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THE METHOD OF DESIGNING A MULTIASPECT DIAGNOSTIC MODEL

Summary. The paper presents a method of designing a multiaspect diagnostic model, i.e. the model that consists of at least two submodels which are applied together. In the described method submodels are created on the basis of knowledge about a construction and an operation of a technical object by taking various aspects into consideration. UML is proposed to work out a multiaspect description of the operation of the technical object. The viewpoints (aspects) which, in the author's opinion, should make possible a precise, unambiguous and exhaustive description of the operation of the technical object are specified and presented. It is shown how to divide a set of diagnostic signal features into subsets, which concern all identified aspects, by means of UML. The way of designing submodels treated as relation models between subsets of values of diagnostic signal features and right subsets of the considered technical states is presented. The general form of a multiaspect diagnostic model is proposed and the idea of its application is shown.

METODA KONSTRUOWANIA WIELOASPEKTOWEGO MODELU DIAGNOSTYCZNEGO

Streszczenie. W referacie przedstawiono metodę konstruowania wieloaspektowego modelu diagnostycznego, tzn. modelu składającego się z co najmniej dwóch, stosowanych łącznie, modeli składowych. W opisywanej metodzie modele składowe tworzone są na podstawie wiedzy o działaniu obiektu z uwzględnieniem różnych aspektów. Do wieloaspektowego opisu działania obiektu technicznego zaproponowano język UML. Wyodrębniono i przedstawiono te punkty widzenia, które w przekonaniu autora powinny umożliwiać dokładne, jednoznaczne i wyczerpujące opisanie działania dowolnego obiektu technicznego. Pokazano w jaki sposób można z zastosowaniem języka UML dokonać podziału zbioru cech sygnałów diagnostycznych na odpowiednie podzbiory, które dotyczą zidentyfikowanych aspektów. Przedstawiono sposób tworzenia modeli składowych, rozumianych jako modele relacji pomiędzy podzbiorami wartości cech sygnałów diagnostycznych i odpowiednich podzbiorów rozpatrywanych stanów technicznych obiektu. Zaproponowano ogólną postać wieloaspektowego modelu diagnostycznego oraz przedstawiono ideę jego zastosowania.

1. INTRODUCTION

Working out of a single (global) diagnostic model for many modern technical objects is usually an uphill task. On the basis of many published research results, e.g. 2, it can be stated that in this case better results are obtained by means of a set of the local models. Recognition of a technical state of a

considered object is possible by taking into account information from the all active local diagnostic models. Thus, it is an implementation of the idea of multimodel, which working efficiency was presented in 4.

A particular form of a multimodel is a multiaspect model. The proposed method of designing a multiaspect diagnostic model concerns the technical objects which operation can be described by means of UML (*Unified Modelling Language*).

2. UML

UML is a standardized general-purpose modelling language in the field of software engineering that makes possible defining a structure and dynamics of the object models, which represent real objects (e.g. a person, a thing, an administrative unit, an event) 3. Thus, in the particular case a technical object may be also examined. It especially concerns these objects, for which one can distinguish functional states (e.g. pumping of liquid, heating of gas, lifting of mass etc.), that is the objects which work according to the established procedures in changeable conditions (e.g. a computer numerical controlled (CNC) machine tool, an industrial robot, a washing machine etc.). If distinction between functional states is difficult they can be separated by digitizing object operation conditions.

In UML aspects are represented in the form of diagrams but a number of considering viewpoints is not equal to the number of available diagrams because some diagrams are semantically equivalent to the others.

3. IDENTIFIED SET OF THE RELEVANT ASPECTS

In the result of the analysis of the all viewpoints considered in UML, the aspects which should be suitable to the use in technical diagnostics, i.e. make possible a precise, unambiguous and exhaustive description of a technical object operation, were identified. They are as follows:
- the functional state aspect (FSA);
- the elements activity aspect (EAA);
- the elements activity constraints aspect (EACA);
- the elements timing aspect (ETA);
- the elements history aspect (EHA).

4. THE METHOD OF DESIGNING A MULTIASPECT DIAGNOSTIC MODEL

Designing of a multiaspect diagnostic model according to the proposed method consists in determining the relation model between symptoms and technical states of a considered object.

4.1. Identification of a set of technical states

For many objects identification of a set Z of technical states which are possible to recognized is not usually difficult. In connection with this designing a multiaspect diagnostic model should be begun by determining a set

$$Z = \{z_0, z_1, z_2, \ldots, z_n\} \tag{1}$$

where: z_0 denotes base state (object is usable) and z_i ($i=1,2,\ldots,n$) denotes other technical state.
It should be emphasized that if it is possible to distinguish functional states φ_j ($j=1,2,\ldots,m$), which make up a set

$$\Phi = \{\varphi_1, \varphi_2, \varphi_3, \ldots, \varphi_m\} \tag{2}$$

then it is not necessary to consider directly the all elements of the set Z because the examined object is always in definite functional state $\varphi_{k \in \{1,2,...,m\}}$ at a given time. Thus, it is sensible to consider suitable subsets of the set Z, i.e.

$$Z_j^* \subseteq Z \tag{3}$$

and it is not required that the subsets are disjoint but the following condition must be accomplished

$$Z = \bigcup_j Z_j^* \tag{4}$$

In other words, it should be enough to consider technical state only of the elements, which have a significant influence on operation of the examined object in a given functional state. For instance: analysis of the statement that the liquid is not pumping does not require considering technical state of the elements which do not have any influence on the pumping process.

4.2. UML model of the technical object

The next step of designing a multiaspect diagnostic model consists in working out the UML model of the examined technical object by means of the method described e.g. in 3, 5. As a result the UML model, represented in the form of the set of diagrams, should describe operation of the considered object in an unambiguous and complete way.

The set Z ought to be taken into consideration during creating the UML diagrams because complete description of the object operation should also comply with the cases of technical states different from the base state.

Moreover, it should be emphasized that modelling process in UML is usually time-consuming for the sake of its iterative character.

4.3. Identification of the set of diagnostic signal features

The set of diagnostic signal features in a multiaspect approach is obtained as a result of the union of suitable subsets which relate to the identified points of view (aspects). Every subset concerns only these diagnostic signal features which are identified on the basis of the suitable UML diagram. It is shown in the fig. 1, where:
- S_j^{FSA} – the subset of diagnostic signal features which are considered in the functional state aspect for the j functional state;
- S_j^{EAA} – the subset of diagnostic signal features which are considered in the elements activity aspect for the j functional state;
- S_j^{EACA} – the subset of diagnostic signal features which are considered in the elements activity constraints aspect for the j functional state;
- S_j^{ETA} – the subset of diagnostic signal features which are considered in the elements timing aspect for the j functional state;
- S_j^{EHA} – the subset of diagnostic signal features which are considered in the elements history aspect for the j functional state;
- S_j – the set of diagnostic signal features which are considered for the j functional state.

4.4. Designing of the aspect models

Values of diagnostic signal features obtained from definite viewpoint (the aspect) depend on current technical state of the examined object in a given functional state. Let $V_{j,k}^{FSA}$, $V_{j,k}^{EAA}$, $V_{j,k}^{EACA}$, $V_{j,k}^{ETA}$, $V_{j,k}^{EHA}$ denote the sets of values of diagnostic signal features, determined by S_j^{FSA}, S_j^{EAA}, S_j^{EACA}, S_j^{ATA}, S_j^{EHA} respectively, for the technical state z_k which is considered in the j functional state and

$j \in J = \{1,2,\ldots,m\}$ whereas $k \in K = \{0,1,2,\ldots,n\}$. In connection with this it is possible to distinguish the following families of sets:
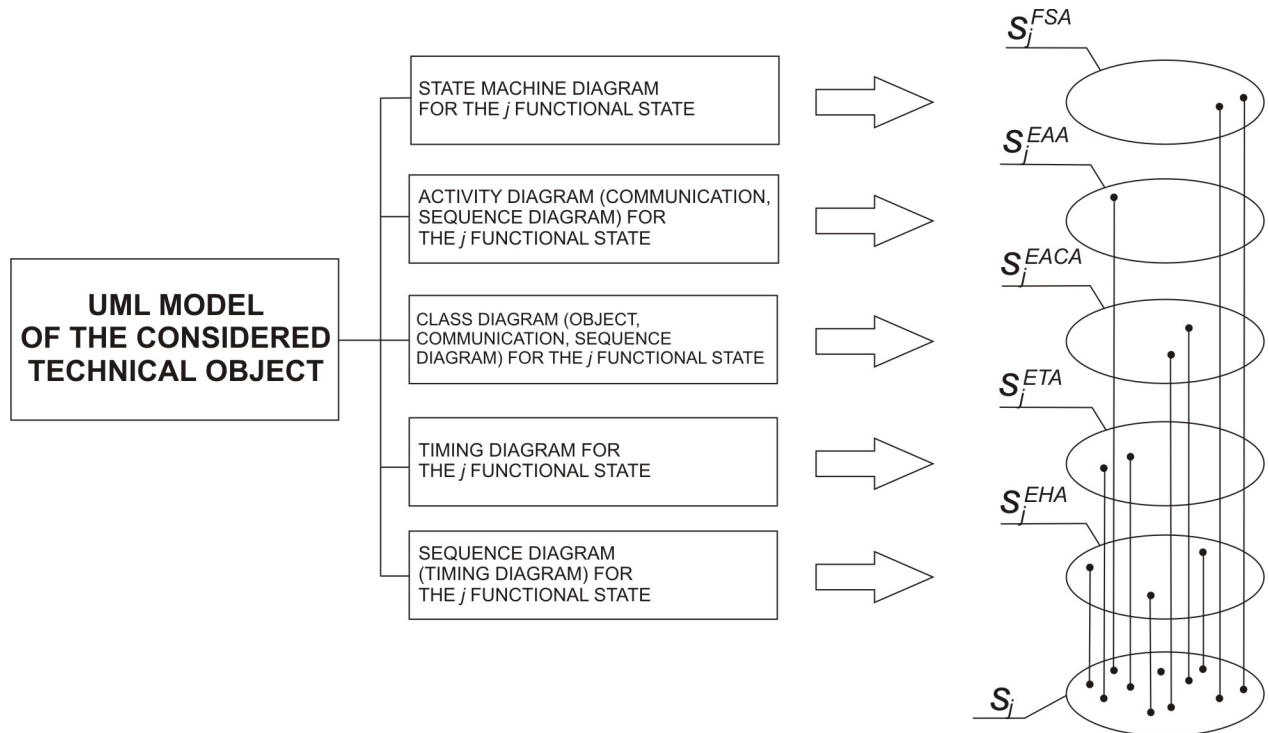

Fig. 1. Identification of the subsets of diagnostic signal features for the j functional state
Rys. 1. Identyfikacja podzbiorów cech sygnałów diagnostycznych dla j-tego stanu funkcjonalnego

$$\forall j \in J \; \forall z_{k \in K} \in Z_j^* : S_j^{FSA*} = \left\{ V_{j,k}^{FSA} \right\}$$

$$\forall j \in J \; \forall z_{k \in K} \in Z_j^* : S_j^{EAA*} = \left\{ V_{j,k}^{EAA} \right\}$$

$$\forall j \in J \; \forall z_{k \in K} \in Z_j^* : S_j^{EACA*} = \left\{ V_{j,k}^{EACA} \right\} \tag{5}$$

$$\forall j \in J \; \forall z_{k \in K} \in Z_j^* : S_j^{ETA*} = \left\{ V_{j,k}^{ETA} \right\}$$

$$\forall j \in J \; \forall z_{k \in K} \in Z_j^* : S_j^{EHA*} = \left\{ V_{j,k}^{EHA} \right\}$$

Then the aspect models for the j functional state can be considered as the relation models R_j^{FSA}, R_j^{EAA}, R_j^{EACA}, R_j^{ETA}, R_j^{EHA} between families of sets (5) and suitable sets (3), i.e.

$$R_j^{FSA} \subset S_j^{FSA*} \times Z_j^*$$

$$R_j^{EAA} \subset S_j^{EAA*} \times Z_j^*$$

$$R_j^{EACA} \subset S_j^{EACA*} \times Z_j^* \tag{6}$$

$$R_j^{ETA} \subset S_j^{ETA*} \times Z_j^*$$

$$R_j^{EHA} \subset S_j^{EHA*} \times Z_j^*$$

In other words, as opposed to the traditional approach where one (global) diagnostic model is identified on the basis of one training data set, in this case local diagnostic models are designed on the basis of suitable (intended for the model) data set.

4.5. Evaluation of the multiaspect model output

The set M of aspect models which represent relations (6) cannot be treated as a multiaspect diagnostic model because it is necessary to join the outputs of the aspect models all together. The relation which should be reflected by the multiaspect diagnostic model will be represented not till then, when the all aspect models are considered together.
Joining of the outputs of the aspect models can be done either by adjusting outputs or by their aggregation. The choice of suitable method should depend, among others, on the established form of the aspect models 0. Fig. 2 shows an application of aggregation operator $\oplus$ for the j functional state.
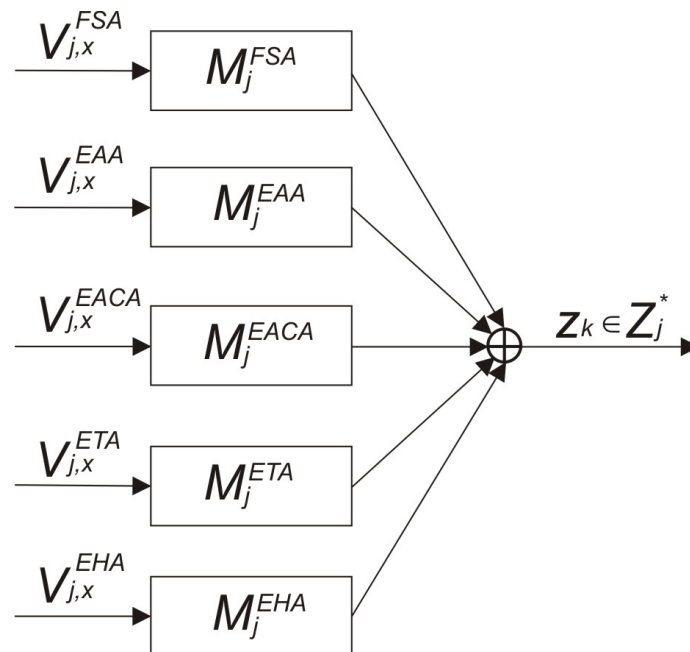

Fig. 2. Aggregation of the outputs of the aspect models for the j functional state
Rys. 2. Agregacja wyjść modeli aspektowych dla j-tego stanu funkcjonalnego

If the designed diagnostic model works correctly, then technical state z_k, recognized by means of the model, corresponds to the current state z_x ($x=k$) for which the sets of values of diagnostic signal features $V_{j,x}^{FSA}$, $V_{j,x}^{EAA}$, $V_{j,x}^{EACA}$, $V_{j,x}^{ETA}$, $V_{j,x}^{EHA}$ have been calculated.

4.6. The general form of the multiaspect diagnostic model

The set of joined aspect models, which is shown in the fig. 2, may be considered as a particular form of the multiaspect diagnostic model. It is true when object operation is described by one functional state ($m=1$).

If there are at least two functional states, then it is necessary to consider the possibility of modification of the conclusions, which had been drawn for a given functional state, on the basis of the obtained conclusions for the other functional state. For instance: if a diagnosis for the second functional state had been pointed at a **probable** heater failure and for the third functional state it was stated **for sure** that the heater was in working order, then it is sensible to assume that the heater had been also efficient in the second functional state. After entering this information into the aspect models, which

concern the second functional state, the earlier conclusions for the state are modified and one can expect that accuracy of the diagnosis will become higher.

The general form of the multiaspect diagnostic model (MDM) and the idea of its application is shown in the fig. 3. The possibility of modification of the conclusions is represented by means of the broken lines. The case when an examined object is in the functional state more than once is not taken into account in order to avoid making the figure unclear.

5. SUMMARY

In the diagnostics domain the idea of the multiaspect model has not been applied till now. It seems that proposed approach consisting in an application of UML to the representation of knowledge about technical objects which operate according to the established procedures in changeable conditions, makes possible modification of the present process of knowledge acquisition. It consists in separation of issues which can be considered independently and simultaneously cohesion of the acquired knowledge is assured.

An important advantage of the presented method is systemization of the process of designing a multiaspect diagnostic model, i.e. decreasing of probability that an important knowledge about the object will be overlooked. Similar models can be designed in an intuitive way so that avoid creating the UML diagrams. However, in this case one cannot be sure that the models are complete.

Moreover it seems that the presented method shows the possibilities of establishing new procedures which concern designing supervision systems or improvement (simplification) of the current procedures, especially in regard to the complicated technical objects. In other words, the method may be used as a base for the new methods of designing diagnostic models or supplement for the methods which concern residual processes.
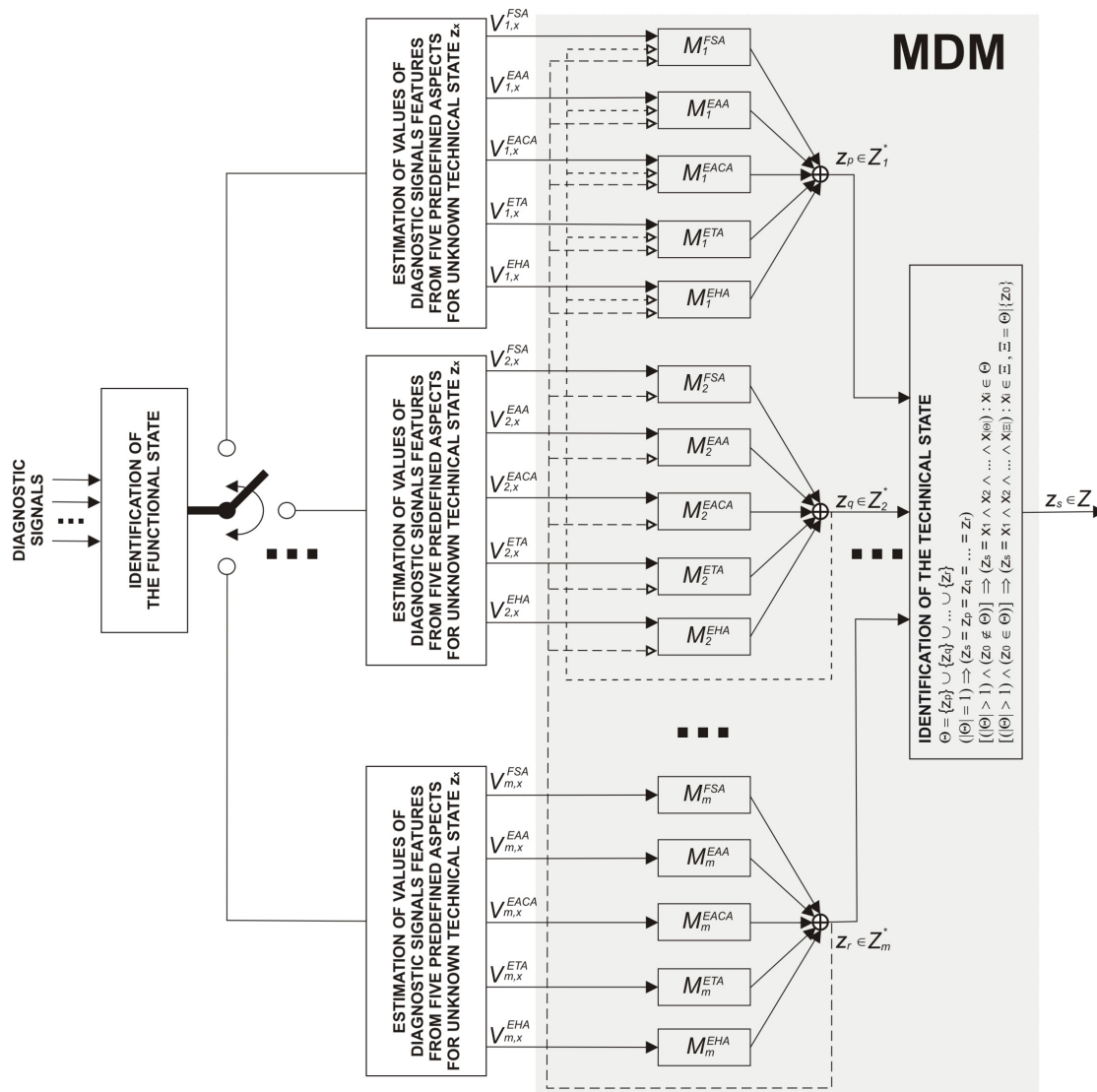
Fig. 3. The general form of the multiaspect diagnostic model and the idea of its application
Rys. 3. Ogólna postać wieloaspektowego modelu diagnostycznego oraz idea jego zastosowania

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