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Determination of an expert knowledge base for servicing of a repairable technical object

Key words

Servicing process, expert system, neural networks, diagnostic information.

Słowa kluczowe

Proces obsługiwania, systemy ekspertowe, sieci neuronowe, informacja diagnostyczna.

Summary

The paper presents a method to design a system to service repairable (military) technical objects, with an artificial neural network. It includes a diagram and structure of a servicing system with a neural network. The way in which the object's servicing information is designed was presented. The manner was presented in which the internal structure was the transformation of a complex object with its functional elements to the form of the object's servicing structure. Analytical basis was presented for the realisation of the servicing of a technical object. A method was described for a conversion of diagnostic information and the expert's specialist knowledge to the form of the set of servicing information.

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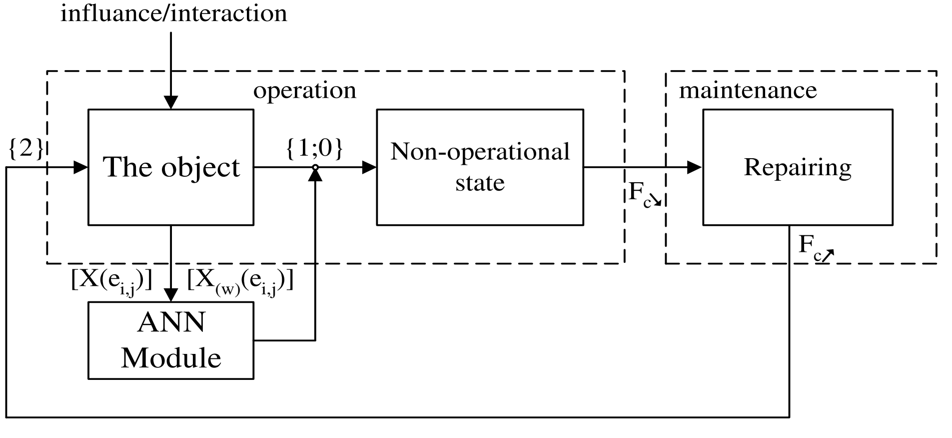
1. Introduction

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 from the nominal state for which the said object was designed. 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, and it usually deteriorates.

In the process of operation [1, 5, 9, 10, 11, 16], the state of the technical object operated is different from the nominal state (usability) for which the said object was designed. In view of the fact that various influences act on the object, there occur ageing changes in it and the functional (constructional) elements wear. The effect of this disadvantageous process is its decreasing functional properties.

Then, technical objects go to the state of unfitness or incomplete fitness (with a trivalent evaluation of states) and no longer realise their operational functions. The scatter of the values of the qualitative function of the operation of an object in the operation space is of a decreasing nature. In order to counteract random changes of the function of the quality of the operation of an object, and in order to maximise this function, technical servicing is organised (Fig. 1).



where: $X(e_{i,j})$ – diagnostic signal in j^{th} element of i^{th} set; $X_{(w)}(e_{i,j})$ – model signal for $X(e_{i,j})$ signal; F_C - function of the use of the object, $W(\varepsilon(e_{i,j})=\{2, 1, 0\})$ – diagnostic information-value of state assessment logic for element "j" within "i" module of the object.

Fig. 1. Diagram of operation process for technical object utilising artificial neural network
Rys. 1. Schemat procesu eksploatacji wykorzystującego sztuczną sieć neuronową

2. The model of an expert servicing system of a technical object

A particularly important element of the maintenance system is the knowledge base (Fig. 2). It can be defined as a 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) $\{R_r\}$, and the set of preventive activities $\{A(e_{i,j})\}$.

It is evident from the analysis (Fig. 2) that the process of the renovation of an object in an analytical approach consists in the 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). The function that renovates the object in the servicing system is presented in the form of the following dependence:

$$M_E\left(e_{i,j}\right) = f\left(W\left(z\left(e_{i,j}\right)\right); A_l\left(e_{i,j}\right); R_r\left(e_{i,j}\right)\right) \tag{1}$$

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

As a result, the maintenance system [3, 4, 6, 12] produces a set of maintenance information $\{M_E(e_{i,j})\}$, which will be used for the organisation of the object's rational (optimised) maintenance system.

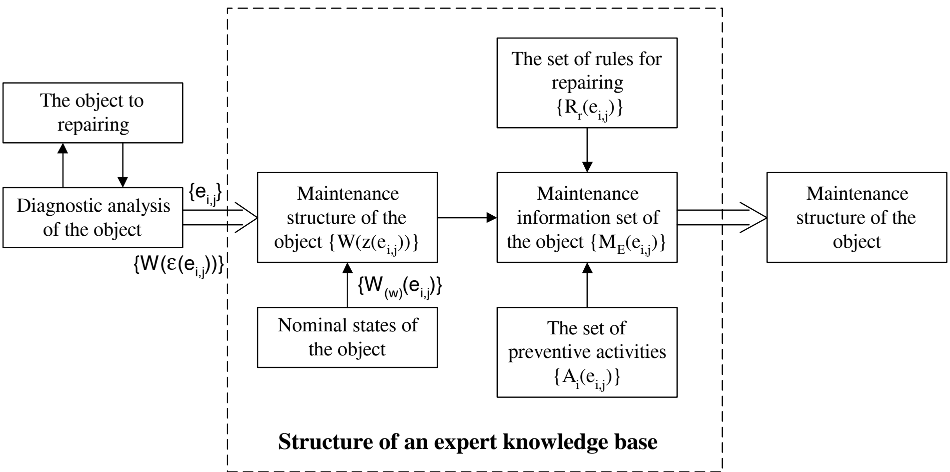


Fig. 2. Diagram of a servicing system with an artificial neural network
Rys. 2. Schemat procesu obsługiwania obiektu technicznego wykorzystującego sztuczną sieć neuronową

A set of the object's servicing information, which constitutes the basis in the process of designing of the structure of the servicing system, is presented in the form of the following dependence:

$$M_E(e_{i,j}) = \{M(e_{i,j}), W(z(e_{i,j}))A_l, R_r\} \tag{2}$$

where: $\{M(e_{i,j})\}$ – a set of elements of the object's servicing structure, $\{W(z(e_{i,j}))\}$ – resulting diagnostic information from the comparison of the object's states, $\{R_r\}$ – a set of servicing rules, $\{A(e_{i,j})\}$ – a set of preventative activities which renovate servicing elements.

2.1. Diagnostic system with an artificial neural network ANN

The division of the object's internal structure $\{e_{i,j}\}$ accepted in the paper explicitly defines the depth of penetration into this structure. The accepted division is considered sufficient, if we distinguish the basic module-element in the structure of the object. One of the purposes of the functional-diagnostic analysis is the determination of the object's state. 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) [2, 7, 13. 14, 15]. 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
Tabela 1. Tabela sygnałów diagnostycznych obiektu

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.

The ANN network developed is presented in Fig. 3. It consists of three layers: F_1 – input layer, F_2 – output layer, and an intermediate layer. The input cells of layer F_1 process the initial diagnostic information according to the scheme presented in Fig. 3 and 4. The whole of the issue of information processing by ANN neurons [7, 14] takes place in D-dimension diagnostic space (ω) (see Fig. 1) determined by the elementary signal vectors (X_n). The input signal in the form of $X_n = [x_1(e_{i,j}), x_2(e_{i,j}), \ldots, x_n(e_{i,j})\ ]^T$ is being passed to all neurons of ANN's input layer.

The input cells memorise the vectors of signal standards $\{X_n\}$. Based 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 $\{X_n\}$ 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. 3, the neuron (i) placed in layer F_1 is connected to neuron (j) placed in layer F_2, where: j = 1,2,…N.

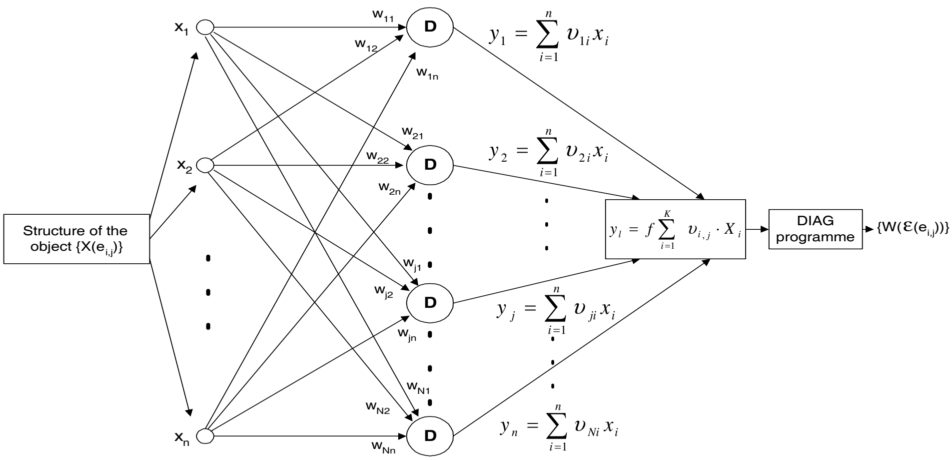


Fig. 3. Diagram of neural networks
Rys. 3. Struktura sztucznej sieci neuronowej

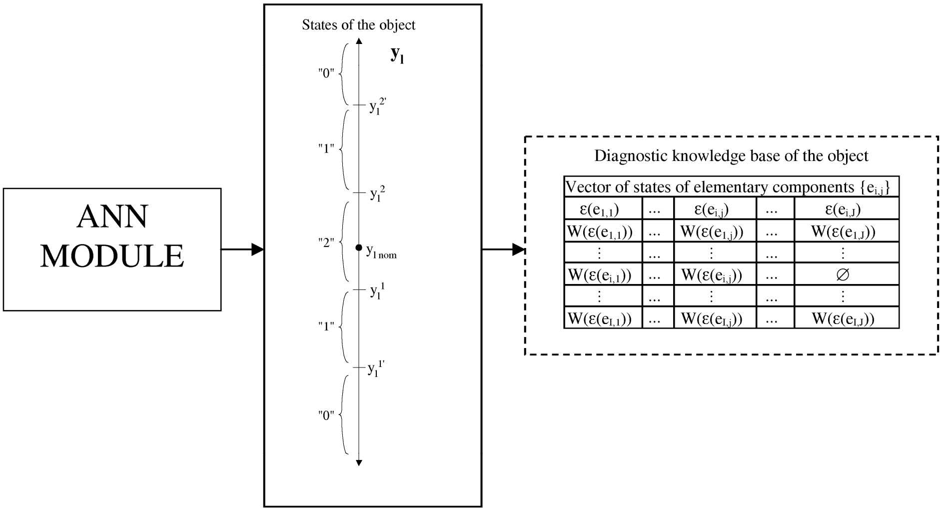
The value of its output function (Fig. 3) is s derived from the relation (3)

$$y_l = f \sum_{i=1}^{K} \upsilon_{i,j} \cdot X_i \tag{3}$$

where: $\upsilon_{i,j}$ – weight coefficient.

The determination of the value of the network's output function $\{y_l\}$ made it possible to explicitly determine the set of elementary vectors of signals which describe the diagnostic space of object (ω). In view of the fact that the purpose of a diagnosis of the object [2, 4, 8, 9] is the recognition of its state in the values of the accepted logic of states' assessment, the results obtained in the form of relations (4, 5 and 6) were subject to the classification process according to the diagram presented in Fig. 4.

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 (Fig. 4). For this purpose, to determine the values of the output function as determined by the network, proper classes of the object's states in the values of the three-value logic {2, 1, 0}[5, 6, 7] were assigned according to the classification diagram.



where: (y_l^1, y_l^2) – the range of non-significant changes of the outputs; ($y_l^{1'}$, y_l^1) and (y_l^2, $y_l^{2'}$)) – the range of significant changes of the outputs, (($-\infty$, $y_l^{1'}$) and ($y_l^{2'}$,$+\infty$)) – the range of inadmissible changes of the outputs

Fig. 4. Range of variability of diagnostic signal features in the diagnostic DIAG programme

Rys. 4. Przedziały zmian wartości sygnałów diagnostycznych w diagnostycznym programie DIAG

The classes of states of elementary components $\{e_{i,j}\}$ are defined as the following:

$$\left(W\left(\varepsilon\left(e_{i,j}\right)\right)=2\right) \Leftrightarrow \left\{y_l \in \left(y_l^1, y_l^2\right)\right\} \tag{4}$$

where: (y_l^1, y_l^2) – the range of non-significant changes of the output function values (y_l).

$$\left(W\left(\varepsilon\left(e_{i,j}\right)\right)=1\right) \Leftrightarrow \left\{y_l \in \left(y_l^{1'}, y_l^{1}\right) \cup \left(y_l^{2}, y_l^{2'}\right)\right\} \tag{5}$$

where: ($y_l^{1'}$, y_l^1) and (y_l^2, $y_l^{2'}$)) – the range of significant changes of the output function values (y_l).

$$\left(W\left(\varepsilon\left(e_{i,j}\right)\right)=0\right) \Leftrightarrow \left\{y_l \in \left(-\infty, y_l^{1'}\right) \cup \left(y_l^{2'}, +\infty\right)\right\} \tag{6}$$

where: (($-\infty$, $y_l^{1'}$) and ($y_l^{2'}$,$+\infty$)) – the range of non-admissible changes of the output function values (y_l).

The results of the object's diagnosis obtained from the relation (4, 5 and 6) are presented in Table 2.

Table 2. Table of object's states
Tabela 2. Tabela stanów obiektu

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

where: $W(\varepsilon(e_{i,j}))$ – 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}), $\varnothing$ – symbol complementing the size of table.

3. Creation of an expert knowledge base for servicing of a repairable a technical object

3.1. Preparation of the set of the elements of the object's maintenance structure

The methods for the minimisation of the set of checks presented in [2, 4] impose specific requirements for the set of elementary components. The elementary component can have, in this case, any number of signal inputs but only one output. In the determined set of the object's functional elements, only those elements will be used during the maintenance whose states required repair. For this purpose, a relation for the comparison of the states of the object's elements included in (Table 1) with their standards was developed in accordance with the following:

$$\left(\underset{e_{i,j\in\{E_i\}}}{\vee} W\left(\varepsilon\left(e_{i,j}\right)\right) \mapsto \underset{e_{i,j\in\{E_i\}}}{\vee} W_w\left(\varepsilon\left(e_{i,j}\right)\right) \right) \Rightarrow \underset{e_{i,j\in\{E_i\}}}{\vee} W\left(z\left(e_{i,j}\right)\right) \tag{7}$$

where: $W(\varepsilon(e_{i,j}))$ – the value of state assessment logics for j^{th} element within i^{th} module of the object, $W_w(\varepsilon(e_{i,j}))$ – the standard value of state assessment logics for for j^{th} element within i^{th} module of the object, $W(z(e_{i,j}))$ – the resulting value of the state assessment logics for for j^{th} element within i^{th} module of the object, $\mapsto$ – comparison relation, $\Rightarrow$ – resulting relation.

The result of the expert's activity described with dependence (1) is the determination of an initial set of maintenance information in the form of a set of elements that need to be repaired. In the further step, a comparison of the states of the object's elements included in (Table 2) with their patterns takes place. Based on the results of such a comparison, an identification of the object's elements with the state value {2} – usability states is made. Such elements are not subject to prevention. They are crossed out and are replaced by symbol "⊗" in the table. Therefore, an initial set of maintenance information is obtained and presented in Table 3.

Table 3. Table of initial maintenance information
Tabela 3. Tabela pośredniej informacji obsługowej

The level of maintenance structure of the object	Vector of element's states ($e_{i,j}$)				
	$z(e_{1,1})$	...	$z(e_{i,j})$	...	$z(e_{i,J})$
1	$W(z(e_{1,1}))$	...	$W(z(e_{1,j}))$	...	⊗
⋮	⋮	...	⋮	...	⋮
i	$W(z(e_{i,1}))$	...	$W(z(e_{i,j}))$	...	$W(z(e_{i,J}))$
⋮	⋮	...	⋮	...	⋮
I	$W(z(e_{I,1}))$	...	$W(z(e_{I,j}))$	...	⊗

where: $W(z(e_{i,j}))$ – z^{th} value of state assessment logics for j^{th} element within i^{th} module of the object, ⊗ – table's size completion symbol.

3.2. Classification of the elements of the internal structure of a technical object

Control of the quantity of the qualitative usability function (F_C) in the operation process requires, among other things, recognition and description of an object's internal structure, the nature of its work, etc. In modern systems for the servicing of technical objects, with a computer-aided organisation of this process, an important role is played in them by specialist (expert) databases. This specialist set of information concerning the object of servicing is determined on the basis of a description of the elements of the object's servicing structure, the grouping of them into classes, and the assigning of a specific subset of preventative activities to them, which are characteristic only of a given class of the elements of the structure.

The results obtained were presented in Table 4.

Table 4. Classes of operational elements of the object
Tabela 4. Klasy elementów obsługowych obiektu

Level of Maintenance structure of the object	Classes of operational elements of the object $\{s(e_{i,j})\}$				
	$(e_{1,1})$	...	$(e_{i,j})$	...	$(e_{i,J})$
1	$s(e_{1,1})$	...	$s(e_{1,j})$	...	$s(e_{1,J})$
⋮	⋮	...	⋮	...	⋮
i	$s(e_{i,1})$	...	$s(e_{i,j})$	...	$s(e_{i,J})$
⋮	⋮	...	⋮	...	⋮
I	$s(e_{I,1})$	...	$s(e_{I,j})$	...	$s(e_{I,J})$

where: $s(e_{i,j})$ – classes of the elements of maintenance structure of the object {s = (I – electronic, II – mechatronic, III – electric, IV – electromechanic, V – pneumatic, VI – hydraulic, VII – mechanic, VIII – digital)}.

3.3. Determination of the set of preventive activities to renovate the servicing object

The servicing of the elements of different classes [1, 2] can be realised by the performing of a group of activities from the subset of preventive activities, which is presents the following dependence:

$$\{A_l\} = \{a_1, a_2, ..., a_l, ..., a_L\} \tag{8}$$

Where: $\{A_l\}$ = {a_1 – replacing the element with a new one, a_2 – servicing, adjustment, tuning, regeneration, conservation, lubrication, cleaning, re-filling of working fluids, control check-up.}

Each maintenance activity from (Table 5) is related to its proper value of the function of the servicing of servicing elements. Such values can be determined only in an empirical way; thus, it is convenient to present them with fuzzy logic values, e.g. <*none, small, average, full*> [8, 9, 10].

Table 5. The set of preventive activities
Tabela 5. Zbiór czynności profilaktycznych

Set of preventive activities	Code for the activity a_l	The value of servicing function
replacing the element with a new one	a_1	complete
servicing	a_2	small
adjustment	a_3	small
tuning	a_4	average
regeneration	a_5	average
servicing	a_6	average
conservation	a_7	small
lubrication	a_8	small
cleaning	a_9	small
re-filling of working fluids	a_{10}	small
control check-up	a_{11}	none

An assumption is accepted in the paper that the maintenance structure of the object is determined by a set of maintenance elements (levels, and maintenance layers in these). For this reason, the determined set of preventive activities $\{A(e_{i,j})\}$ possesses a structure which is compliant with the object's maintenance structure (levels, and layers of preventive activities in these). The developed set of preventive activities to renovate the object presents the following dependence:

$$\{A(e_{i,j})\} = s(e_{i,j})\{a_1, a_2, ..., a_l, ..., a_L\} \tag{9}$$

where: s – classes of groups of maintenance elements, s = {I – electronic, II – mechatronic, III – electric, IV – electro – mechanical, V – pneumatic, VI – hydraulic, VII – mechanical, VIII – digital}.

3.4. Determination of the set of preventive activities to renovate the servicing object

From the determined set of preventive activities (see 5), their subsets were determined and assigned [2, 3, 6, 5, 8, 12, 14] to further elements of the set of the object's maintenance structure on the basis of the following dependence:

$$R_r: \quad if \;\; W_Z\left(e_{i,j}\right) \;\; then \;\; for \;\; M\left(e_{i,j}\right) \rightarrow \left\{a_l\right\} = M_E\left(e_{i,j}\right) \tag{10}$$

where: R_r – r^{th} rule of maintenance, → – symbol of assignment, $\{a_l\}$ – the subset of l^{th} activities from the set of preventive activities.

The maintenance information set $\{M_E(e_{i,j})\}$ in the form (Tables 4 and 5) was transformed to the final form of the set of maintenance information, which directly determines the structure of the object's maintenance system (cf. Table 6).

Table 6. The structure of object's maintenance system
Tabela 6. Struktura system obsługiwania obiektu

Structure of object's maintenance system $\{M_E(e_{i,j})\}$	
Elements of maintenance structure	**Elements of structure** of maintenance activities
$e_{i,j}$	$\{a_l\}$
$e_{1,1}$	$\{s(a_1, a_2,\ldots,a_l,\ldots,a_L)\}$
⋮	⋮
$e_{i,j}$	$\{s(a_1, a_2,\ldots,a_l,\ldots,a_L)\}$
⋮	⋮
$e_{I,J}$	$\{s(a_1, a_2,\ldots,a_l,\ldots,a_L)\}$

where: s – classes of the elements of maintenance structure of the object {s = (I – electronic, II – mechatronic, III – electric, IV – electromechanic, V – pneumatic, VI – hydraulic, VII – mechanic, VIII – digital)}.

The set of operational rules $\{R_r(e_{i,j})\}$ constitutes an important subset of the set of operational information. 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 were used, which were put in Tables 3, 4, 5 and 6. The dependencies (9 and 10) were used for the development of this set of information, as well as sets of information, which were presented in Tables 3, 4, 5 and 6. The results obtained are presented in Table 7 and Fig. 5.

The effect of the method presented in the article is the determined 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) constitutes the basis for the designing of a reliable system of the maintenance (prevention) of a technical object. A maintenance system (Fig. 5) is understood to be a dynamic set that 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.

Table 7. The set of operational rules for the object
Tabela 7. Zbiór reguł obsługowych obiektu

Element no. in the object	Rules of operation
$e_{1,1}$	R_1: If $\varepsilon(e_{1,1})$ is $\{1\}$ then $M(e_{1,1}) \rightarrow \{5,7,8,11\} = M_E(e_{1,1})$
⋮	⋮
$e_{1,j}$	R_2: If $\varepsilon(e_{1,j})$ is $\{\otimes\}$ then $M(e_{1,j}) = M_E(e_{1,j})$
⋮	⋮
$e_{1,J}$	R_3: If $\varepsilon(e_{1,J})$ is $\{\otimes\}$ then $M(e_{1,J}) = M_E(e_{1,J})$
⋮	⋮
$e_{i,1}$	R_4: If $\varepsilon(e_{1,4})$ is $\{\otimes\}$ then $M(e_{i,1}) = M_E(e_{i,1})$
⋮	⋮
$e_{i,j}$	R_5: If $\varepsilon(e_{i,j})$ is $\{\otimes\}$ then $M(e_{i,j}) = M_E(e_{i,j})$
⋮	⋮
$e_{i,J}$	R_6: If $\varepsilon(e_{i,J})$ is $\{1\}$ then $M(e_{i,J}) \rightarrow \{6,8,10,11\} = M_E(e_{i,J})$
⋮	⋮
$e_{I,1}$	R_7: If $\varepsilon(e_{I,1})$ is $\{\otimes\}$ then $M(e_{I,1}) = M_E(e_{I,1})$
⋮	⋮
$e_{I,j}$	R_8: If $\varepsilon(e_{I,j})$ is $\{\otimes\}$ then $M(e_{I,j}) = M_E(e_{I,j})$
⋮	⋮
$e_{I,J}$	R_9: If $\varepsilon(e_{I,J})$ is $\{\otimes\}$ then $M(e_{I,J}) = M_E(e_{I,J})$

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 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 (Fig. 5), which is composed of the following: the object's maintenance elements, the prevention activities (depending of the state) selected by an expert, including the maintenance means for a given element $\{A(ei,j)\}$, and maintenance rules $\{R_r(e_{i,j})\}$.

The issues presented in the article of the building of a set of operating information concerns various fields of knowledge, including technical diagnostics, the theory of operation, information technology, expert systems,

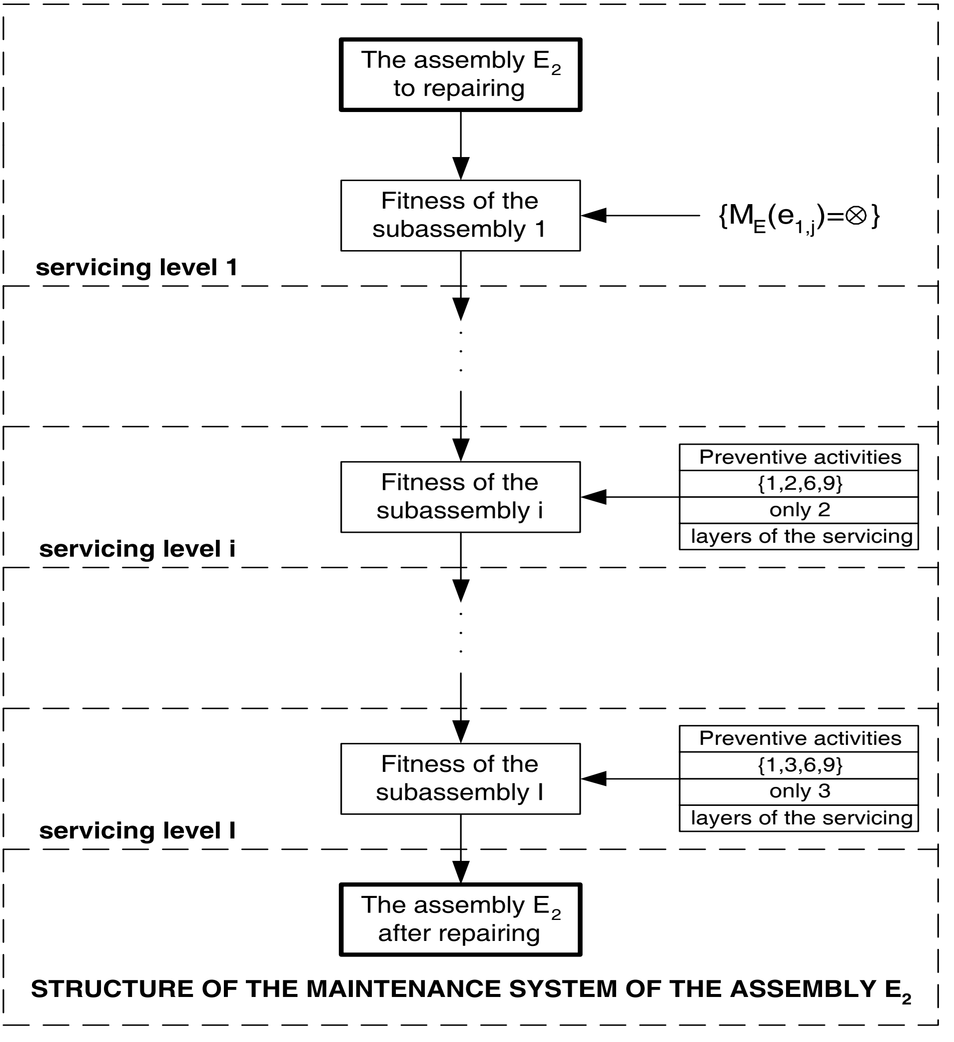


Fig. 5. Structure of the maintenance of the assembly E_2 (example)
Rys. 5. Schemat struktury systemu obsługiwania w zespole E_2 (przykład)

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 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 organisation of the operation process, is being constantly developed in various aspects (directions). 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.

5. Conclusions

The paper presents a method to organise servicing of technical objects with the required short shutdown time (aeroplanes, radio-location systems, etc.). The basis of the method proposed is the use of information developed by an artificial neural network. The idea of the preventative method proposed is as follows: a technical object is used while its state is constantly recognised (monitored) by a neural network. In the case when a diagnostic system recognises the state of an incomplete usability {1} or non-usability {0}, then the time is determined when a renovation of the object should begin in the servicing system. A strategy of this type of servicing of technical objects is known as [4, 5, 6] preventative treatment, according to the state with control of parameters. This method is being constantly perfected and improved. A characteristic feature of this method is an elimination of costly and time-consuming repairs. An expected time of the use of an object is accepted, which is limited only by the reliability of its functional elements, which can also be systematically modified in accordance with the needs.

The method of prevention of objects according to the state requires that two problems be solved, and in the literature, they are being developed independently. The first one of them concerns the development of a method to determine the date of the execution of maintenance (i.e. when the regeneration of the object should begin). This issue is the domain of the theory of forecasting of the object's states in time and is continuously being developed. The second issue is the construction (designing) of an effective system for the maintenance of a technical object. In the author's opinion, the method presented in the article serves as an answer to the second issue. The author explicitly states that the research results presented are unique and innovative in the light of the existing literature.

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Wyznaczanie ekspertowej bazy wiedzy do obsługiwania naprawialnego obiektu technicznego

S t r e s z c z e n i e

W pracy zaprezentowano metodę projektowania systemu obsługiwania naprawialnych obiektów technicznych, ze sztuczną siecią neuronową. Opisano w nim schemat i strukturę systemu obsługiwania z siecią neuronową. Zaprezentowano sposób wyznaczania informacji obsługowej obiektu. Przedstawiono sposób przekształcania struktury wewnętrznej złożonego obiektu z jego elementami funkcjonalnymi do postaci struktury obsługowej obiektu. Zaprezentowano analityczne podstawy realizacji obsługiwania technicznego obiektu. Opisano metodę przekształcania informacji diagnostycznej i wiedzy specjalistycznej eksperta do postaci zbioru informacji obsługowej.