USING TEXT MODELS IN DIAGNOSTIC TASKS.

WYKORZYSTANIE TEKSTOWYCH MODELI W ZADANIACH DIAGNOSTYKI

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Abstract: This paper contains developing of a method of solving diagnostic tasks for complex technical objects (**STO**) based on using text models (TM_i) to describe the functioning of **STO**. A TM_i model is a text description, in normalized form, of all fragments of **STO** functioning process. The description of TM_i is for med using semantic vocabularies of different types, which are generated on the basis of usage of information about all the aspects of **STO** construction and functioning. Such interpretation description is a subject area for tasks of **STO** diagnostics. Detection of malfunction and deviations of a functioning process of **STO** from an established functioning mode is implemented on the basis of analysis of semantic parameters of text description of the **STO** functioning process in order to determine semantic anomalies which occur in the descriptions of the **STO** functioning process, as well as in the descriptions of fragments of its functioning. Semantic anomalies occur in case when values of semantic parameters go beyond their established limits.

Keywords: complex technical objects, semantic parameters, text models.

Streszczenie: W pracy przedstawione są naukowe aspekty tworzenia systemów sterowania obiektami społecznymi. Opracowano strukturę systemu sterującego wraz z układem monitorowania i układem modelu tekstowego pomagającego w symulacji poszczególnych obiektów społecznych i środowiska społecznego jako całości. Do działań sterujących używa się strumieni informacji, będących tekstowymi opisami informacji, gdyż zakłada się, że mają one wpływ na poszczególne osoby tworzące obiekty społeczne i na same obiekty społeczne. W celu przeprowadzenia analizy istoty wpływu strumienia informacji (IP_i) na obiekt społeczny (SO_i), a także dla analizy skuteczności jego wpływu na obiekt społeczny, użyto modeli tekstowych TM_i , opisujących odpowiednie obiekty społeczne. Oprócz modeli tekstowych i strumieni informacyjnych w niniejszym artykule przedstawiono system monitorowania źródeł informacji pochodzących od poszczególnych osób, które stanowią SO_i oraz samego SO_i . Opracowane w niniejszym artykule koncepcje modeli tekstowych TM_i są nowe nie tylko w dziedzinie badań społecznych, lecz również w obszarze teorii regulacji automatycznej. Po raz pierwszy opracowano i przebadano koncepcję zależności pomiędzy TM_i a parametrami semantycznymi właściwymi dla SO_i .

Słowa kluczowe: obiekt społeczny, parametry semantyczne, modele tekstowe.

1. Introduction

To solve tasks of diagnostics of complex technical objects (*STO*), we need to clarify the problem of classifying malfunctions, because different malfunction types require different methods of their detection. The following malfunction types can be assumed as the most general classification:

- designing malfunctions (*pn*);
- non-designing malfunctions (*nn*).

Designing malfunctions are those which can be foreseen during the stage of *STO* designing. An example of such malfunctions can be those which occur due to foreseen changes of parameters characterizing *STO* and its certain units. Among these parameters can be a resource value of certain parts or units, unacceptable deviation values of the functional parameters if a representation of units or part allows to know what unacceptable changes in *STO* or its certain units could be caused by these deviations. In general this means that during *STO* designing it is possible to form dependencies between the causes of malfunctions and the parameters characterizing them.

The *nn* type includes malfunctions which do not allow to determine dependencies between changes of functional parameters and possible changes of technical state of certain nodes or *STO* in general during the designing stage. Examples of such occurrences are as follows:

- a possibility for external negative factors to appear, with unknown parameters;
- absence of mathematical or empirical models connecting the processes of a different physical nature, which are used in *STO*;
- when hidden designing mistakes occur, which did not become apparent during object testing and trial performance, etc.

The *pn* malfunctions are diagnosed on the basis of data regarding diagnostic parameters and the possible causes of their discovery. Diagnostic parameters are used to recognize malfunctions, and the information about their causes of occurrence is used to localize the places of influence of negative factors which eventually lead to these malfunctions [1,2]. This is due to possible diversification of malfunction causes and malfunction effects in the *STO* structure.

In case of *nn* malfunctions the following situations can occur:

- diagnostic parameters which describe the form of malfunction occurrence can be known while the causes of the occurrence are unknown,
- an occurring malfunction only appears as unacceptable changes of functioning modes of *STO* or its units, which means there is no data regarding both diagnostic parameters and causes of the corresponding malfunctions.

This paper describes a developed method of diagnostics of a *nn* type malfunction, based on using text models TM_i .

2. Fundamentals of text model system

A text model is a description of how to interpret a functioning process of an *STO* unit or *STO* as a whole in the normalized text form [3]. Building a TM_i of a certain *STO* requires a description of a subject area containing *STO*, all of its components and external factors which could influence *STO*. This description consists of a set of semantic vocabularies Sc_i [4]. A semantic vocabulary consists of elements, which are text descriptions of words x_i or phrases φ_i , and a text description of interpretation of the corresponding element:

$$x_i := \langle a_{i1} * \dots * a_{in} \rangle \text{ I } \langle p_{i1}, \dots, p_{ik} \rangle,$$

where a_{ij} are words which make up the description of x_i interpretation, and p_{ij} are auxiliary parameters which can supplement the data regarding the x_i element.

Describing the TM_i requires using words or phrases $(x_i \vee \varphi_i) \in Sc_i$. The TM_i structure corresponds to the *STO* structure. For example, a sentence ψ_i , which consists of phrases φ_i , describes a certain fragment ω_i of a unit W_i , or $\omega_i \in W_i$. A paragraph $\pi_i \in TM_i$ describes a certain unit W_i from *STO*. A model TM_i in general describes *STO*. Formally you can write the following:

$$\begin{aligned} [TM_i = (\pi_1 * \dots * \pi_n)] &\Rightarrow [\pi_i = (\psi_{i1} * \dots * \psi_{im})] \Rightarrow [\psi_{ij} = (\varphi_{ij1} * \dots * \varphi_{ijk})] \Rightarrow \\ &\Rightarrow [\varphi_{ijk} = (x_{ijk1} * \dots * x_{ijkg})]. \end{aligned}$$

For example, let us examine a description of one unit W_i and assume a single phrase φ_{ijk} is a separate component of the description. Then a formal description of this unit as a TM_i can be written in the following way:

$$TM_i = \pi_i = \{\psi_{i1}(\varphi_{i11} * \dots * \varphi_{i1m}) * \dots * \psi_{in}(\varphi_{in1} * \dots * \varphi_{ink})\}.$$

A unit W_i can be described with different accuracy of representing its structure and its functioning process. A TM_i functioning description is an interpretative description of a current state of all the elements and represents their structure, its connection with a structural environment in the unit scope and parameters with their values, relevant to the described component and characterizing its state. A description of every parameter is extended by a description of a surrounding parameter which interacts with the parameter of the described element. In this description every element is supplemented with information describing a condition of synchronizing its functioning with others surrounding elements or parameters. Depending on the type of W_i , synchronization can be defined and, correspondingly, described at the level of the whole W_i .

During the functioning process of W_i the following occurrences can take place:

- possible changes of parameters characterizing the current state of the functioning process;

- besides the changes of the parameters, a W_i structure configuration can change, which means during the functioning process certain unit elements are moving;
- an extension of such description can be a description of a process of transforming heat energy of fuel combustion into mechanical energy of bearings' movement in the engine cylinders, etc.

To simplify the task review let us confine ourselves with the first case. Within the scope of TM_i values of the parameters displaying the functioning process are changing with specified ranges of accuracy, each of which displays a qualitative change in the corresponding processes. For example, for a cylinder pressure parameter the following value ranges, displayed in the text model, are specified:

- “acceptable” parameter values;
- “acceptable boundary” parameter values;
- “unacceptable” parameter values;
- “critical” parameter values, etc.

Values of these ranges for certain elements φ_{ijk} in a vocabulary Sc_i are specified as parameters p_{ij} which are part of the vocabulary. The functioning process of certain units and STO in general is continuous during a certain time interval Δt_i , and TM_i is a certain text description. So let us examine how TM_i displays the dynamics of the corresponding functioning process. In modern STO automated or automatic control systems are used. This means during the designing stage STO is equipped with a whole set of sensors for different parameters, including diagnostic parameters. Let us assume that, once it is operable, STO is functioning in the specified mode. Information about current values of the parameters p_{ij} is transferred to the control system and the diagnostic system, built on the basis of using text models. Values of a parameter identified by the element φ_{ijk} are transferred to the description of this element's parameters which are part of an interpretative description φ_{ijk} in a vocabulary Sc_i , which is the following vocabulary component:

$$\varphi_{ijk} := \langle a_{ijk1} * \dots * a_{ijkn} \rangle \text{ I } \langle p_{ijk1}, \dots, p_{ijkq} \rangle.$$

If the current parameter value is within the range p_{ijkc} , where $1 < c < q$, and the interpretative description of this range for φ_{ijk} is used in the text description of TM_i at the moment t_i , which corresponds to the moment when the corresponding parameter value is being read from a sensor, then there is no change of φ_{ijk} parameter value in TM_i . Otherwise, if the current value of the p_{ij} parameter falls within the range p_{ijkc} , where $(1 < c < q) \& (c \neq 1)$, then the text interpretation “...cylinder pressure parameter is within (acceptable limits)...” is changed with the following interpretation: “...cylinder pressure parameter is within (unacceptable limits)...” if the p_{ijkc} range corresponds to such interpretation.

There are also parameters which represent structural changes. A possible example of these is a parameter of range of a slider movement along the guide, which can be described as follows:

- “the slider does not reach the border limiters”,
- “the slider has reached the border limiters”,
- “the slider has not changed direction after reaching the border limiters” and so on.

In these cases the corresponding changes are made within TM_i , in the descriptions of text interpretation of the corresponding φ_{ijk} components. Thus, TM_i represents the dynamics of changes in W_i , which displays the functioning process of the corresponding unit.

3. Method of solving a diagnostic task

To solve a diagnostic task on the basis of using TM_i , which includes the description of STO structure and the description of the functioning process ($Pr_i(STO)$), we require tools for analyzing the corresponding text descriptions. Such analysis tools are semantic parameters σ_i which allow to conduct not only qualitative analysis but also quantitative analysis of the corresponding parameters. In the scope of this paper the following semantic parameters will be used [5,6]:

- semantic contradiction (σ^S),
- semantic conflict (σ^K),
- semantic redundancy (σ^N),
- semantic insufficiency (σ^D).

Interpretation of these parameters is natural for text descriptions and represents particularities of perception of certain text features by the reader. For example, semantic contradiction defines a situation when a sentence contains words or phrases which contradict each other to a degree. Semantic conflict defines a situation when a sentence contains two consequent phrases which describe two different entities both equally subject by the previous text fragment of the corresponding sentence. As distinct from semantic conflict, semantic redundancy occurs in case of two corresponding phrases represent two equal entities in different forms. Semantic insufficiency defines a situation opposite to the one with semantic redundancy.

In order to get quantitative results of the semantic analysis, we need to have methods of numeric valuation of the stated parameters. According to [7,8], calculation of values of semantic parameters is based on using a basic semantic parameter, which is semantic meaningfulness of a text σ^Z consisting of one word or one phrase. Definition of semantic meaningfulness is performed by different ways, among which are:

- involvement of the experts in the subject area,
- calculating the number of words in the descriptions of interpretative extensions of certain elements in semantic vocabularies, provided these descriptions are normalized,
- number of occurrences of a certain word or a phrase within one model TM_i .

Another way is based on an assumption that, the more important the elements are for the functioning of *STO*, the more complete their interpretative description should be and the more words are needed to describe them.

When using semantic parameters in analysis of text descriptions, intervals of acceptable and unacceptable values are defined to determine their values, and these intervals are marked $\delta\sigma^*$. For example, the value of semantic contradiction is defined as an absolute difference value of semantic meaningfulness of two words the semantic contradiction is measured between:

$$\sigma^S(\varphi_i, \varphi_j) = |\sigma^Z(\varphi_i) - \sigma^Z(\varphi_j)|.$$

The basic diagnostic task is to detect malfunctions occurring in a technical object and to determine the causes of this malfunction [9,10]. Detection of a malfunction when using TM_i is based on detecting semantic anomalies.

Definition 1. A semantic anomaly ($\alpha\sigma_i$) is a fragment in a text description TM_i where at least one semantic parameter is outside of a set range.

In this case detecting malfunctions consists of calculating the values of semantic parameters σ^S , σ^K , σ^N , σ^D . Let us assume that in the initial version there are no semantic anomalies in the TM_i . So, semantic analysis can be performed only in case when changes have occurred in the TM_i . This analysis can be performed firstly within the boundaries of the fragments where the changes took place. The boundaries of such fragment of a text description, during the initial stage of analysis, can be defined by size of the sentence where the changes occurred. Certain boundary values of semantic parameters are defined for each *STO* and each $Pr_i(STO)$ on the basis of expert analysis performed by specialists during the *STO* designing stage. The $\delta\sigma_i$ values can change during the *STO* functioning. The text description of the fragment where changes occurred, in the scope of a system of text model tools, allows to generate output of text descriptions which interpret the detected malfunction in the subject area of the corresponding *STO*.

To determine the causes of malfunction, given that it is localized in another fragment of the *STO* structure regarding the fragment where the malfunction occurred, within the TM_i a description is implemented of a sequence of events in *STO* which have caused a semantic anomaly. Let us review the following proposition.

Proposition 1. A text description of a model TM_i of an object *STO* describes, as a given approximation, all aspects defining $Pr_i(STO)$, which is formally described by the following relation:

$$\forall(x_i \in TM_i) \exists x_i \{ [Pr_i(TM_i) \rightarrow (x_i \notin STO)] \}.$$

Let us review the following statement.

Statement 1. If a semantic anomaly occurred in TM_i , then there are descriptions within the limits of TM_i which have caused the corresponding anomaly.

Let us assume that in $tm_i \rightarrow \alpha\sigma_i$. This means $\sigma_i(\varphi_i, \varphi_j) > \delta\sigma_i$ exists in tm_i . It results from this that values $[\sigma^Z(\varphi_i) \vee \sigma^Z(\varphi_j)]$ have changed in $(\varphi_j \vee \varphi_i)$. If $\Delta\sigma^Z(\varphi_j) > \tau_j$, where τ_j is a boundary for regulating a parameter $\varphi_j = \xi_j$, where ξ_j is a parameter of a process $Pr_i(STO)$, which corresponds to φ_i in TM_i , this means there is a function $y_j = f(y_k)$ in STO and, respectively, there is an element φ_k in TM_i which is connected to φ_j by a text fragment $j(f(\varphi_k, \varphi_j))$. If the TM_i has $\sigma_i^S(\varphi_k, \varphi_j) \leq \delta\sigma^S$, then $[\sigma_i^S(\varphi_i, \varphi_j) \in tm_i] \& (\alpha\sigma_i \in tm_i)$, which means a malfunction occurs in (φ_i, φ_j) , which can be interpreted as a malfunction in $\omega_i \in STO$. Let us assume $\sigma_i^S(\varphi_k, \varphi_i) \leq \delta\sigma^S$, then in STO exists $\xi_i = f(\xi_k)$, such that $j(f(\varphi_k, \varphi_i)) \rightarrow \sigma_i^S(\varphi_k, \varphi_i) \geq \delta\sigma_i$. This means there is such tm_j in TM_i , where $j(f(\varphi_k, \varphi_r))$ is described. If $\sigma_i^S(\varphi_k, \varphi_r) \geq \delta\sigma^S$, the malfunction is in φ_r . If $\sigma_i^S(\varphi_k, \varphi_r) \leq \delta\sigma^S$, then we proceed to φ_h for which $j(f(\varphi_r, \varphi_h))$ exists in TM_i . Because STO is structurally finite, TM_i is a finite description. Besides, TM_i is complete with a given approximation ε . This means that when continuing the chain of semantic analysis within TM_i looking like $\varphi_i \rightarrow \varphi_j \rightarrow \varphi_r \rightarrow \dots \rightarrow \varphi_h$, we will achieve φ_g^* , for which $\sigma_i^S(\varphi_{g-1}, \varphi_g) \geq \delta\sigma^S$. Then φ_g^* identifies the place which causes the malfunction in φ_i .

In order to use TM_i for diagnostics, it is necessary to generate not only Sc_i but also a system of boundary values for semantic parameters used in the semantic analysis. Each type of semantic parameters requires to generate a vocabulary of their interpretations, which represents the relations of boundary values $\delta\sigma_i$ with unacceptable deviations in $Pr_i(STO)$. For example, if $\xi_i = f(\xi_j)$ takes place, which is represented in $tm_i \in TM_i$ as $(\varphi_i * \varphi_j)$ and, respectively, $\sigma^S(\varphi_i, \varphi_j) > \delta\sigma^S$ exists, this means that $\neg(\varphi_i \rightarrow \varphi_j)$ is taking place. This is interpreted as an unacceptable difference value between ξ_i and ξ_j . When the case in question is $\sigma^K(\varphi_i, \varphi_j)$, this parameter represents an unacceptable value of similarity between (φ_i) and (φ_j) . From the point of view of functional interpretation of σ^K this means $\neg\{\xi_i = f(\xi_m)\} \leftrightarrow [\xi_j = f(\xi_r)]$. Interpretations for σ^N and σ^D can be formed in a similar way.

4. Summary

When using conceptions of a text model system, it is possible to solve basic diagnostic tasks, such as detecting malfunctions and determining their causes. When doing so, the corresponding TM_i must be complete in the given scope of STO description. Thanks to representation of all parameters in TM_i , provided for by given ranges of parameters, and critical changes occurring in $Pr_i(STO)$, it is possible to detect non-designing malfunctions. This is possible because, when solving diagnostic tasks, it is not necessary to use explicit, or empirical dependencies between parameters, which, when changed, can lead to unacceptable deviations and, respectively, to occurrence of malfunctions.

Thanks to using text descriptions of the functioning process of STO , it is possible to detect situations that can be interpreted as manifestations of malfunctions, on

a level of text interpretations of the functioning process, corresponding to changes in the process.

In the scope of the proposed approach it is possible to supply operators or the maintenance staff with information regarding negative changes in the *STO* functioning process in a user-friendly form to directly perceive the corresponding events in a technical system.

5. References

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