Ontology of Concepts of Technical Diagnostics in the Field of Electronics: from Standards to the Practice of Real Application

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***Abstract*—This article discusses the issue of comparing terminology used in the fields of diagnostics of computer equipment and electronic systems of automotive equipment.**

***Keywords*—diagnostics, electronic systems of motor vehicles**

I. Introduction

Electronic (including computer, information) technologies have become an integral part of all spheres of modern human activity. The number of specialists who consider themselves to be involved in this field is a significant part of the engineering and scientific community and continues to grow. During the entire life cycle of electronic products – development, production and operation, specialists (and users during operation) are faced with the need to monitor the technical condition, maintenance, repair and restoration of operability. Users and the overwhelming majority of specialists rely on general engineering knowledge and intuition when solving technical diagnostics problems, while TECHNICAL DIAGNOSTICS is an area of knowledge that has developed into an independent technical discipline, including the theory, methods and means of determining the technical condition of objects [1]. Like any discipline, technical diagnostics has its own specifics, from the definition of concepts to formal and informal methods and techniques for solving applied problems. As the technological development of electronic (computer, information) diagnostic objects progresses towards their complication, automation and intellectualization, approaches, methods and means of diagnostics undergo development, and, as a rule, towards their complication and integration. Sometimes it is quite difficult to understand the intricacies of terms, definitions of directions, algorithms, software and hardware releases, etc., related in one way or another to technical diagnostics, and the volume of information is large and constantly growing. Upon careful study of the subject of technical diagnostics, one can notice a number of "narrow points" related to synonymization, ambiguous interpretation of individual terms, and sometimes obvious differences in the definitions of concepts. Such discrepancies complicate communication between specialists, do not contribute to the development of classical provisions of the theory, but are especially harmful to the educational sphere, when a novice engineer needs to master a large volume of unstructured information. Vivid examples can be the requirements of standards in this area, both basic [2] and derivatives - industry standards [3], [4], [5], [6]. In this regard, debating the wording of certain provisions (terms) used by authoritative specialists [7], [8], [9] seems unproductive. Therefore, this article proposes an ontological approach to the consideration and discussion of technical diagnostics concepts. This means that the review of definitions and explanations of technical diagnostics concepts will be carried out in a structured and systematized form [10], with references to information sources with priority to reference books and standards.

II. Brief recommendations for applying the ontological approach

A. Maintaining the Integrity of the Specifications

Ontology is a formal description of the terms or concepts of a subject area and the relationships between them (Gaber 1993). Ontologies are necessary for a common understanding by people and/or software agents of the structure of information; for the possibility of collective analysis, accumulation and targeted application of knowledge in a subject area. In an ontology, a class describes a concept of a subject area. A class may have subclasses that represent more specific concepts than the superclass . For example, the class TECHNICAL DIAGNOSTICS may include the subclasses Technical conditions, Cause-and-effect relationships of failures, Methods and means of diagnostics, Assessment of the quality of diagnostics. The description includes the properties and attributes of the class (sometimes called slots or roles), as well as constraints of roles or slots (facets). An ontology together with a set of individual instances of classes forms a knowledge base. In reality, it is difficult to determine where an ontology ends and a knowledge base begins [10]. In practice, ontology development includes defining the classes in the ontology, arranging the classes into a taxonomic hierarchy (subclass – superclass), defining the slots and describing the permissible values of these slots; filling in the values of the instance slots. It should be kept in mind that an ontology is a model of the real world, and the concepts in the ontology should reflect this reality. There is no single correct way to model a subject area – there are always viable alternatives. Therefore, ontology development is an iterative process that will almost always revise the initial version and continue throughout the ontology's life cycle. An example of constructing an ontology in the subject area of systematization of the characteristics of the Internet of Things is given in [11].

III. Main ontological classes of concepts of technical diagnostics

The presented hierarchy of basic concepts does not introduce taxonomy of types yet, at the same time the inheritance of the terms "diagnostics" and "object" is clearly traced. This allows to easily and unambiguously form semantic links between terms without special definitions and explanations. For example, "A failure may occur in the diagnostic object", "The ultimate goal of diagnostics is to determine the technical condition or diagnosis of the diagnostic object", "The quality of the diagnosis will be determined by the nature of the failure, the type of diagnostics, the adaptability of the object to diagnostics (testability or testability)" and the specific diagnostic method used, etc., Fig. 1. In the figure, the hierarchy of concepts is reflected conditionally, since associative links in the semantic network can be established from any vertex, depending on the specific case (query formulation).

A. *Otology and detailing of definitions of some concepts*

For individual concepts, such as "Diagnostic Object", it is easy to construct an ontological taxonomy. In this case, the variant shown in Fig. 2 reflects the authors' subjective view of the subject area. Such a classification is intuitively understandable from general engineering knowledge and does not require special explanations. Obviously, this taxonomy can be supplemented both in breadth, for example, by the feature of repairability of diagnostic objects (repairable and non-repairable); and in

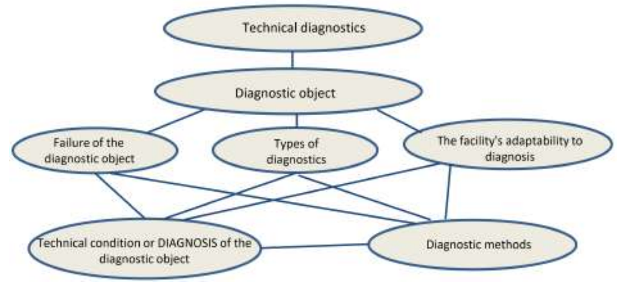

Figure 1. Enter Caption

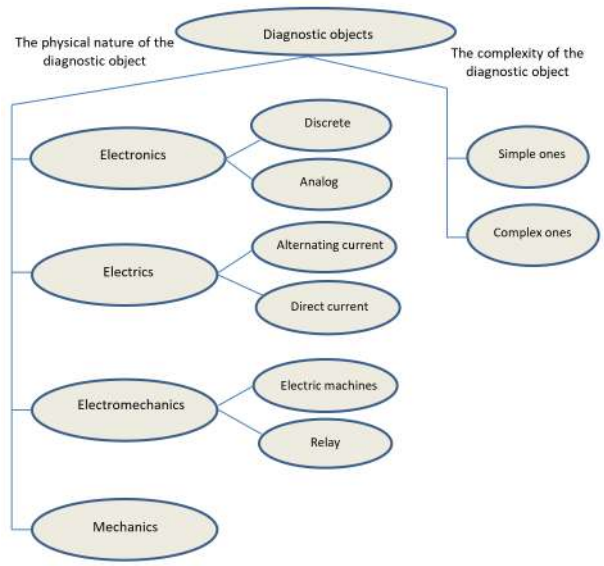

Figure 2. Ontological taxonomy of the concepts "Diagnostic object"

depth, for example, digital diagnostic objects can be both programmable and a rigid function, electric machines can be both engines and generators, etc. Instances of this ontology will be specific products (microcircuits, indicators, sensors, power supplies or individual semiconductor devices, etc.), which will have a path from the root to the graph leaf and possess the corresponding characteristics. At the same time, some concepts are of key importance and at the same time have ambiguous interpretation in various sources, therefore they require additional clarification. The first part of ISO 26262 contains terms and definitions used in the framework of consideration of the issue of functional safety: Availability: The ability of a product to perform a necessary function under specified conditions, at a specified time, or for a specified period, provided that the necessary external resources are available."

GOST 20911-89 "TECHNICAL DIAGNOSTICS" establishes terms and definitions of basic concepts in the field of technical diagnostics and control of the technical condition of objects used in science and technology. The terms established by this standard are mandatory for use in all types of documentation and literature included in the scope of standardization or using the results of this activity:

B. Basic terms:

- Diagnostics is a field of knowledge that covers the theory, methods and means of determining the technical condition of objects.
- Diagnostics –determination of the technical condition of an object. Fig. 2 shows a generalized graphical representation of diagnostics.
- Object of diagnostics is a technical system, device or component whose condition is being assessed (e.g. motor, transformer).
- Reliability of diagnostics is the degree of objective correspondence of diagnostic (control) results to the actual technical condition of the object.
- Completeness of diagnostics is a characteristic that determines the possibility of identifying failures (malfunctions) in an object using the selected diagnostic method.
- The suitability of an object for diagnostics (testability) is a property of an object that characterizes its suitability for diagnostics (testing) using specified diagnostic (testing) tools.

The assessment of the technical condition of the diagnostic object is carried out in terms of three components:

C. Diagnostic parameter - a measurable characteristic of an object, used to analyze the state of being classified:

- design (physical and technical parameters);
- functional (performance of intended functions);
- by measurement method (direct, indirect).

D. Diagnostic methods - actions applied to the object can be classified:

- hardware (use of sensors, measuring devices);
- software (data analysis algorithms);
- expert systems (knowledge bases with rules).

E. A diagnostic model is a formalized description of an object that links parameters with states and is classified as:

- mathematical (equations, statistical models);
- physical (models based on the laws of physics);
- sensor – oriented (sensor data).

When considering the results of the assessment, the following concepts are used: Diagnostic sign – a value or change in a parameter that indicates a malfunction. Associated with parameters and states. Threshold value is a critical level of a parameter at which the state of an object changes. Thus, by comparing the specified diagnostic parameters with the established thresholds of diagnostic features, accepted diagnostic methods and diagnostic models, the most complete assessment of the technical condition of the diagnostic object is carried out.

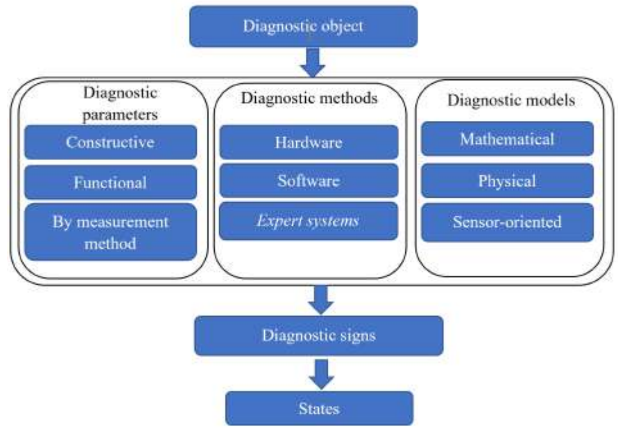

Figure 3. Schematic representation of connections and diagnostic relationships

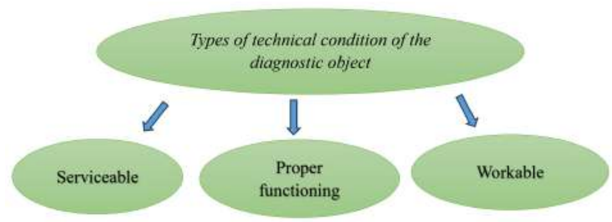

Figure 4. Enter Caption

F. Types of technical condition of the facility:

- operational – in which the object can perform all prescribed functions while maintaining values within the specified limits;
- serviceable – meets the requirements of regulatory documentation;
- proper functioning – in which it performs its function correctly without errors.

G. The stages of the object's condition are determined through diagnostic parameters and can be classified as follows:

- proper (normal functioning);
- faulty (has a deviation of the object's characteristics from the norm, which can lead to failure, while maintaining partial operability)
- borderline (risk of becoming faulty);
- failure (complete loss of functionality is an event in which an object loses its ability to perform a function).

H. ISO 26262 describes the opposite condition in a number of terms, depending on the cause.:

- Failure: The termination of an element's ability to perform a necessary function.
- Fault: An abnormal mode that can cause an element or device to fail.

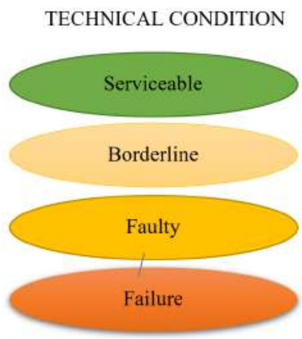

Figure 5. Stages of the facility's technical condition

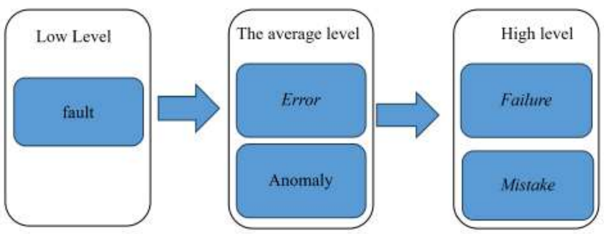

Figure 6. Classification of malfunctions according to the degree of security threat

- Anomaly: Condition (event) that deviates from expected values, for example, in requirements. specifications, project documentation, user documentation, standards, or in practice.

I. At the same time, the theoretical foundations of computer diagnostic tools describe it somewhat differently:

- Fault is a physical defect, imperfection, or flaw that occurs in the hardware and software of a computing system, as well as in its storage devices.
- Error is a deviation of the results obtained from the correct values or their accuracy.
- Failure is the failure of a system to perform any predefined functionality or to obtain a result other than the expected value.
- Mistake – errors made at the design stage in software, circuit design, or incorrectly selected components..

J. Further analysis shows that within the framework of ensuring functional safety, the main emphasis is on the quantitative assessment of faults, the dependence of faults on the disclosure of potential threats and the consequences of failures:

- Single-point failure: A failure resulting from a single fault that directly results in the violation of a safety goal
- Single-point fault: A failure in an element not covered by a security mechanism that directly results in the violation of a security goal.

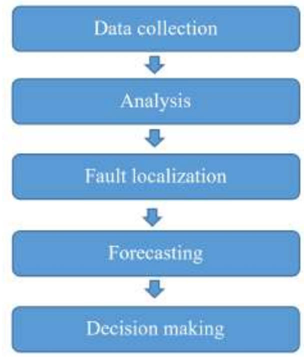

Figure 7. Diagnostic sequence

- Dual-point failure: A failure resulting from the combination of two independent failures that directly causes a violation of a safety goal. A dual failure is a multiple failure of the second order.
- Dual-point fault: An individual fault that, when combined with another independent fault, results in a dual failure.
- Multiple-point failure: A failure resulting from a combination of several independent failures that directly results in the violation of a safety goal.
- Multiple-point fault: An individual failure that, when combined with other independent failures, results in a multiple failure.
- Cascading failure: A failure of an element or device that results in the failure of another element or elements of the same device.
- Detected fault: A failure whose existence is detected within a specified time by a safety mechanism that detects the failure.
- Latent latent fault: A multiple fault whose presence is not detected by the safety mechanism and is not perceived by the driver during the multiple fault detection interval.
- Perceived fault: A failure, the presence of which is detected by the driver within a specified time interval.
- Permanent fault: A malfunction that occurs and does not disappear until it is corrected or repaired.
- Random hardware failure: A failure that occurs at a random point in the lifetime of a hardware element in accordance with a probability distribution.
- Safe fault: A failure whose occurrence does not significantly increase the probability of violating a security goal.
- Common Cause Failure (CCF): The failure of two or more elements of a device as a result of a single specific event or root cause.
- Dependent failures: Failures whose probability of simultaneous or sequential occurrence cannot be represented as a simple product of the unconditional

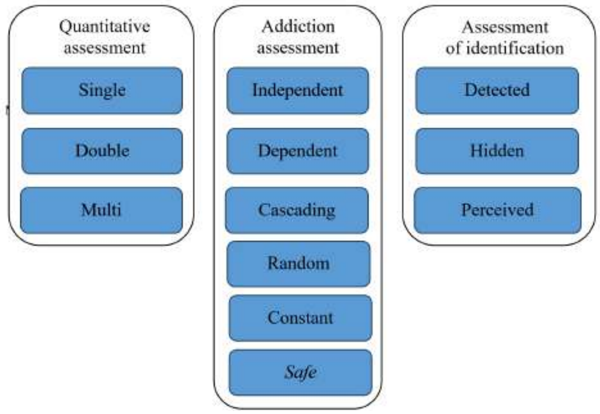

Figure 8. Classification of faults according to the assessment method

probability of each of them.

- Independent failures: Failures whose probability of simultaneous or sequential occurrence can be represented as a simple product of the unconditional probability of each of them.
- Diagnostic coverage: The proportion of hardware element failure rates that are detected or controlled by implemented safety mechanisms. Diagnostic coverage can be estimated using residual failures or using undetected multiple failures that can occur in hardware elements. Diagnostic coverage is essentially the result of the practically achieved implementation of diagnostic completeness, i.e. the share of implemented diagnostics in relation to the possible

The complete diagnostic process can be presented in the form of a diagram.

D. Knuth's article [13], on the evolution of the TEX typesetting system , one of the earliest and most frequently mentioned schemes for classifying software faults, denoted by letters of the Latin alphabet, is considered:

K. Software fault classification scheme by D. Knuth's :

- A – incorrect, incorrect algorithm (algorithm awry);
- B – a mistake or negligence (blunder or botch);
- D – data structure corruption (damage) structure debacle);
- F – forgotten function (forgotten function);
- L – reasons related to the programming language (language liability);
- M – mismatch between system modules between modules);
- R – reliability, failure with bad input data (robustness);
- S – a surprising, unusual scenario of functioning (surprising scenario);
- T – typical typo (trivial typo).

L. The classification system proposed by B. Beizer:

- time of fault introduction – for example, at the level of specification, implementation, or test procedure;
- effects of fault activation – such as unwanted control flow or data corruption;
- location – such as the object or application module that contains the fault;
- type of required correct action – for example, required, not required, or ambiguous.

M. The developers at IBM proposed the so-called orthogonal classification of faults (orthogonal defect classification) [14] types of faults:

- Function – that characterizes incorrect functionality or its absence, which may require a formal change to the project;
- Interface – identifies errors in communication between the user and the application, between its modules or application drivers;
- Checking – is characterized by a data error in the source code;
- Assignment includes addressing faults, including erroneous initialization;
- Timing / serialization – contain many faults that can be easily corrected with improved project development management;
- Build / package / merge – identify issues due to errors in library systems and in change management and version control;
- Documentation – characterizes errors in documentation and, first of all, in the user manual for a software product;
- Algorithm – includes problems related to the efficiency or correctness of a software product that can be corrected by re-implementation without requiring a change in design.

The classifications proposed by D. Knuth, B. Beiser and the IBM company together allow for a more detailed characterization of the faults that arise.

The classification, applied, can be generalized as: emergency causes (causes crash) uniting all those malfunctions in a program that can cause a crash or freeze of the entire computing system, significantly disrupting the stability of its operation;

N. Applied generalized classification:

- Critical faults are anything that causes the program itself to freeze or crash without affecting the computing system as a whole ;
- functional faults are characterized by deviations in the functional behavior of the software compared to the required functionality;
- installation (setup) – faults introduced at the stage of installation of the software application;

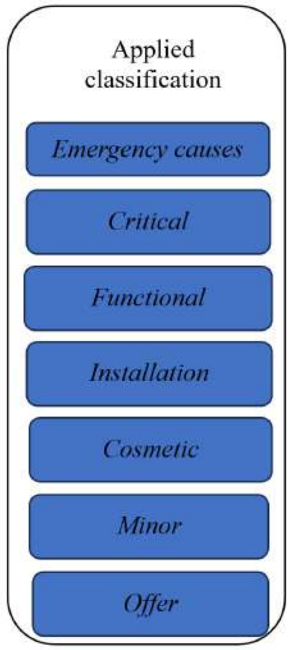

Figure 9. Applied fault classification.

- Cosmetic defects include design errors (e.g. wrong line color or font), user interface errors, etc.
- minor faults are theoretically insignificant faults, or faults of unspecified genesis;
- suggestion, which consists of a proposal to improve the software in terms of some of its characteristics or properties. Sometimes similar malfunctions are designated how feature.

The classifications presented are an average interpretation of a large number of classifications, including those discussed above. Summary: This ontology systematizes key terms of technical diagnostics, defining their interrelations and hierarchy. It can be expanded by adding subclasses, examples and specific methods for specific industries (aviation, energy, mechanical engineering).

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ОНТОЛОГИЯ ПОНЯТИЙ ТЕХНИЧЕСКОЙ ДИАГНОСТИКИ В СФЕРЕ ЭЛЕКТРОНИКИ: ОТ СТАНДАРТОВ К ПРАКТИКЕ РЕАЛЬНОГО ПРИМЕНЕНИЯ

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В данной статье рассмотрен вопрос сравнения терминологии, принятой в областях диагностирования средств вычислительной техники и электронных систем автотракторной техники. Обзор определений и пояснения понятий технической диагностики будут выполняться в структурированном и систематизированном виде со ссылками на источники информации с приоритетом на справочники и стандарты.

Received 31.03.2025