SOME CONCEPT OF DIAGNOSTIC REASONING FOR SYSTEMS WITH UNCERTINTY

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A***bstract:*** *The diagnostic reasoning for systems with uncertainty is the main difficulty in modern diagnostic. Uncertainty is present in the most of diagnosed systems – from medicine to technical applications. Usage of different methods in tasks of diagnostic reasoning connected with these problems has been presented. A wide range of conclusions associated with diagnostic systems creating can be used by designers of these systems.*
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1. INTRODUCTION

The diagnostic decision is always the decision of choice. We choose between different kinds of destruction, faults or causes of illnesses as the diagnostic decision. Making such decisions can be presented as a *rule* [3] –

IF {some conditions} THEN {diagnostic decision} (1)

During making a diagnostic decision different kinds of information must be considered as a set of conditions. As in the most of the systems which include a human operator, the basic troubles are connected with knowledge representation and the tools used to analysis of these systems. The descriptions of diagnosed systems are various: from continuous to discreet, from state to dynamics, from linear to nonlinear, from qualitative to quantitative, etc. In other words there is a wide range of those descriptions. A lot of them include different kind of uncertainty and the classical methods of reasoning based on Boolean logic are not good enough. We must make the system, which considers these various kinds of knowledge representation and can be designed through such a methodology [4,5,8,10], which provides suitable isolability, sensitivity and robustness conditions. The designing process in that system ought to be optimised – the system ought to be composed from minimal quantity of condition components, which generate maximal quantity of diagnostic information. Conflict situations should be found and removed. Only these systems can be effectively used in diagnostic reasoning with high level of safety.

This paper presents an unique approach for diagnostic reasoning. It integrates different descriptions of the diagnosed system. Diagnostic of aircraft control and navigation system as the application of this method will be the subject of further consideration.

2. GENERAL CONCEPTION OF DIAGNOSTIC SYSTEM

According to the rule (1) the diagnostic reasoning means finding the rule which projects each situation described as set of conditions - $\mathbf{w_i} \in \mathbf{W(t)}$ onto set of fault descriptions - $\mathbf{d_i} \in \mathbf{D(t)}$. In spite of this, that most of considered signals $\mathbf{w_i}$ are continuous, in diagnostic rules are used as transformations to finite values set. These transformations are very important to correctness of diagnostic systems. Some of these are symptoms of faults – **R**, generated by fault detection systems. During the diagnose of aircraft control and navigation system these process can be presented as in fig.1.

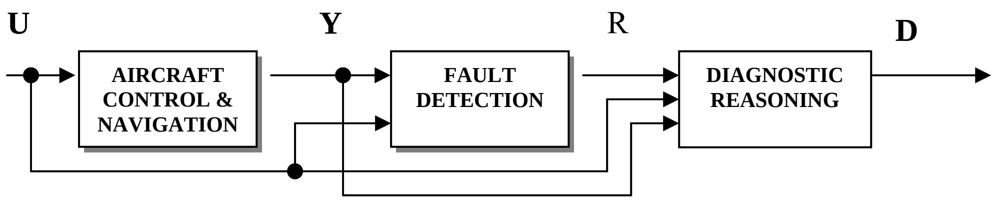

Fig. 1. Schema of diagnostic reasoning in aircraft control and navigation system

In aircraft control and navigation system fault detection systems are designed with the use of various methods [1,2,3,6,7]:

- hardware redundancy,
- analytical redundancy based on:
    - physical model of diagnosed subsystem for well known but not easy described subsystems (for example - aircraft power installations),
    - observer technique for systems without large influence of noises (for example – aircraft control system with actuators and measurement systems,)
    - Kalman filter with Bayesian hypothesis testing (for example - AHRS),
    - fuzzy classification (for faults decreasing with exploitation – mechanical lash),
    - neuron nets as a model of some modes of aircraft flight (high manoeuvred flight).

Using a result of fault detection's - **R**, and modes of flight – **U, Y,** the diagnostic reasoning can be taken in which actual diagnostic knowledge - **D** must be considered. This means that diagnostic reasoning is the dynamical process with the set of conditions **W** = {**R(t), U(t), Y(t), D(t)**} and the set of decisions **D** = {**D(t+1)**}. Then our system is a 4-tuple [3]:

$$\mathbf{S= (X,W \cup D,V,f)} \tag{2}$$

where:

- **X** - is a nonempty, finite set of objects, called *universe*;
- **Q = W∪D** - is a finite set of *attributes*;
- **W** - is a set of *condition (observable) attributes*;
- **D** - is a set of *decision attributes*;
- $V = \bigcup_{q \in W \cup D} V_q$, where V_q is a domain of attribute q;
- **f** - is an *information function* assigning a value of attribute to every object and every attribute, i.e., $f: X \times Q \rightarrow V$, such that for every $x \in X$ and for every $q \in Q$, $f(x,q) \in Vq$.

In such system we cannot distinguish two states $x, y \in X$ using attributes $P \subseteq Q$ if $f(x,a) = f(y,a)$ for each $a \in P$. It is [9] the indiscernibility relation - **IND(P)**. This relation is an equivalence relation over **X**. Hence, it partitions **X** into equivalence classes. Such partition (classification) is denoted by **X/IND(P)**. When knowledge is represented by value of attributes an important problem is to find and express relationships among attributes. In rough sets theory [9] a measure of dependency of two sets of attributes is defined for that purpose. The measure is called a *degree of dependency* of **D** on **W** (where **D** and **W** are sets of attributes) and denoted $\gamma_W(D)$. It is defined as:

$$\gamma_W(D) = \frac{\mathrm{card}(\mathrm{POS}_W(D))}{\mathrm{card}(X)} \tag{3}$$

The set $\mathbf{POS_W(D)}$ is called *positive region of classification* **X/IND(D)** (denoted by fault) for the set of condition attributes **W**. Informally speaking, the set $\mathbf{POS_W(D)}$ contains those objects of **X** which may be classified as belonging to one of the equivalence classes of **IND(D)**, employing attributes from the set **W**:

$$\mathbf{POS_W(D)} = \bigcup_{\mathbf{Z} \in \mathbf{X/IND}(D)} \underline{\mathbf{W}}\mathbf{Z} \qquad (4)$$

where: $\underline{\mathbf{W}}\mathbf{Z}$ – **W**-*lower approximation* of $\mathbf{Z \subseteq X}$:

$$\underline{\mathbf{W}}\mathbf{Z} = \cup\{\mathbf{Y} \in \mathbf{X/IND(W)}: \mathbf{Y \subseteq Z}\}$$

The coefficient γ expresses numerically the percentage of objects, which can be properly classified. If $\gamma_W(D)=1$ we say that **D** is *totally* depends on **W** in **X** (the diagnostic rule **IF{W}THEN{D}** is true). For $0<\gamma_W(D)<1$ we say that **D** depends to degree $\gamma_W(D)$ on **W** (the diagnostic rule isn't true).

3. ANALYSING OF DIAGNOSTIC REASONING SYSTEM

Having information system for some faults and diagnostic methods we are able to analyse the set of tests for each fault. The usage of indiscenibility relation in diagnostic reasoning allows to separate the set of states - $X \setminus POS_W(D)$, which were not investigated with the usage of classical methods.

If degree of dependency for one group of condition attributes W_1 is equal $\gamma_1(D)$ and is equal degree of dependency $\gamma_2(D)$ for other group W_2, which include the first group ($W_2 \subset W_1$), then we must find relative reducts of this system. A relative reduct **T** with respect to **P** $(P,T \subseteq Q)$ is such a minimal subset of the set of attributes **R** $(T \subset R, R \subseteq Q)$ which preserves its relation to some classification of subjects:

$$\mathbf{POS_T(X/IND(P)) = POS_R(X/IND(P))} \qquad (5)$$

These rules can be allowed during designing the optimal fault diagnosis system. The problem of minimising the number of diagnostic subsystems is equivalent to finding relative reducts of the information system. We can say that linking the next diagnostic subsystem supplies additional information if the degree of dependency $\gamma_W(D)$ of decision attributes **D** on condition attributes **W** will be increased.

When we applied this information during designing and analysing of aircraft control and navigation diagnostic system [3] we decreased the number of residual generators which detect faults in different subsystems. During this process we wanted to find the system, which could provide maximum quantity of diagnostics information, and also could be the most sensitive for detected faults and quickly functioning. To make this optimisation the relative reducts were founded. After the choice of the generator that is possible to design (described by attributes included in relative reducts) its synthesis was made. We can analyse the influence of the particular parameters on isolability, sensitivity and robustness. The fault sensitivity can be changed during the changes of the values of the generator's parameters. After making each residual generator the information system was modified and a new relative reduct was determinated. This theory was also used to analysing influence of signals transformation on fault classification. This task showed the importance of coding real signals to finite sets of value. Application of the wrong method of coding caused changes in degree of dependency and reliability of diagnostic decision.

Generality of notation of information system enables us to make analysis with presented theory in control and navigation diagnostic systems, which are often presented by graphs, diagnostics matrix or decision tables.

4. CONCLUSION

The usage of some elements of this theory allows to prepare diagnostic system which should consist of different detection systems. The method presented in this work allowed to make this system optimal - it consists of a minimal quantity of elements and presents a maximal quantity of diagnostics information. What is especially interesting, this theory can be used during analysing process of different tasks (from detection to acquisition) realised by diagnostics systems. All the information presented in this paper can be very useful for researchers and engineers, who are interested in diagnostics systems.

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