shutdowns is required (an ineffective use of the object).
KEYWORDS: intelligent system, servicing process, system modelling, expert system, artificial neural networks, knowledge base, diagnostics information.

1. INTRODUCTION

Technical diagnostics facility provides the user with diagnostic information for the organization of the use. A particular example is the information expressed in trivalent logic. Diagnosing technical objects in trivalent logic identifies the object states: fitness - {2}, the state of unfitness - {0}, and the incomplete state of fitness - {1} [1, 2, 7-12]. The resulting diagnostic information about the object with such a diagnosis, due to the recognition of the suitability of the incomplete state of the inside of the object of knowledge is the basis for deciding maintenance or use organizing strategies of constructing a new direction in the handling of technical objects called the handling of the prior [3, 7, 13-17, 19-27, 28]. In this situation, when these two areas of expertise: theory and the theory of diagnostic use of technical facilities, cooperate with each other in the organization of the use of a technical object, you can no longer talk about the operating system.

However, new solutions and possibilities are constantly being sought; hence, the author's papers and studies are presented concerning a practical application of a trivalent evaluation (classification) of the object's states [4-7, 9, 10]. However, there is no full description in the literature of methods to develop ways and algorithms for the processing of diagnostic information obtained by diagnostic systems: an artificial neural network etc. to the form of an expert knowledge base of a maintenance system, presented in a computer programming language [7, 13-17, 21]. A new problem, which in the author's opinion requires a solution, is the use of information developed in the trivalent evaluation of information states by the artificial neural network of information (knowledge) for the development of the method to control the prevention of technical objects, referred to in the literature as operation according to the object's state.

The literature in the references concerns papers which were written after the year 1985 as well as later studies up to the year 2016.

The papers by (Barlow 1995, Birolini 1999, Nakagawa 2005 and Pokoradi 2015) [1, 2, 19, 20-24] presents the theoretical background of the reliability of technical devices in the operation process. The author presented mathematical basis of the policy rules of the organization of repairs (replacement of components (constructional elements)) of devices. Another important practical problem which was solved in the study is the representation of the ways and methods to set periods of repairs (replacements of functional parts) of devices and their optimization.

The paper also covers preventative maintenance procedures including drawbacks of this type of maintenance. A large part of the paper deals with the issues of the development and verification of the maintenance policy strategy. The study is also of a large practical importance as regards the organization of the development of theoretical models of technical devices' maintenance processes as well as the conditions and rules of their modification.

The paper by (Duer 2012 and 2013, Kobayashi 2011, Rosiński 2010) [5, 6, 7, 8, 10, 11, 16, 25-26] constitutes the first item in the references. It covers the theory of operation of technical devices. It includes a mathematical description of a model of a technical object as regards its reliability and operation. The paper also presents an organization of the operation process with the use of the object's models presented. The authors also possess a lot of experience in diagnostic testing of technical devices, the effect of which is their previous studies.

The studies (W. Kacalak 2012, D. Waterman 1986, I.M. Zurada 2007) [13-15, 17, 29] includes theoretical and mathematical grounds of the functioning of artificial intelligence and export systems. The author presented and characterized the difference between these fields of knowledge. The paper constitutes a guide as regards the elaboration of the set of inferring rules, knowledge representation, its collection and ways of analysis. To a large extent, the paper assists practical problems connected with the creation of expert knowledge, including its application in the diagnostics and operation of technical devices.

The paper by M. M. Gupta, L. Jin, N. Homma, W. Kacalak [13-15, 18] constitutes a valuable compendium of knowledge on the functioning of artificial neural networks. The paper also includes biological and mathematical background of the construction and functioning of a single neurone and a neural network. The authors described well the theoretical grounds of the construction of static neural networks as well as ways to teach and train them. The paper is useful for the purpose of designing artificial neural networks of various types, including those which function on the basis of radial base functions. The authors also made great efforts to develop chapters in their paper concerning dynamic neural networks, the rules concerning their construction, teaching and training. A substantial part of the work concerns the use of sets and fuzzy knowledge in the functioning of artificial neural networks.

The paper by (Duer 2010-2016) [4-7, 8, 10, 24], makes the use more specific (and improved) of the results of diagnostic testing in the organization of a technical object's maintenance system. The paper presents the mechanism of a negative change of states in a technical object, as a result of which there occurs in the object a reduction of its operational properties: a change of the state. The author also presented a diagram and a description of artificial neural network structures and mathematical dependencies which express the idea of the functioning of the network in compliance with the algorithm developed for it. The paper also presents theoretical grounds for diagnosing of technical objects in trivalent logic with the use of an artificial neural network. The results of the study were supported with an example of a diagnostic information database for the device tested.

The study by (Barlow 1995, Rosiński 2008) [1, 26] covers mathematical basis for the reliability and the quality of operation of technical devices in probabilistic and statistical approaches. Methods of an analysis and testing of reliability with the use of Markow's method (among others) were discussed. The paper includes well-developed mathematical models of reliability for technical, medical etc. devices (products).

The knowledge of the operation process of a technical object through the determination of the times of the occurrence of repairs (shutdown) and operation will make it possible to control this process (Fig. 1).

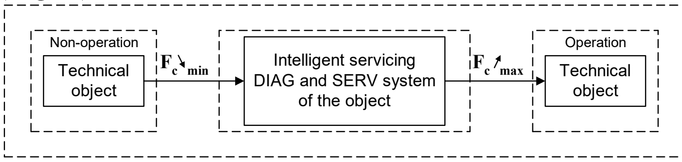

Figure 1. Diagram of an intelligent system for regulation agreement of the quality of the use of the object (F_C)

where: F_{Cmin}, F_{Cmax} – min. and max. value of function of the use of the object, DIAG - is a powerful computer software, a hybrid, a combination of neural network with the module diagnostic inference. DIAG is designed to diagnose analog-class technical objects, SERV – Expert software is a computer program designed to assist in the process of determining the knowledge base maintenance of the technical object.

The application of an automatic adjustment and control system (Fig. 1) of the level of the functional properties of a technical object constitutes an appropriate approach to the issue of a qualitative control of the use of a technical object in the process of operation. The purpose of this adjustment system is to maintain in an automatic and continuous manner the functional properties on the required level (which guarantees a qualitative use of the object). The automatic diagnostic system (Fig. 1) utilizes not only a measurement A/D converter card with appropriate signal interfaces but also some computer tool used for proper signal registration as well as for acquiring and processing data registered [1, 2, 3, 7, 18, 27, 29].

The purpose of such a process is to build a diagnostic knowledge base basing upon an analysis of both the object and the results of the measurement stored.

2. THE INTELLIGENT DIAGNOSTIC SYSTEM OF THE TECHNICAL OBJECT

The object's state is determined on the basis of an examination of the set of output (diagnostic) signals $\{X(e_{i,j})\}$(Table 1) [4, 5, 7, 9]. The set of its functional elements $\{e_{i,j}\}$ determined during a diagnostic study of the object constitutes the basis for the list included in the table of a set of diagnostic signals (Table 1).

Table 1. Table of object's input diagnostic signals

Object	Level of object E_i	Vector of initial diagnostic signals $\{X(e_{i,j})\}$				
		$X(e_{1,1})$	...	$X(e_{i,j})$	...	$X(e_{i,J})$
O	E_1	$X(e_{1,1})$	...	$X(e_{1,j})$	...	$X(e_{1,J})$
	⋮	⋮	...	⋮	...	⋮
	E_i	$X(e_{i,1})$	...	$X(e_{i,j})$	...	$X(e_{i,J})$
	⋮	⋮	...	⋮	...	⋮
	E_I	$X(e_{I,1})$	...	$X(e_{I,j})$	...	$X(e_{I,J})$

where: $X(e_{i,j})$ – diagnostic signal of j^{th} element in i^{th} assembly, E_i – i^{th} functional assembly of the object, e_j – j^{th} subassembly in i^{th} assembly of the object.

The realization of the task of a comparison of the image of the diagnostic signal with the image of its standard (nominal) signal is the purpose of the neural network in that is used in the diagnostic system [4, 7]. For this purpose, it is useful to present the images of the diagnostic signals compared in a vector form. The analytical form of the equation which describes the diagnostic process of technical objects (Fig. 1) performed with a comparison method of signals with their model, was presented in the form of the following dependence:

$$\underset{e_{i,j}\in\{E_i\}}{\forall}\ \underset{X(e_{i,j})\in X}{\exists} X(e_{i,j}) \mapsto \underset{e_{i,j}\in\{E_i\}}{\forall}\ \underset{X_{(w)}(e_{i,j})\in X_{(w)}}{\exists} X_{(w)}(e_{i,j}) \Rightarrow W(\varepsilon(e_{i,j})) \quad (1)$$

where: $W(\varepsilon(e_{i,j}))$ – value of state assessment logics for j^{th} element within i^{th} module, $X(e_{i,j})$ – diagnostic signal in j^{th} element of i^{th} of the object, $X_{(w)}(e_{i,j})$ – model signal for $X(e_{i,j})$ signal, E_i – i^{th} functional assembly of the object.

The effect of such an activity (comparison) of signals is a decision, which is worked out by the network, as to which of the three distinguished states {2, 1, 0} a given element of the object which worked out this signal, is to be qualified to.

In the literature which describes neural networks Minkowski measure is used in network methods based on the rule of similarity for an analysis of the metrics of vectors of signals. It is presented in the form of the following dependence:

$$D_M(X_i, X_{(w)i}, \alpha) = \left(\sum_{i=1}^{N} \left|X_i - X_{(w)i}\right|^{\alpha}\right)^{1/\alpha} \quad (2)$$

where: $D_M(X_i, X_{(w)i}\ \alpha)$, – standard deviation of the vector the signal metric, ($\alpha = 2$).

The network whose diagram is presented in (Fig. 2) consists of three layers: F_1 – input layer, F_2 – hidden layer and F_3 – output layer. The neural cells of the network process te diagnostic information according to the algorithm (Fig. 2).

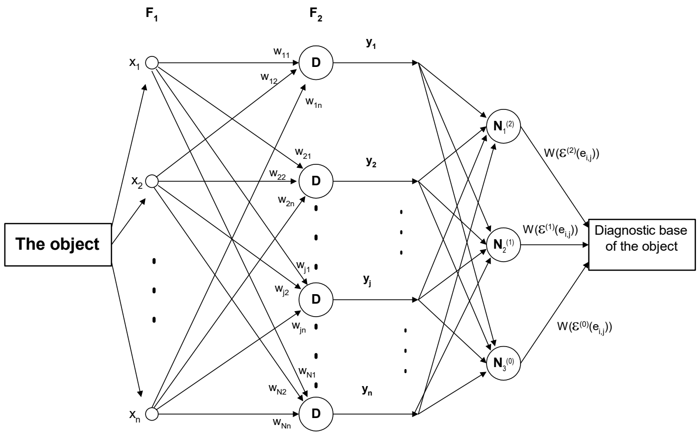

Figure 2. Structure of an artificial neural network in the DIAG system

The results were obtained from the diagnosis of the object examined according to the diagram presented in (Fig. 2), which are calculated as a result of the realization of dependences (1 and 2), which are set up in the form of the table of states (Table 2).

Table 2. Table of the states of the object's elements

Number of the assembly	Vector of the states of basic elements in the structure of the object $\{e_{i,j}\}$				
	$\varepsilon(e_{1,1})$	...	$\varepsilon(e_{i,j})$	...	$\varepsilon(e_{i,J})$
E_1	$W(\varepsilon(e_{1,1}))$	...	$W(\varepsilon(e_{1,j}))$	...	$W(\varepsilon(e_{1,J}))$
⋮	⋮	...	⋮	...	⋮
E_i	$W(\varepsilon(e_{i,1}))$	...	$W(\varepsilon(e_{i,j}))$	...	$\varnothing$
⋮	⋮	...	⋮	...	⋮
E_I	$W(\varepsilon(e_{I,1}))$	...	$W(\varepsilon(e_{I,j}))$	...	$W(\varepsilon(e_{I,J}))$

where: $W(\varepsilon(e_{i,j}))$ - is the value of the state of j^{th} element in i^{th} unit (from the set of the accepted trivalent logic of the assessment of states -{2, 1, 0}), $\varnothing$ is the element which complements the dimension of the table.

3. TAKING DECISIONS IN THE DIAGNOSTIC INTELLIGENT SYSTEMS ON THE BASIS INFORMATION FROM AN ARTIFICIAL NEURAL NETWORK

The neural network of the diagnostic system (Fig. 3) identifies – classifies the states of the set of distinguished basic elements in the structure of the object $\{e_{i,j}\}$. The results of the diagnosis of the object are presented In the final form in (Table 1). The current state of the functional units of the object $\{E_i\}$ and the state of the object under examination {O} is determined on two stages by the inference module in the diagnostic system. On the first stage, the diagnostic module determines the state of (i^{th}) units of the object. For this purpose, the states of (j^{th}) functional elements are analyzed in a given (i^{th}) unit of the object. The inference rule to identify the state of (i^{th}) functional unit of the object takes the form of the following dependence:

$$W(\varepsilon(E_i)) = \min_{1 \le j \le J} (W(\varepsilon(e_j)) \qquad (3)$$

where: $W(\varepsilon(E_i))$ - is the value of the state of i^{th} functional unit of the object, $W(\varepsilon(e_{i,j}))$ - is the value of the state of j^{th} element in i^{th} unit (from the set of the accepted trivalent logic of the assessment of states -{2, 1, 0}).

The idea of the identification of the states of units presented in the form of dependence (3) is graphically depicted in (Fig. 3). It results from the analysis in (Fig. 3) that if at least one of the states of the elements contained in the structure of a given (i^{th}) unit is in the state ($W(\varepsilon(e_j))$) with the lowest valence marked from set - {2, 1, 0}, the state of a given unit, which is interpreted with the inference rule (dependence 3), is such as the lowest state of this (j^{th}) element.

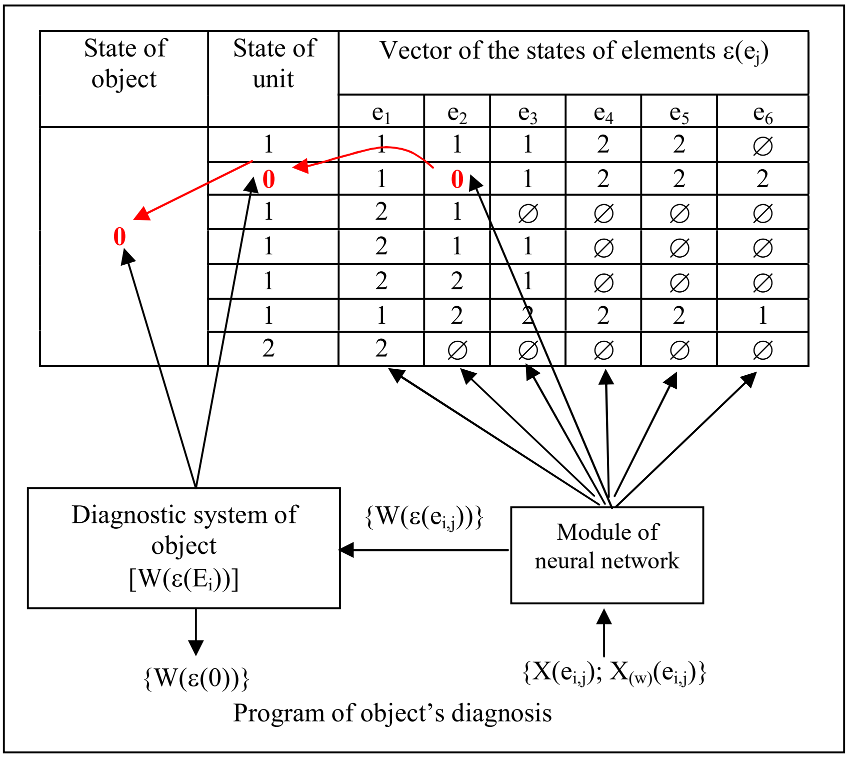

Figure 3. Scheme of the making decisions in the diagnostic intelligent systems on the basis information from an artificial neural network

The state of the object of diagnosis is determined on the second stage of the work of the diagnostic module. The determined set of states of (i^{th}) units of the object ($W(\varepsilon(E_i))$) is the base of this inference process. For this purpose, the states of (i^{th}) functional units of the object are analyzed. The inference rule to identify the state of the object is presented in the form of the following dependence:

$$W(\varepsilon(O)) = \min_{1 \le i \le I} (W(\varepsilon(E_i)) \qquad (4)$$

where: $W(\varepsilon(O))$ - is the value of the state of the object, $W(\varepsilon(E_i))$ - is the value of the state of i^{th} functional unit of the object (from the set of the accepted trivalent logic of the assessment of states -{2, 1, 0}).

The idea of the identification of the states of object ($W(\varepsilon(O))$) on the grounds of the states having been distinguished in its structure of units {E_i}, which is presented in the form of dependence (4), is also graphically depicted in (Fig. 3). It is evident from the analysis in (Fig. 2) that if at least one of the states of units ($W(\varepsilon(E_i))$) contained in the structure of the object, is in the state ($W(\varepsilon(E_j))$) with the lowest valence marked from the set of states {2, 1, 0}, then the state of the object, which is explained by the inference rule (dependence 4), is such as the lowest state of this (i^{th}) unit. The final result of the examination of the state of a technical object in an intelligent diagnostic system can be presented in a tabular form (cf. Table 3).

Table 3. Table of the states of object

State of object	State of unit	Vector of the states of basic elements $\{e_{i,j}\}$				
		$\varepsilon(e_{1,1})$	...	$\varepsilon(e_{i,j})$	...	$\varepsilon(e_{i,J})$
$W(\varepsilon(O))$	$W(\varepsilon(E_1))$	$W(\varepsilon(e_{1,1}))$	...	$W(\varepsilon(e_{1,j}))$	...	$W(\varepsilon(e_{1,J}))$
	⋮	⋮	...	⋮	...	⋮
	$W(\varepsilon(E_i))$	$W(\varepsilon(e_{i,1}))$	...	$W(\varepsilon(e_{i,j}))$	...	∅
	⋮	⋮	...	⋮	...	⋮
	$W(\varepsilon(E_I))$	$W(\varepsilon(e_{I,1}))$	...	$W(\varepsilon(e_{I,j}))$	...	$W(\varepsilon(e_{I,J}))$

4. EXAMINATION OF THE QUALITY OF THE REGENERATION OF AN OBJECT IN A MAINTENANCE INTELLIGENT

SYSTEM WITH THE USE OF DIAGNOSTIC INFORMATION OF THE OBJECT

The examination the method of taking diagnostic decisions on the basis of the quality of the regeneration of an object in a maintenance system (Fig. 3) organized on the basis of maintenance information was conducted for the two following manners of expert inference:

1. The method of taking decisions by an intelligent system (model I).
2. The traditional method of taking decisions in the case of a finished set of the probabilistic method (model II).

The core of the qualitative process of the preventive procedures of a technical object involves a two-stage examination. On the first stage, a regeneration (model I) of the object is conducted on the basis of the maintenance information (Fig. 3) which is determined with the use of a given expert inference method. It is only on the second stage that the quality of taking decisions by an expert for simple parametric type hypotheses these procedures is assessed on the basis of control diagnosing of the object after the one method procedures have been conducted. The diagnosing of a control object is performed in a diagnostic system with the use of the (DIAG) neural network. It was assumed in the experimental examination of the methods (model I) and (model II) [2, 4, 6].

The first method of the object's (model I) is performed with the use of the method of taking decisions by an expert for simple parametric type hypotheses (model I). From there, the testing vector was developed of the maintenance information being determined for the method (model I), which accepts the following form (5) and (Table 4):

$$\{M_E(e_{i,j})_I\} = \lfloor M_E(e_{1,1})_I, \ldots, M_E(e_{i,j})_I, \ldots, M_E(e_{I,J})_I \rfloor \quad (5)$$

where: $M_E(e_{i,j})_I$ – servicing information of jth element in ith assembly for model I.

Table 4. Structure of the servicing information of the object for (Model I)

Object	Servicing levels of object	Vector of the servicing information of the object $[M_E(e_{i,j})_I]$				
		$M_E(e_{1,1})_I$	…	$M_E(e_{i,j})_I$	…	$M_E(e_{i,J})_I$
O	1	$M_E(e_{1,1})_I$	…	$M_E(e_{1,j})_I$	…	$M_E(e_{1,J})_I$
	⋮	⋮	…	⋮	…	⋮
	i	$M_E(e_{i,1})_I$	…	$M_E(e_{i,j})_I$	…	$M_E(e_{i,J})_I$
	⋮	⋮	…	⋮	…	⋮
	I	$M_E(e_{I,1})_I$	…	$M_E(e_{I,j})_I$	…	$M_E(e_{I,J})_I$

On the basis of this information: dependence (5) and (Table 5) the maintenance system was organized, in which the technical object was regenerated. Once the (model I) have been performed, the technical object undergoes control diagnosing with the use of the diagnostic artificial neural network in DIAG program. The results obtained of the diagnosing of the object (for model I) were presented in the form of (Table 5 and Fig. 4).

Table 5. Table of control states of the object for model I

State of the object	Number of the assembly	State of assembly	Vector of states of elements in the object $\{\varepsilon(e_{i,j})\}$					
2	E_1	1	2	1	Ø	Ø	Ø	Ø
	E_2	2	2	2	2	2	2	2
	E_3	2	2	Ø	Ø	Ø	Ø	Ø
	E_4	2	2	2	2	0	Ø	Ø
	E_5	2	2	Ø	Ø	Ø	Ø	Ø
	E_6	2	2	2	Ø	Ø	Ø	Ø
	E_7	2	2	2	2	2	1	Ø

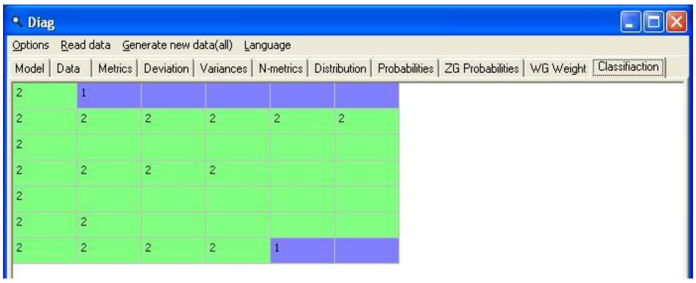

Figure 4. The final results obtained of DIAG diagnostic programme - "TABLE OF STATES OF THE OBJECT" for model I

Further, similarly as described above, the maintenance was performed of the technical object for the (model II) method of expert inference. The procedures of the object were performed with the use of the testing vector of maintenance information that was determined for the method of expert method (model II), and which was presented in the following analytical form (6) and (Table 6):

$$\{M_E(e_{i,j})_{II}\} = \lfloor M_E(e_{1,1})_{II}, \ldots, M_E(e_{i,j})_{II}, \ldots, M_E(e_{I,J})_{II} \rfloor \quad (6)$$

where: $M_E(e_{i,j})_{II}$ – servicing information of jth element in ith assembly for (model II).

Table 6. Structure of the servicing information of the object for model II

Dbject	ervicin g levels f object	ector of the servicing information of the object $[M_E(e_{i,j})_{II}]$				
		$M_E(e_{1,1})_{II}$	…	$M_E(e_{i,j})_{II}$	…	$M_E(e_{i,J})_{II}$
O	1	$M_E(e_{1,1})_{II}$	…	$M_E(e_{1,j})_{II}$	…	$M_E(e_{1,J})_{II}$
	⋮	⋮	…	⋮	…	⋮
	i	$M_E(e_{i,1})_{II}$	…	$M_E(e_{i,j})_{II}$	…	$M_E(e_{i,J})_{II}$
	⋮	⋮	…	⋮	…	⋮
	I	$M_E(e_{I,1})_{II}$	…	$M_E(e_{I,j})_{II}$	…	$M_E(e_{I,J})_{II}$

After the preventive procedures have been performed, the technical object, as in the previous case, underwent control diagnosing with the use of

DIAG program. The results obtained of the diagnosing of the object for method (model II) were presented in the form of (Table 7 and Fig. 5).

Table 7. Table of control states of the object for model II

State of the object	Number of the assembly	State of assembly	Vector of states of elements in the object $\{\varepsilon(e_{i,j})\}$					
1	E_1	2	2	2	Ø	Ø	Ø	Ø
	E_2	2	2	2	2	2	2	2
	E_3	2	2	Ø	Ø	Ø	Ø	Ø
	E_4	2	2	2	2	2	Ø	Ø
	E_5	2	2	Ø	Ø	Ø	Ø	Ø
	E_6	2	2	2	Ø	Ø	Ø	Ø
	E_7	1	1	2	2	2	2	Ø

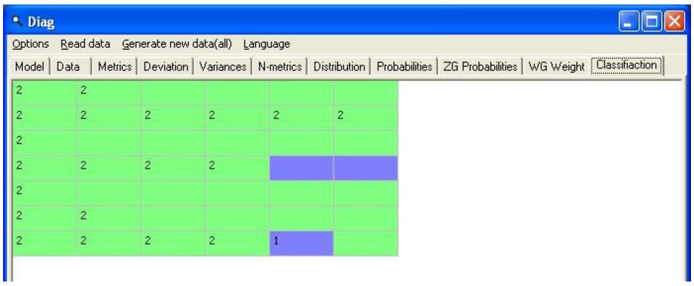

Figure 5. The final results obtained of DIAG diagnostic programme - "TABLE OF STATES OF THE OBJECT" for model II

A function of the qualitative evaluation of the maintenance process of the object was developed. The qualitative function of the control qualitative evaluation of the preventive procedures process of a technical object (F_r) in a maintenance system is presented in [1, 2, 4, 6, 7, 9].

The results obtained from the examination in the experiment were the subject of an analysis and a study with the use of dependence (7).

The function of the regeneration quality of a technical object (α) in a maintenance system is the quantity which defines the set of the object's fully regenerated elements in relation to the set of all the elements of the object intended for prevention:

$$F_r = \frac{n-k}{n} \cdot 100\% \qquad (7)$$

where: n - set of all the elements of the object for prevention, k – set of fully regenerated elements of the object.

If the time is known of the diagnosis (recognition of the states) of the individual elements of the object, then the function can be established of the qualitative regeneration of the object in the maintenance system ($F_r = f(t_d(e_{i,j}))$), where: t_d is the diagnosing time of the states of a technical object for j^{th} element in i^{th} unit of the object ($e_{i,j}$). The quantities obtained are graphically presented in (Fig. 6).

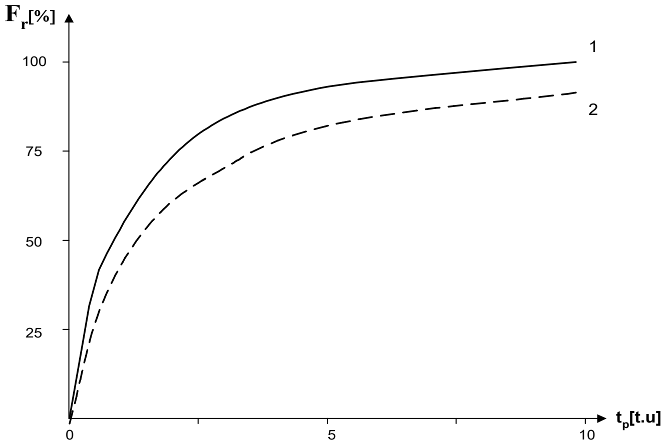

Figure 6. Diagram of the qualitative function of the regeneration of the elements of a technical object (F_r) by the maintenance system

where: 1 – the diagram for the vector of the testing maintenance information (model II); 2 - the diagram for the vector of the testing maintenance information (model I); $t_d(e_{i,j})$ - the regeneration time of the j^{th} primary element in the i^{th} functional units of the object.

It is evident from the analysis of the regeneration quality in the maintenance system organized on the basis of the testing maintenance information for (models I and II) (Fig. 6) that the most reliable expert maintenance information was obtained for (model I = 98%). The quality of the maintenance information is slightly worse for (model II = 93%). Therefore, it can be stated that for the three manners of expert inference examined: deductive, probabilistic and inductive, the first one of them can be of the greatest practical significance.

The problem of the description of a technical object: "an incomplete usability state", which is presented among other things in the author's papers [4-12]: technical diagnostics presents the basis and organization of diagnostic inference in technical objects as the final element of diagnosing. The effect of diagnostic inferring is the determined (recognized) states of the object's functional elements, on the basis of which the object's resultant stage is determined. Diagnosing of a technical object can also be performed in divalent logic {1, 0} or trivalent logic (of the three-value logic) {2, 1, 0}. The basis for diagnosing of technical objects is constituted by possible changes of the values of output diagnostic signals (mainly in the analogue form, but also in other forms) from the object's functional elements. Divalent logic constitutes the basis for the application of the trivalent logic of the evaluation of the object's states. Changes of the values of diagnostic signals are only in the range of their permissible and boundary changes. The range of these changes for a given object is constant regardless of the type of the valence used for the determination of the object's states. Additionally, for trivalent logic, the range of changes was divided-determined: state {1}, state of incomplete usability.

5. CONCLUSIONS

The issues presented in the article of the creation of a set of diagnostic information concern various fields of knowledge, including technical diagnostics, the theory of operation, information technology, expert systems, fuzzy sets, artificial neural networks etc. Each of these fields is well and broadly worked out in the literature. It is the author's opinion that one can claim with a full responsibility that even the basic problem, that is the use of diagnostic information obtained in the diagnosing process of a technical object in the designing and organization of the operation process, is being constantly developed in various aspects (directions). At present, the direction of the applications of neural networks, among others in the diagnostics of technical objects, is being intensively developed.

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