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Expert Knowledge Base to Support Maintenance of a Radar System

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ABSTRACT

This paper presents the method for the creation of an expert knowledge base of a military object, for example a radar system. Such a knowldge base can be widely used to support the process of the maintenance of a complex technical object. The first step is a maintenance evaluation of the object. During this kind of analysis, it is necessary to perform the grouping and classification of the functional elements of the object. It is realised using the functional scheme of the object presented. Further, diagnostic information is combined with specialised experts' knowledge and transformed it into a set of servicing information. The participation of experts in the process of expert knowledge base preparation is significant. The purpose is to capture information that will be a fundamental for the design of a maintenance system dedicated to the particular technical object. The methods proposed were verified with appropriate examples, in which the set of specialised diagnostic information of the object was determined.

Keywords: Maintenance process, expert system, knowledge base, diagnostic information

1. INTRODUCTION

Technical objects used in the operation process (Fig. 1) are exposed to external reactions, and to energy changes (ageing processes, etc.). The state of a technical object used in the process of operation is different after a certain period of time from the nominal state for which the said object was designed.

In the process of the use of the object, the values of elementary functions $F_c(e_{i,j})$ presented in Fig. 1 depend from the divergence between the actual state of the object described with vector $[\upsilon(e_{i,j})]$, which determines plane (ω) of the real properties of the functionality function, and the nominal vector described with $F_C(e_{i,j})$, which determines nominal plane (M_E) of the properties of the functionality function. The effect of this unfavourable process is diminishing functional properties. For this reason, the quality of the use of the object is subject to changes; it usually deteriorates functional quality function ($F_C(t)$) and the coefficient of the quality of the use of the object (F_C) (Fig. 2). The quality of the use of an object can be measured with two quantities: the use function of the object $F_C(t)$ and F_C index of the use function of the object. The values of function $F_C(t)$ are determined by the divergence between the actual state of the object in the space of the use features (ω), and the state of the usability in the nominal space of usability features (M_E). The nominal space of usability features (M_E) is determined by elementary nominal vectors of the object's usability function $F_C(e_{i,j})$.

A preventive servicing of an object in the state of planned servicing comprises location of an element in an incomplete usability or non-operation. It is only on the next stage that preventative activities are realised which restore usability features to the object. A preventative repair (renovation) of the object results in the object being in the state of operation.

2. EXPERT SERVICING SYSTEM WITH AN ARTIFICIAL NEURAL NETWORK TO RENOVATE RADAR SYSTEM

Repairable technical objects for which a short time of their shutdown is required (radar systems, airplanes, etc) are frequently equipped with specialist adjustment systems which reconstruct their functional functions to the nominal level. An adjustment system of the object's functionality functions (Fig. 2) is a sophisticated system of regeneration of the object, which includes the subsystems for diagnosing and maintenance. The purpose of the diagnostic system is current and constant recognition (monitoring) of the state of the object.

The maintenance sub-system regenerates an object in the states of shutdown through a reconstruction of its functionality properties to the nominal level. An adjustment system presented in this manner (Fig. 2) can perform its function if such a diagnostic system has been developed which will recognise the object's states in the values of trivalent logics {2, 1, 0}. A diagram of the above-mentioned process of control of the operation process by the system of adjustment of the object's functionality function is presented in Fig. 2.

Realisation of the object's prevention is a transformation of the information described with diagnostic plane $\{\omega(e_{i,j})\}$ to the level of the servicing information represented with

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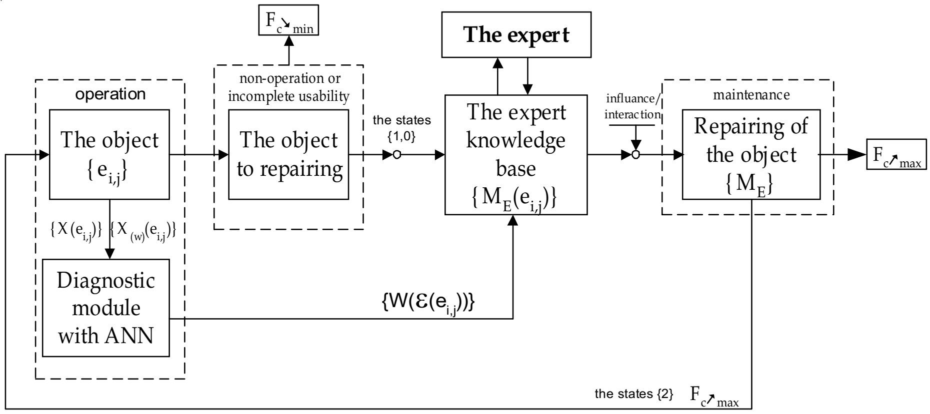
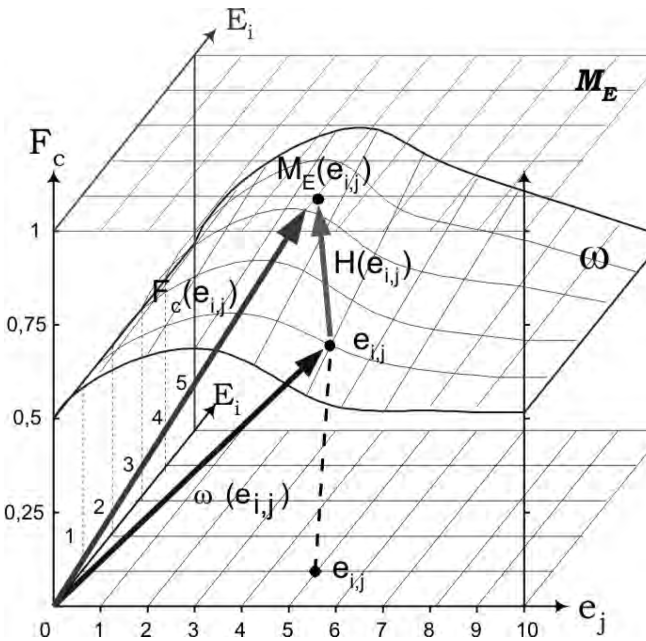


F_C	function of the use of the object
$W(e(e_{i,j})=\{2,1,0\})$	diagnostic information-value of state assessment logics for element „j" within „i" module of the object

Figure 1. Diagram of operation process for technical object utilising artificial neural network.

plane $\{H(e_{i,j})\}$. A reproduction of the qualitative property of usability function F_C of the object in the servicing process on the example of $F_C(e_{i,j})$ is presented in Fig. 1. It is evident from an analysis of the diagram of the refurbishing of the object present in figure that the vector of qualitative usability function F_C described with quantity $\{\omega(e_{i,j})\}$ during operation is subject to a deviation from nominal state $M_E(e_{i,j})$ by vector $H(e_{i,j})$.

The effect of the process of the object's renovation is restoration of its usability features on a nominal level.



ω	the plane of actual usability features of the object
M_E	the plane of the nominal usability features of the object
$F_c(e_{i,j})$	the value of use function
$\omega(e_{i,j})$	vector of actual diagnostic signal
$H(e_{i,j})$	vector of differential metric of diagnostic signal

Figure 2. Distribution of changes of object's states during servicing time.

A control check of the restored usability features of the object is performed through an activity which consists in a determination of vector $M_E(e_{i,j})$ according to Eqn(1) as

$$M_E(e)_{i,j} = \sum_{i=1,j=1}^{I,J} \left(\omega\left(e_{i,j}\right) + H\left(e_{i,j}\right)\right) \quad (1)$$

where $M_E(e_{i,j})$ elementary vector which determines the nominal plane of the usability features $\{M_E\}$ of the object.

A particularly important element of the maintenance system is the knowledge base (Fig. 3). It can be defined as specialised set of the object's maintenance information which is determined by: (i) the maintenance structure of the object $\{W_z(e_{i,j})\}$, (ii) the set of rules for maintenance (repairing) $\{R_r\}$ and (iii) the set of preventive activities $\{A(e_{i,j})\}$.

Reproduction of the usage properties of the technical objects is realised by performing of preventive activities[7,8] in the maintenance system (Fig. 3).

It is evident from the analysis (Fig. 2) that the process of the renovation of an object in an analytical approach consists of transfer of the object's usability features from the level of the plane of the current use (ω) to the level of the plane of nominal usability features (M_E). As a result, the maintenance system produces a set of maintenance information $\{M_E(e_{i,j})\}$, which will be used for organisation of the object's rational (optimised) maintenance system. The function which renovates the object in the servicing system is presented in the form of Eqn (2) as:

$$M_E\left(e_{i,j}\right) = f\left(W\left(z\left(e_{i,j}\right)\right); A_l\left(e_{i,j}\right); R_r\left(e_{i,j}\right)\right) \quad (2)$$

where $\{W_z(e_{i,j})$ is the maintenance structure of the object$\}$, $\{R_r(e_{i,j})\}$ is the set of rules for maintenance (repairing), $\{A(e_{i,j})\}$ is the set of preventive activities, $\{M_E(e_{i,j})\}$ is the maintenance system produces a set of maintenance information.

Various solutions are sought in this area. For this reason, expert systems are applied, among others, in the

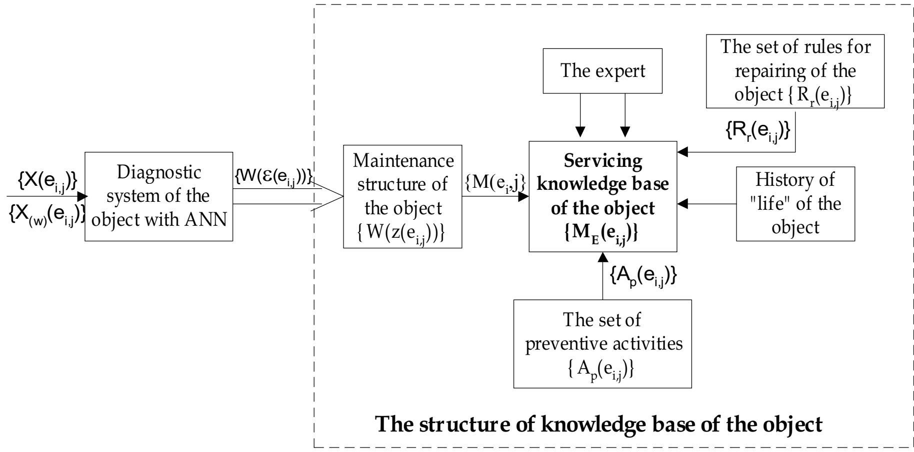


Figure 3. Diagram of an expert system for technical object maintenance.

organisation of maintenance processes for technical object. Important components of the expert system (Fig. 3) include a measuring system which provides an initial set of diagnostic information (Table 1), which constitutes the basis for the determination of the object's maintenance structure, a set of rules $\{R_r(e_{i,j})\}$ and a set of preventive activities $\{A(e_{i,j})\}$.

Table 1. Object's states

State of object	State of assembly	Vector of states of elements ε (e_j)					
		e_1	e_2	e_3	e_4	e_5	e_6
O	1	1	1	1	2	2	∅
	0	1	0	1	2	2	2
	1	2	1	∅	∅	∅	∅
	1	2	1	1	∅	∅	∅
	1	2	2	1	∅	∅	∅
	1	1	2	2	2	2	1
	2	2	∅	∅	∅	∅	∅

A particularly important element of the maintenance system is the knowledge base. It can be defined as specialised set of the object's maintenance information which is determined by the following:

- the maintenance structure of the object $\{W_z(e_{i,j})\}$,
- the set of rules for maintenance (repairing) $\{R_r(e_{i,j})\}$
- the set of preventive activities $\{A(e_{i,j})\}$.

As a result, the maintenance system produces a set of maintenance information $\{M_E(e_{i,j})\}$, which will be used for organisation of the object's rational (optimised) maintenance system.

3. CREATION OF KNOWLEDGE BASE FOR SERVICING A RADAR SYSTEM

The method for the creation of an expert knowledge base presented will be verified on the example of a radar system. The radar system presented in Fig. 4 is a part of a surface-to-air missiles system. The purpose of the radar system is to fight air targets (aircrafts, helicopters, rockets, drone vehicles), as well as ground and water targets in the range of missiles. The radar system considering the specificity of its function of the use (combating of air object) belongs to the group of technical equipment which is characterised by a high index of operational readiness. This class of technical objects requires a specific approach as regards the maintenance of their fitness for use states. An optimal prophylactic strategy for this class of objects is an organisation of operation of the object according to the state. This means that the technical object used is diagnosed on a continuous basis (state testing). The diagnostic system recognises the states of the object and updates the user of the object about a given state. If an incomplete usability state {1} is identified in the object, then the regeneration of the object should begin. Therefore, the basis of the operation of an object in such a system is constituted by a reliable and effective diagnostic system.

The method presented here concerning the control of the exploitation of a technical object on the basis of its state was verified on the example of a repairable technical object, which is a radar system. A functional and diagnostic analysis of the object was carried out for this purpose. A functional model was prepared and described the object: a missile homing station of an anti-aircraft missile set,

Figure 4. Rocket homing station (NEWA SC) of (SA-3) system. (WZE S.A. photo)

which is presented in Fig. 4.

As a result of the descriptive manner of the division of the object's internal structure, the object was subject to a three-level division of its structure. As a consequence of this division of the internal structure (Fig. 5), seven functional assemblies were distinguished (E_1, E_2,…, E_7), and up to five basic elements – modules [1, 4, 5, 6] were distinguished in each one of them. As a result of the analysis carried out, a functional and diagnostic diagram was developed, on the basis of which a set of operational elements and a set of output (diagnostic) signals were established.

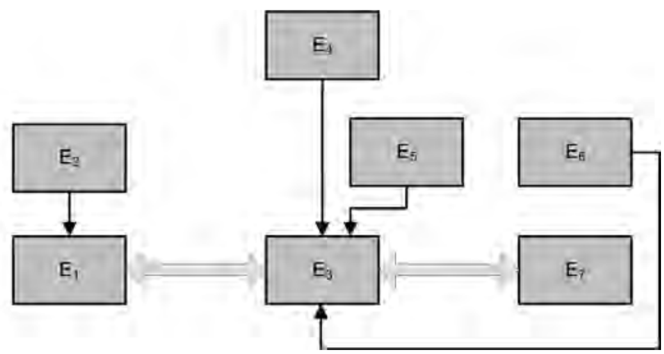
The technical state of the set, a radar system, was determined on the basis of the measurements made of the distinguished set of the properties of diagnostic signals, which were subject to tests (comparison with their models), using DIAG computer diagnosing software. The results obtained are presented in Table 1.

For further determination of the diagnostic control (operational) information, assembly E_6, radio transmitter of commands, was chosen as an example. The radio transmitter of commands in the station of a radar system (Fig. 6) is composed of two functional subassemblies.

The radio transmitter of commands in the station of the radar system (Fig. 6) is composed of two functional subassemblies. The first one comprises high power microwave assemblies with a supplier placed in one housing. The second sub-assembly is a control decoder. The high power microwave equipment and the supplier are placed on the antenna column, while the decoder block is placed in the command and homing cabin of the set, a radar system.

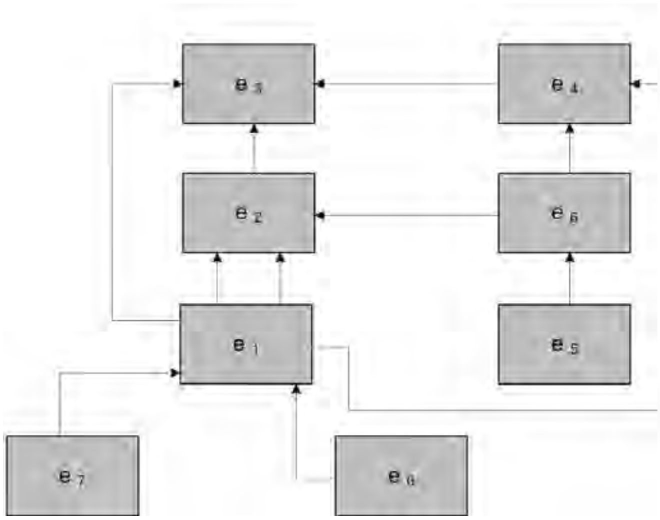
The internal structure of assembly E_6 was divided, as a result of which a set of functional elements was determined. The determination of the operating structure of assembly E_6 was conducted in compliance with the dependence (1). The results obtained are presented in Table 2.

Modern measurement system utilises not only measurement A/D converter card with appropriate signal



E_1 commanding block
E_2 assembly of identification 'our own–stranger'
E_3 homing block
E_4 receiver
E_5 transmitter
E_6 radio transmitter of commands
E_7 drive control block.

Figure 5. Functional model of missile homing station of a radar system.



e_1 control block
e_2 transmitter of commands
e_3 antenna switch
e_4 transmitter of video impulses
e_5 code key RNK
e_6 analogue degrees of the decoder
e_7 system of formation of complex modulating impulse

Figure 6. Functional model of the assembly of the radio transmitter of commands.

interfaces but also some computer tool used for proper signal registration as well as for acquiring and processing registered data. The purpose of such process is to build diagnostic knowledge base based upon the analysis of both the object and the results of measurement stored.

The measurement system (Fig. 7) was implemented and used within the diagnostic module which recognises the states of object. The system is consists of the following elements:

- Measurement structure of investigated object received from the functional analysis. By such analysis, it is possible to establish the set of object's elements (modules) $\{e_{i,j}\}$ with adequate output signal along with the set of diagnostic signals necessary to measure $\{X(e_{i,j})\}$.
- Signal track assuring that the levels of measured signals match the range of A/D converter inputs.
- A/D converter to measure and acquire the values of diagnostic signals $\{X(e_{i,j})\}$,
- PC application (software) to control the operating of A/D converter and register measurement data.

Table 2. Internal structure of assembly E_6

Sub-assembly of E_6 assembly	Structure of E_6 assembly					
e_1	$e_{1,1}$	$e_{1,2}$	-	-	-	-
e_2	$e_{2,1}$	$e_{2,2}$	$e_{2,3}$	$e_{2,4}$	$e_{2,5}$	$e_{2,6}$
e_3	$e_{3,1}$	-	-	-	-	-
e_4	$e_{4,1}$	$e_{4,2}$	$e_{4,3}$	$e_{4,4}$	-	-
e_5	$e_{5,1}$	-	-	-	-	-
e_6	$e_{6,1}$	$e_{6,2}$	-	-	-	-
e_7	$e_{7,1}$	$e_{7,2}$	$e_{7,3}$	$e_{7,4}$	$e_{7,5}$	-

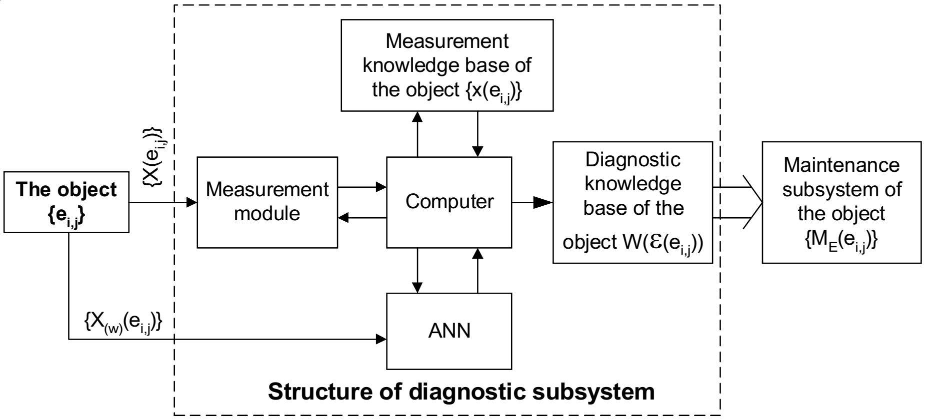


Figure 7. Scheme of measurement module in the diagnostic system.

For diagnosing process, a measuring track[8] was designed for the diagnostic system. A properly designed measuring system for the diagnostic system enables one to obtain a reliable measuring knowledge base for the diagnostic system $\{X(e_{i,j})\}$. The object's measuring information created in this manner constitutes the input information in the diagnosing system with a neural network.

3.1 Structure of an Artificial Neural Network in the DIAG Software Program

The ANN network developed is presented in Fig. 8. It consists of three layers: F_1 is the input layer, F_2 is the output layer and the intermediate layer. The input cells of layer F_1 process the initial diagnostic information according to the algorithm of the DIAG program presented in Fig. 10. The whole issue of information processing by ANN[7] neurons (Fig. 8) takes place in D-dimension diagnostic space (ω) determined by the elementary signal vectors (X_i). The input signal in the form of $X_i = [X_1, x_2, ..., x_n]^T$ is being passed to all neurons of the ANN's input layer.

The input cells memorise the vectors of signal standards $\{X_i\}$. Basing upon that, the neurons from the input layer determine the measures of similarity between the input signal vector and its standard, and the length of the input signal $\{X_i\}$ to all vectors of weights $w_{i,j} = [w_1, w_2, ..., w_n]^T$, where i =1,…,N. In the ANN network presented in Fig. 8, the neuron i placed in layer F_1 is connected to neuron j placed in layer F_2, where: j = 1, 2,…N.

Neuron i sends the signal of value (x_i) with the connecting strength ($w_{i,j}$) of the activation function. Following the literature of the subject [3, 6, 7, 11-14], the Minkowski's measure is used for the analysis of the measures of signal vectors. The Minkowski's measure can be expressed by Eqn. (3) as:

$$D_M\left(X_i, X_{(w)i}, \alpha\right) = \left(\sum_{i=1}^{N}\left|X_i - X_{(w)i}\right|^{\alpha}\right)^{1/\alpha} \tag{3}$$

where D_M is the standard deviation of the signal measure vector.

In the comparative analysis of diagnostic signals, a special case of Minkowski's measure was applied, with

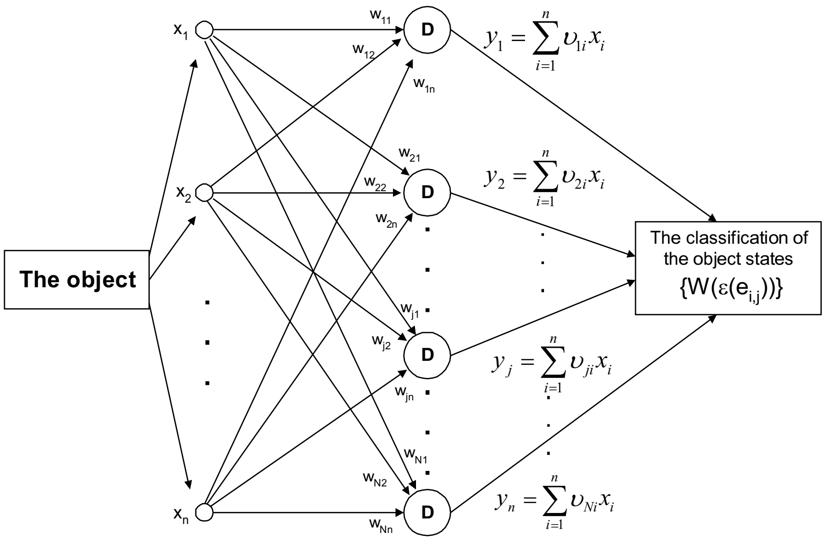


Figure 8. Diagram of neural networks.

parameter $\alpha = 2$. Then, the Eqn (1) becomes the Euclidean measure and can be used with the ANN network[3,7]. For this reason, in the process of input data processing, a transformation of input data is performed to reduce too high initial disproportions between the initial values in particular dimensions. One of certain input data transformation methods, which is at the same time quite effective, is the normalisation of input data which transforms the values into range of [0, 1].

For the ANN presented in Fig. 8, neuron i is connected with neuron j, so it transmits a signal of value (X_i) with weight coefficient ($w_{i,j}$) and the activation function, represented by the following relation as Eqn(4):

$$f_l(x,w) = \sum_{i=1}^{K} w_{i,j} \cdot X_i \tag{4}$$

The value of its output function is derived from the Eqn (5)

$$y_l = f\sum_{i=1}^{K} \upsilon_{i,j} \cdot X_i \tag{5}$$

The classification process of the object's states is realised in the output layer of the network. The value of the output function of the network determined for a given input signal vector constitutes the basis for the classification of the states. The output layer neuron possesses a memory cell, where the diagnostic inference rules of the network are recorded. Those classes of the object's states which are recognisable, including the ranges assigned to them of the changes of the network's output function values, are presented in (Fig. 9).

On the final stage of the work of a neural network, a classification process of the object's states is realised according to the algorithm. For this purpose, to the values of the output function as determined by the network, proper classes of the object's states[2-3] were assigned according to the classification diagram (Fig. 9). The results of the object's diagnosis are presented in Table 3.

Table 3. Table of object's states

State of object	State of Module	Vector of states of elementary components $\{e_{i,j}\}$				
		$\varepsilon(e_{1,1})$	...	$\varepsilon(e_{i,j})$	...	$\varepsilon(e_{i,J})$
	$W(\varepsilon(E_1))$	$W(\varepsilon(e_{1,1}))$	...	$W(\varepsilon(e_{1,j}))$	...	$W(\varepsilon(e_{1,J}))$
	⋮	⋮	...	⋮	...	⋮
$W(\varepsilon(O))$	$W(\varepsilon(E_i))$	$W(\varepsilon(e_{i,1}))$	...	$W(\varepsilon(e_{i,j}))$	...	∅
	⋮	⋮	...	⋮	...	⋮
	$W(\varepsilon(E_I))$	$W(\varepsilon(e_{I,1}))$	...	$W(\varepsilon(e_{I,j}))$	...	$W(\varepsilon(e_{I,J}))$

$W(\varepsilon(e_{i,j}))$ – value of state assessment logics for j[th] element within i[th] module (from the set of the accepted three-value logic of states' assessment) - {2, 1, 0}), ∅ - symbol complementing the size of table.

3.2. Obtaining of Operational Knowledge Base for Servicing of Assembly E_6: Radio Transmitter of Commands

The use of DIAG software requires preparation of input diagnostic information on the basis of a functional and diagnostic analysis of a given object. A functional and diagnostic model of an object needs to be made. On the basis of this, the following was determined:

- A set of basic elements,
- A set of diagnostic signals $\{X(e_{i,j})\}$, and
- A set of their model (standard) signals $\{X_{(w)}(e_{i,j})\}$.

The results of measurements for chosen elements of object are presented in Fig. 10.

For the method presented, an effective diagnostic system[7] (Fig. 7) was built whose task was to recognise

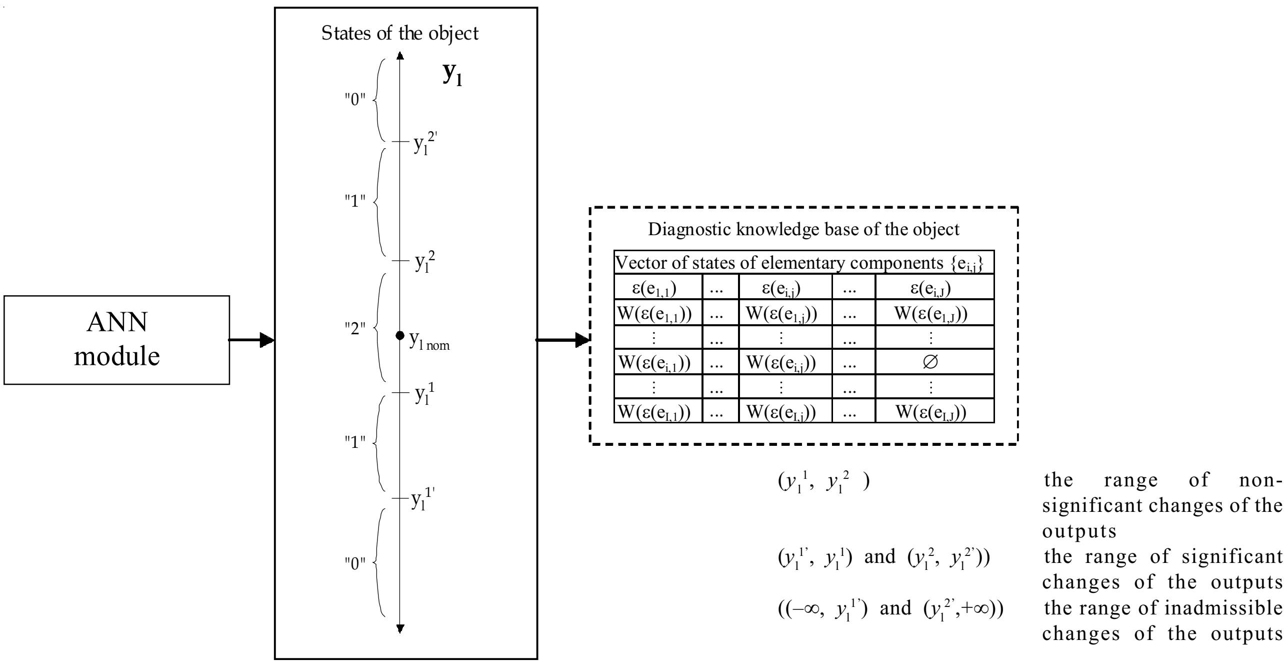
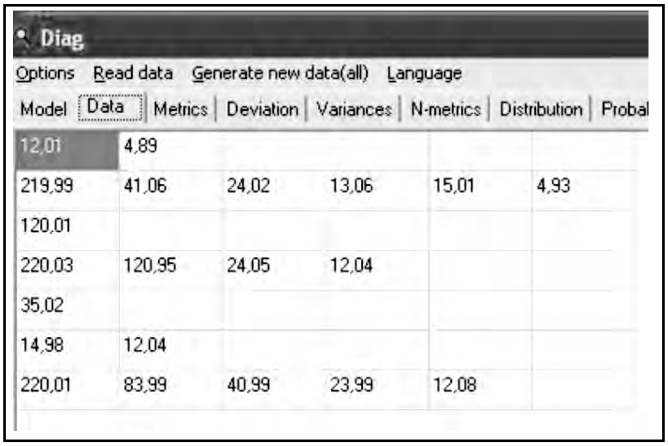


Figure 9. The scheme of a classification of the object's states.

(classify) the object's states in trivalent logics {2, 1, 0}. The diagnostic system used in the tests was constructed on the basis of the measuring information obtained and DIAG diagnosing software. DIAG software is a specialist computer program developed for the method presented. The diagnostic information obtained during diagnosing in the form of the knowledge base $\{W(\varepsilon(e_{i,j}))\}$ constitutes the input information in the process of obtaining of the expert knowledge base which assists the maintenance of the technical object tested.

The test of the state of the object using DIAG program was conducted according to the algorithm. On the basis of the measurements made of the properties of the



12,01	4,89				
219,99	41,06	24,02	13,06	15,01	4,93
120,01					
220,03	120,95	24,05	12,04		
35,02					
14,98	12,04				
220,01	83,99	40,99	23,99	12,08	

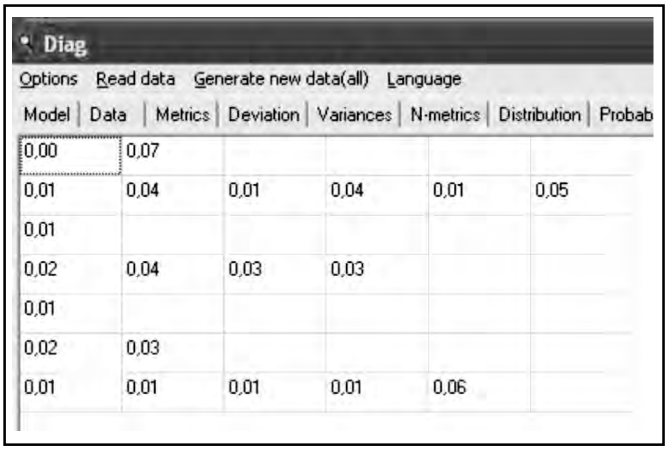
Figure 10. Matrix of measures of diagnostic signals from the assembly E_6.

distinguished diagnostic signals, tests and an analysis by DIAG program with an artificial neural network (ANN), which belongs to the group of self-organising networks, were made of these. The neural system does not require any strenuous training because the weight coefficients (Fig. 11) of the networks are determined during calculations (these are simply known).

The diagnostic information was developed in a diagnostic system of recognition of the states of a reparable technical object, using of an artificial neural network. The accepted method of diagnosing by a neural network consists in comparing of the image of vectors of diagnostic signals with the images of their models.

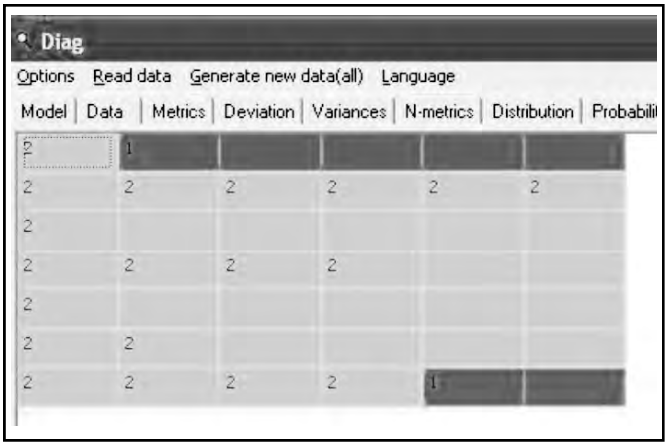
The operation of DIAG software by the user is done with the aid of dialogue windows of the program located on the menu bar: Options–Read data–Generate new data. After starting of the programme, the menu bar is displayed: "Options", "Read data" and "Generate new data" (Fig. 11).

The elements from this set were grouped into subsets of classes using the classification method proposed. The state of the object was determined on the basis of the measurements of the diagnostic signal features processed. These were processed and analysed by an ANN. The final results obtained of DIAG program are presented in the form of a table of states (Table 4 and Fig. 12).



0,00	0,07				
0,01	0,04	0,01	0,04	0,01	0,05
0,01					
0,02	0,04	0,03	0,03		
0,01					
0,02	0,03				
0,01	0,01	0,01	0,01	0,06	

Figure 11. Matrix of weight coefficients of the networks of the assembly E_6.



2	1				
2	2	2	2	2	2
2					
2	2	2	2		
2					
2	2				
2	2	2	2	1	

Figure 12. The final results obtained of DIAG program were presented in the form of a table of states of assembly E_6.

As a result of the functional and diagnostic analysis conducted according to the same diagram of procedures as for the whole set (NEWA SC), a set of output signals was determined, which were subject to tests using DIAG software. On the basis of the examination of the object's state, tables of states were determined for assembly E_6 (Table 4), and a comparison was made of the states with the model state, which is presented in Tables 5 and 6.

On further state of the listing (development) of the set of the object's operational information, a classification (grouping) of elements was conducted to distinguished classes (groups) of operational elements. Using the manner of classification of operational elements as presented in the article, the object's functional elements were grouped into operational classes. The results obtained are presented in Table 7.

An important element in the set of operational information is the set of prophylactic (operational) activities performed on the object's functional elements with the aim of their regeneration. While using the determined set of operational elements (Table 6 and 7), during the transformation of operational information, to the operational elements, suitable subsets (sets) of prophylactic activities $\{A(e_{i,j})\}$ were assigned, which are suitable for a given class of each element. The results obtained of the listing of the set of operational information $\{M_E(e_{i,j})\}$ is presented in Table 8.

The set of operational rules $\{R_r(e_{i,j})\}$ constitutes an important subset of the set of operational information, whose diagram was presented in Fig. 3. The set of operational rules was compiled according to the algorithm presented in the article. For this purpose, the previously obtained results in the form of stage sets of operational information

Table 4. Table of state of assembly E_6

State of E_6 assembly	State of e_i subassembly	Vector of states of elements in E_6 $\{\varepsilon(e_{i,j})\}$ assembly					
	1	2	1	Ø	Ø	Ø	Ø
	1	2	2	2	2	2	2
	2	2	Ø	Ø	Ø	Ø	Ø
1	2	2	2	2	2	Ø	Ø
	1	2	Ø	Ø	Ø	Ø	Ø
	1	2	2	Ø	Ø	Ø	Ø
	1	2	2	2	2	1	Ø

Ø lack of basic element: symbol which completes the size of the Table

Table 5. Results of comparison of states of assembly E_6

State of E_6 assembly	State of e_i subassembly	Vector of states of elements in E_6 assembly $\{\varepsilon(e_{i,j})\}$					
	1	⊗	1	Ø	Ø	Ø	Ø
	⊗	⊗	⊗	⊗	⊗	⊗	⊗
	⊗	⊗	Ø	Ø	Ø	Ø	Ø
1	⊗	⊗	⊗	⊗	⊗	Ø	Ø
	⊗	⊗	Ø	Ø	Ø	Ø	Ø
	⊗	⊗	⊗	Ø	Ø	Ø	Ø
	1	⊗	⊗	⊗	⊗	1	Ø

⊗ lack of basic element: symbol which completes the size of the Table

Table 6. Set of servicing information $\{M_E\}$ of assembly E_6

Servicing levels of E_6 assembly	Servicing structure of E_6 assembly $\{M_E(e_{i,j})\}$					
	e_1	e_2	e_3	e_4	e_5	e_6
1	⊗	$E_{1,2}$	Ø	Ø	Ø	Ø
2	⊗	⊗	⊗	⊗	⊗	⊗
3	⊗	Ø	Ø	Ø	Ø	Ø
4	⊗	⊗	⊗	⊗	Ø	Ø
5	⊗	Ø	Ø	Ø	Ø	Ø
6	⊗	⊗	Ø	Ø	Ø	Ø
7	⊗	⊗	⊗	⊗	$e_{7,5}$	Ø

Table 7. Classes of operational elements of assembly E_6

Class of element	Subassembly of assembly E_6- radio transmitter of commands						
	e_1	e_2	e_3	e_4	e_5	e_6	e_7
I - electronic	-	-	-	-	-	-	$e_{7,5}$
III – electric	-	$e_{1,2}$	-	-	-	-	-

Table 8. Structure of operational activities for assembly E_6

Class of element	Elements of operational structure	Elements of structure of operational activities
I – electronic	$\{e_{7,5}\}$	{1,7,8,}
III – electric	$\{e_{1,2}\}$	{1,3,6,8}

{1 to 10} the set of preventive activities:
{1} control check-up,
{2} servicing,
{3} adjustment,
{4} tuning,
{5} regeneration,
{6} conservation,
{7} lubrication,
{8} cleaning,
{9} re-filling of working fluids,
{10} replacing the element with a new one.

were used, which were put in Tables 5 to 8. The results obtained were presented in Table 9 and Fig. 13.

The method determines set of service information, which was presented in the form of $\{M_E(e_{i,j})\}$. This specialist knowledge base (a set of maintenance information)[13] constitutes the basis for the designing of a reliable system of the maintenance (prevention) (Fig. 13) of a technical object. A maintenance system is understood to be a dynamic set which consists of a specialist who organises and supervises this system, means of maintenance (tools, materials, etc.) and the object of the maintenance presented in the form of a model of the object of maintenance, and relationships between them.

The model of the object of service is determined by a set of the maintenance elements of the object $\{(e_{i,j})\}$, i.e., such elements which possess states (with a trivalent evaluation of states): incomplete usability: state-{1}, or a non-operation state-{0}, and are subject to regeneration in the maintenance system. The obtained maintenance

Table 9. Set of operational rules for assembly E_6

Element no. in E_6 assembly	Rules of operation
$e_{1,1}$	R_1: If å($e_{1,1}$) is {⊗} then $M(e_{1,1}) = M_E(e_{1,1})$
$e_{1,2}$	R_2: If å($e_{1,2}$) is {1} then $M(e_{1,2})$? {1,3,6,8}= $M_E(e_{1,2})$
$e_{2,1}$	R_3: If å($e_{2,1}$) is {⊗} then $M(e_{2,1}) = M_E(e_{2,1})$
$e_{2,2}$	R_4: If å($e_{2,2}$) is {⊗} then $M(e_{2,2}) = M_E(e_{1,1})$
$e_{2,3}$	R_5: If å($e_{2,3}$) is {⊗} then $M(e_{2,3}) = M_E(e_{2,3})$
$e_{2,4}$	R_6: If å($e_{2,4}$) is {⊗} then $M(e_{2,4}) = M_E(e_{2,4})$
$e_{2,5}$	R_7: If å($e_{2,5}$) is {⊗} then $M(e_{2,5}) = M_E(e_{2,5})$
$e_{2,6}$	R_8: If å($e_{2,6}$) is {⊗} then $M(e_{2,6}) = M_E(e_{2,6})$
$e_{3,1}$	R_9: If å($e_{3,1}$) is {⊗} then $M(e_{3,1}) = M_E(e_{3,1})$
$e_{4,1}$	R_{10}: If å($e_{4,1}$) is {1} then $M(e_{4,1}) = M_E(e_{4,1})$
$e_{4,2}$	R_{11}: If å($e_{4,2}$) is {⊗} then $M(e_{4,2}) = M_E(e_{4,2})$
$e_{4,3}$	R_{12}: If å($e_{4,3}$) is {⊗} then $M(e_{4,3}) = M_E(e_{4,3})$
$e_{4,4}$	R_{13}: If å($e_{4,4}$) is {⊗} then $M(e_{4,4}) = M_E(e_{4,4})$
$e_{5,1}$	R_{14}: If å($e_{5,1}$) is {⊗} then $M(e_{5,1}) = M(e_{5,1})$
$e_{6,1}$	R_{15}: If å($e_{6,1}$) is {⊗} then $M(e_{6,1}) = M(e_{6,1})$
$e_{6,2}$	R_{16}: If å($e_{6,2}$) is {⊗} then $M(e_{6,2}) = M_E(e_{6,2})$
$e_{7,1}$	R_{17}: If å($e_{7,1}$) is {⊗} then $M(e_{7,1}) = M_E(e_{7,1})$
$e_{7,2}$	R_{18}: If å($e_{7,2}$) is {⊗} then $M(e_{7,2} = M_E(e_{7,2})$
$e_{7,3}$	R_{19}: If å($e_{7,3}$) is {⊗} then $M(e_{7,3}) = M(e_{7,3})$
$e_{7,4}$	R_{20}: If å($e_{7,4}$) is {⊗} then $M(e_{7,4}))= M_E(e_{7,4})$
$e_{7,5}$	R_{21}: If å($e_{7,5}$) is {1} then $M(e_{7,5}) \rightarrow$ {1,7,8,} = $M_E(e_{7,5})$

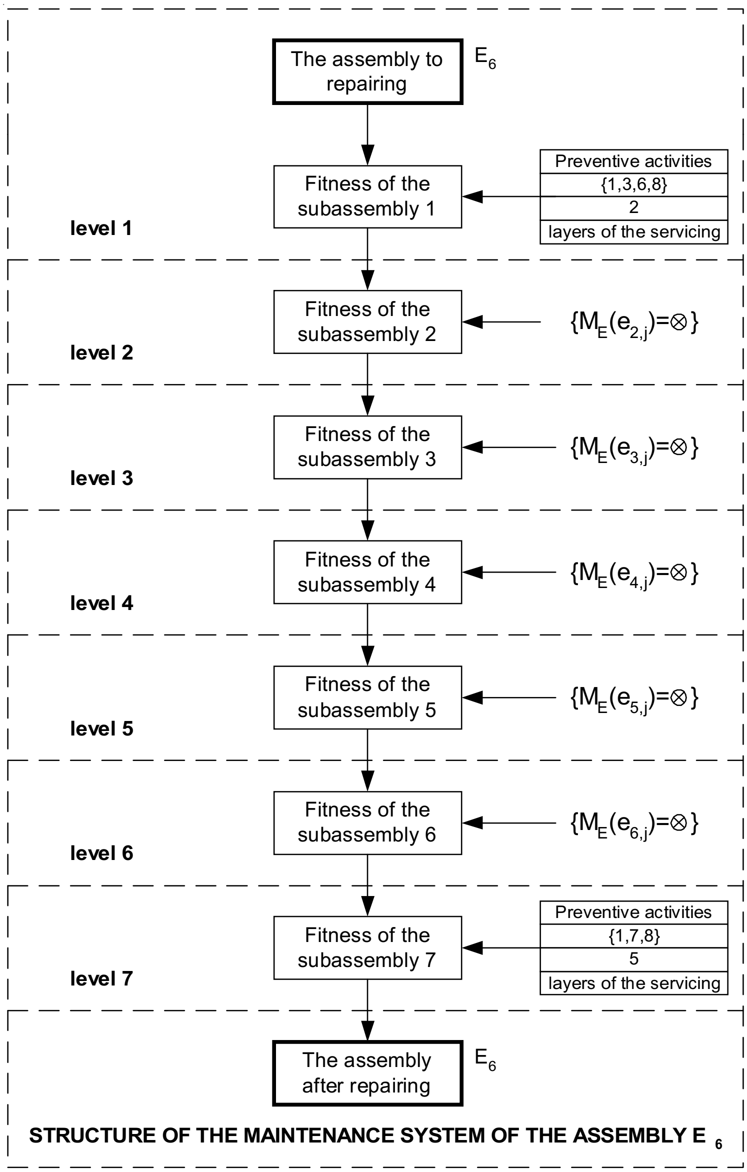


Figure 13. The scheme of structure of the maintenance system of an assembly E_6.

information $\{M_E(e_{i,j})\}$, as a result of the application of the method proposed, allows one to design a reliable system of the maintenance of the object. The designing of a maintenance system consists in the determination of the structure of the maintenance system, which is composed of object's maintenance elements, the prevention activities (depending of the state) selected by an expert, including the maintenance means for a given element $\{A(e_{i,j})\}$, and maintenance rules $\{R_r(e_{i,j})\}$.

The final form of the maintenance knowledge base is presented in the form of the information included in (Table 9 and Fig. 13). This table includes a set of maintenance rules for assembly E_6. Each rule included in this table determines explicitly which element of a given assembly of the object must be subject to regeneration, and what range of prevention activities (from the set of the activities) is to be performed on it. The execution of the determined set of maintenance rules will result in the regeneration of the whole element, assembly and the whole object. The technical object, once the maintenance has been performed, is subject to a control check-up (testing) of the state, and in the case of a negative result of the control, the object is once again referred to prevention.

4. CONCLUSIONS

This paper presents the method for the creation of an expert knowledge base. An important elements of an expert knowledge base is information, of the set of the elements of the object's maintenance structure, of the set of preventive activities to renovate the servicing object, of the set of preventive activities to renovate the servicing of technical objects with the required short shutdown time (airplanes, radiolocation systems, etc). The basis of the method proposed is the use of diagnostic information developed by diagnostic system. The diagnostic information is developed in a diagnostic system of recognition of the states of a reparable technical object, using of an artificial neural network. The accepted method of diagnosing by a neural network consists in comparing of the image of vectors of diagnostic signals with the images of their models. For this purpose, the technical object examined was subject to a diagnostic study. An important stage of the work is a functional and diagnostic analysis of the object. For this reason, the paper presents and describes the method of the division of the object's internal structure. As a result of this division, a set of basic elements and a set of diagnostic signals were determined.

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