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The Technical System Troubleshooting Defining Using Concept Patterns

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Abstract

In the proposed work the possibility of technical system's troubleshooting diagnostics with help of integrated nanosensor devices that require the appropriate information system development is described. The mentioned systems should allow the big data collecting, analysis , transfer and in particular cases even support the decision making process. In order to define the troubleshooting of the system we are offering to represent the knowledge base in information system with help of concept patterns. Using the proposed method it is possible to select the optimal set of nanosensors defining the troubleshooting of the concrete type technical system.

Keywords*: Concept, Knowledgebase, Nanosensors, Technical System Troubleshooting*

1. Introduction

The technical progress gained in 21 century leads human to use different kind of technical devices in everyday life. These devices are getting more and more demanded in people's ordinary life and on their faultless functioning are relied successful performance of diverse activities. Thus existence of technical system properties like "smart systems", "troubleshooting self-diagnostics" and etc. are getting to the top issues to get solved. As small is the technical system as harder is the technical node implementation on them to fulfil the troubleshooting diagnostic task. The nanosensors are considered to be the one of problem solutions. That is why the research held on integrated sensor devices, along with appropriate information system development for sensor based information processing and analysis is such an important issue. The significant part of research is devoted to information system development that supports the data (received from sensor) collecting, analysing and sometimes even decision making. In the sensor based system management several methods are used. Particularly, the artificial intelligent based methods are common. At least the following seven "tools" for above mentioned problem solving are used: the knowledge-based systems, fuzzy logic, automatic knowledge acquisition, neural networks, genetic algorithms, case-based reasoning, and ambient-intelligence) [1, 2, 3, 4, 5, 6]. In the provided paper we will consider the knowledgebase representation concept pattern method for technical system troubleshooting in information systems. Based on this method it is possible to select the nanosensor optimal set providing the troubleshooting defning possibility.

2. Pattern Formation Method

Let us define some T Technical System, that might be in n different states. Lets represent these states as $T = \{T_1, T_2, \ldots, T_n\}$ object set. Suppose on m different nodes of T system we have $S = \{S_1, S_2, \ldots, S_m\}$ nanosensors. Each S_j, j=1,…,m is received from signal derived from nanosensor:

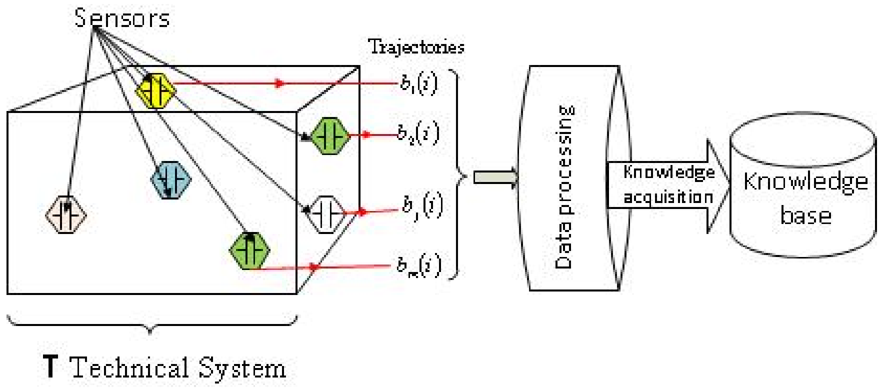

Fig. 1.

In along with evaluation to which class this object belongs to: $T^+ \subset T$ or $T^- \subset T$, each property S_j , j=1,…,m may receive value $b_{jk} \subset B, k = 1,2,\dots,n_j$.

The sorted set of values $S_1, S_2, \dots, S_m$, in case of T_i object definition (T system states), call the "trajectory". Each object T_i might be presented with help of appropriate „trajectories":

$$T_i = \{b_1(i), b_2(i), \dots, b_m(i)\}, \; b_j(i) \in B, \; j = 1, 2, \dots, m$$

After observation of objects from subclasses, subject should define the notion that is appropriate of T^+ and T^- subclasses. The method of Analytical Heuristics [7] gives possibility to construct pattern appropriate of T^+ and T^- on the basis of evaluated objects.

Pattern formation process consists of the following stages:

Property binarization based on its "value set"

For the most general binarisation method the set splitting method might be used. According to this method set is split into two fulfilling each other sets: "is" and "is not". In this case appropriate notations will be T_i have property (S_k , k = 1, 2, …, m.) or T_i not have property ($\overline{S}_k$,k = 1, 2, … ,m.).

Re-Coding of Properties

Let us introduce the numeric AI-set:

In this case instead of property set $S = \{S_1, S_2, \dots, S_m\}$ we will have :

$$N_A = \{1, 2, \dots, m\},$$

Instead of value set

$$B = \{b_{11}, b_{12}, \dots, b_{m\, n_m}\}$$

we have:

$$\underline{N}_B = \left\{\check{1}, \check{2}, \dots, \check{n}\right\},$$

where

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$$\overset{\vee}{k} = \begin{cases} k \\ \bar{k} \end{cases}, \quad k = 1, 2, \ldots, n ;$$

Instead of „trajectory“

$$T_i = \{ b_1(i),\ b_2(i), \ldots, b_m(i) \}$$

we will have

$$\underline{N}_{S_i} = \left\{ \overset{\vee}{\alpha}_1(i), \overset{\vee}{\alpha}_2(i), \ldots, \overset{\vee}{\alpha}_m(i) \right\},$$

where

$$\overset{\vee}{\alpha}_j(i) \in \underline{N}_B,\ j = 1, 2, \ldots, m .$$

Orthonormal Binary State Vector Construction

Let's introduce V matrix with the following dimension: $n \times m$ ($2n = 2^m$). The columns of this matrix represent state orthonormal vectors(the filters) ψ_i, $i = 1, 2, \ldots, m$, that is produced via $\underline{N}_B$ elements.

Filtration Operation **-** for Each T_i trajectory the orthonormal filter should be applied:

Each trajectory

$$T_i = \left\{ \overset{\vee}{\alpha}_1(i), \overset{\vee}{\alpha}_2(i), \ldots, \overset{\vee}{\alpha}_m(i) \right\}$$

equals to conjunctive product of state orthonormal vectors

$$\varphi(T_i) = \left(\overset{\vee}{\psi}_1\ \overset{\vee}{\psi}_2, \ \ldots, \overset{\vee}{\psi}_m \right)_i, \quad i = 1, 2, \ldots, n$$

where

$\overset{\vee}{\psi}_j = \psi_j$, if the j-th element of trajectory belongs to ψ_j vector as „is“: e_j, $j = 1, 2, \ldots, m$

and

$\overset{\vee}{\psi}_j = \overline{\psi}_j$, if the j-th element of trajectory belongs to ψ_j vector as „not is“: $\overline{e}_j$, $j = 1, 2, \ldots, m$.

The operation of Disjunctive Superposition

$$\varphi_+ = \bigcup_{S_i \in S^+} \varphi(T_i) \text{ in the case of } T^+ \text{ pattern} \quad (1)$$

$$\varphi_- = \bigcup_{S_i \in S^-} \varphi(T_i) \text{ in the case of } T^- \text{ pattern} \quad (2)$$

If

- the number of objects in case of T^+ and T^- subclasses is enough big,
- the objects are non-identical and are widely representing the appropriate subclass,
- the enough number of properties and their value set are defined correctly and the binarization of these sets are made successfully

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then patterns φ_+ and φ_- are containing the full information on T^+ and T^-, and are in no opposition to each other.

In case of great *n* and *m* it is impossible to describe pattern with crisp logic formulation, thus the next stage : pattern simplification is needed.

Conditional transition operation on Boolean variables

If in (1) and (2) we replace each ψ_i vector with x_i, and each $\overline{\psi_i}$ vector with $\overline{x}_i$, then the Functionals φ_+ and φ_- will receive the full disjunctive normal form [10]:

$$\varphi_+ = \bigvee_{I_+(\sigma_1 \sigma_2 \ldots \sigma_m)} x_1^{\sigma_1} x_2^{\sigma_2} \ldots x_m^{\sigma_m}$$
$$\varphi_- = \bigvee_{I_-(\sigma_1 \sigma_2 \ldots \sigma_m)} x_1^{\sigma_1} x_2^{\sigma_2} \ldots x_m^{\sigma_m}$$

where $\sigma_i = \begin{cases} 1 & if \quad x_i \\ 0 & if \quad \overline{x}_i \end{cases} \quad i = 1, 2, \ldots, m$,

$I_+(\sigma_1\ \sigma_2 \ldots \sigma_m)$ – collection set, appropriate of T^+ subclass trajectories;
$I_-(\sigma_1\ \sigma_2 \ldots \sigma_m)$ – collection set, appropriate of subclass trajectories;

After the binarization of these normal disjunctive forms the pattern binary form is being received [10]:

$$K_+ = f^+\left(\xi_1^{\sigma_1},\ \xi_2^{\sigma_2} \ldots \xi_l^{\sigma_l}\right) = \vee \xi_1^{\sigma_1}\ \ \xi_2^{\sigma_2} \ldots \xi_l^{\sigma_l}$$

where $l < m$ and $\xi_1^{\sigma_1},\ \xi_2^{\sigma_2}, \ldots, \xi_l^{\sigma_l}$ are used to reselect those variables $x_i^{\sigma_i},\ x_j^{\sigma_j}, \ldots, x_k^{\sigma_k}$ that stayed after minimization of φ_+ full disanctive normal form (analogious form is received for φ_-). Other variables $\xi_{l+1}, \ldots, \xi_m$ are less important as they have no impact on on object evaluation result.

The pattern binary form K_+ contains some important values of properties and it describes exclusiveness that is typical to T^+ subclass finite collection of objects. for a quite large(great) number of *n* and *m,* the pattern K_+ contains those rules (knowledge in general case) that was used by evaluator who spitted the set of objects into T^+ and T^- subclasses, thus with help of binary pattern K_+, the evaluation of elements, excluded from pattern formation , is possible: enough condition for new object to belong to T^+, is that new trajectories variables $\xi_1, \ldots, \xi_l$ should have values fixed at least in one of the implicants of pattern K_+ , variables $\xi_{l+1}, \ldots, \xi_m$ have the arbitrary values. note that binary pattern is easily presented as a productive rule.

The implicants received from the above mentioned method are representing the generalized descriptions of nanosensor set generated signals, used in T type technical system troubleshooting diagnostics. At the information system we will have $T^+ \subset T$ or $T^- \subset T$ state appropriate generalized descriptions represented via the concept patterns. These patterns are the main content sources for the information system knowledgebase.

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3. Method Testing

In order to test the method, the imitation model software for thirty two technical nodes containing technical system had been created. On each node the damage immitation using Monte-Carlo method was fulfilled and allover 256 different states were described. After we group the received different states in the following two subsets: $T^+ \subset T$ - describing non-demaged system, $T^- \subset T$ - describing the demaged system. Here are the number of trajectories in each subset: T^+ - 89 trajectories, T^-- 167 trajectories. To develop the appropriate concept–pattern for each state around 80 % of trajectories from each subset was used, and on its basis the knowledge base was formed. To test the reliability of created expert system we used rest trajectories (20%) and received positive results for each subset. the numbers are as follows: T^+- 83%, T^-- 86%. It worth to note, that none of trajectories from T^- was appointed to T^+ and vice-versa.

4. Conclusions

Method testing revieles that our proposed method might be used in technical system generalized description, but futere work should be done to improve its reliability.

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