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DEVELOPMENT OF AN INFORMATION SYSTEM FOR DECISION SUPPORT AND AUTOMATION OF CONTROL OF TV3-117 AIRCRAFT ENGINE IN CRITICAL SITUATIONS BASED ON KNOWLEDGE ENGINEERING

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Abstract

Purpose: *The purpose of this article is to develop an information system for decision support and automation of control of the aircraft engine TV3-117 in critical situations based on knowledge engineering.* **Methods:** *The following methods are applied in the article: simulation modeling method at the stage of designing an information system for decision support; special methods and means of object-oriented modeling of the subject area, which are developed for the design of information systems in order to recreate the conceptual model of experts in a formalized model of knowledge representation; hierarchical search method to search for use cases; ontological analysis with the aim of identifying and combining relevant information-logical and functional aspects of the system under study. In the modeling process, paradigmatic relationships are established between the cognitive elements of the process of controlling a complex dynamic object in critical situations (cause-effect, similarities), as well as generalization, association, depending on the implementation, necessary for the development of a complex of object-oriented models of the control process.* **Results:** *The conducted studies show that an additional analysis of all the possibilities of the applied knowledge representation models is needed to solve specific problems in the considered problem area. The methodology of object-cognitive analysis is the basis for creating an information system for decision support, including the intellectual component of the acquisition, accumulation, processing, provision, updating and dissemination of knowledge. The obtained object-oriented models of the subject area and ontology of the decision support system are the basis for the development of methods and algorithms for finding management solutions in critical situations.* **Discussion:** *The results obtained are applied within the framework of the concept of intellectualizing the process of control and diagnostics of the TV3-117 aircraft engine technical state in flight modes, one of the points of which is the intellectual processing and storage of information about the results of flight tests and operation of the TV3-117 aircraft engine based on the requirements of modern databases and knowledge bases, with the possibility of their integration into modern CASE-technologies.*

Keywords: aircraft engine; information system; object-oriented models; critical situations; ontology

1. Introduction

One of the main objectives of improving the complex objects control system is to ensure the safety of their operations and the restoration of their performance in critical situations. Modern aircraft gas turbine engine is a highly reliable complex technical system. Improvement of aeronautical engineering and ground handling services, increasing the efficiency of management TV3-117 aircraft engine control, improving the quality of training of flight personnel and compliance with safety contribute to the fact that in the modern world safety level likelihood of emergencies in flight due to the power plants failure is quite small. However, international practice of operation of aviation systems shows that the possibility of occurrence of critical situations is not excluded, especially taking into account the intensity of air traffic.

Critical situations (COP) arise due to the adverse effects of the environment, the failure of hardware and software, human error, resulting in disruption of the restrictions imposed on the operation characteristics of the object of the process [1–3]. In case of failure to make timely and correct governing

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decisions, the critical situation can lead to an emergency or disaster, with implications in the form of threats to health and people's life, as well as considerable material damage due to the increase in the number of rejected takeoff and flight delays. Therefore, increasing the efficiency of decision making under uncertainty information about critical situations, lack of time is a crucial moment in securing the functioning of such complex objects such as aircraft engines.

Macroprocess decision in a critical situation comprises the following steps: detection of critical situations; collection and analysis of information about emergencies; recognition of critical situations; certain situations management purposes when solving problems; development of performance evaluation criteria for decision-making; generating a list of possible solutions; forecasting the effects of management decisions; assessment of options; plan of action to eliminate the critical situation; realization of control actions and monitoring their effectiveness. The processes of functioning of objects in the real critical situations often occur under conditions of nonmodelable external perturbations and internal changes of the object. The complexity of the activities of the pilot assessment of critical situations arising in aircraft systems is the reason that, according to studies, held in Ukraine and abroad [4–6], about 80 % of accidents and disasters is due to human error (probably provoked by equipment failures or adverse weather conditions). Therefore, it is necessary to help the flight staff to recognize the critical situation properly and make the right decision for the aircraft management.

2. Problem statement

The state of the managed object at each point in time t_i is determined by vector variables $\overline{X}(t_i)=\left(x_j(t_i)\right)^T$, $J = 1 \dots n$, where n – the number of variables of the object state. Information about the state of the object from the sensor and the object measuring system from the operator, observations are recorded at discrete points in time and characterize the trajectory measurements, defining a plurality of states of the object $S(X)=\left\{\overline{X}(t_i), t_i \in [t_0, T_H]\right\}$, where T_H – time of observation. According to the above definition, the combination of state of the object, resulting from failures, human error and/or adverse effects of the environment creates a critical situation. Model dynamics changing situations in the management of the object out of critical situations – is a situational network, the presentation of which is a directed graph with vertices corresponding to the reference description of the state of the control object, and edges corresponding to the transition from one state to another – results of action on the basis of decisions taken and/or the external environment. Situation parameters are: $Y(t)$ – multiple output (observed) variables that reflect the state of $\overline{X}(t_i)$ object (system) and fixed on the observation time interval T_H; control actions $u \in U$; solutions $dec \in D$; criteria of management efficiency $\lambda \in \Lambda$; exogenous factors $\xi \in \Xi$ (external effects, acting as the cause of critical situations); endogenous factors $f \in F$ (Component failures of the control object, data conversion and transmission errors, subjective operator error).

Let $\Theta(X) \in S(X)$ be an area of safe states of the object (corresponding to normal, a normal mode of functioning), and the area $\Gamma(X)$ be an area of critical states (corresponding to the non-standard mode). The boundary $\Gamma_H(X)$ represents the object to transition from safe to the critical mode of operation (or vice versa). The boundary $\Gamma_B(X)$ region $\Gamma(X)$ represents the transition from critical conditions to emergency $\Theta(X)$ when the object becomes unmanageable and return it to the critical and security regime is either absolutely impossible or is accompanied by partial destruction of the object. A simplified example of a possible critical situation of a change of the variable $x(t)$ in the state space of the object under uncertainty, with an error evaluation variable $\Delta = x(t) - \hat{x}(t)$ is shown in Fig. 1. In case of violation of the normal operating mode, ~~of~~ the object enters the area of the security status of $\Theta(X)$ in the area of critical situations (curve F_0–F_1). Then the process may go different ways. In the event of the timely and correct decision, the object may return to a safe state (curve F_1–F_3), otherwise the process could become unmanageable, and the object will be in the field of emergency situations (curve F_1–F_2).

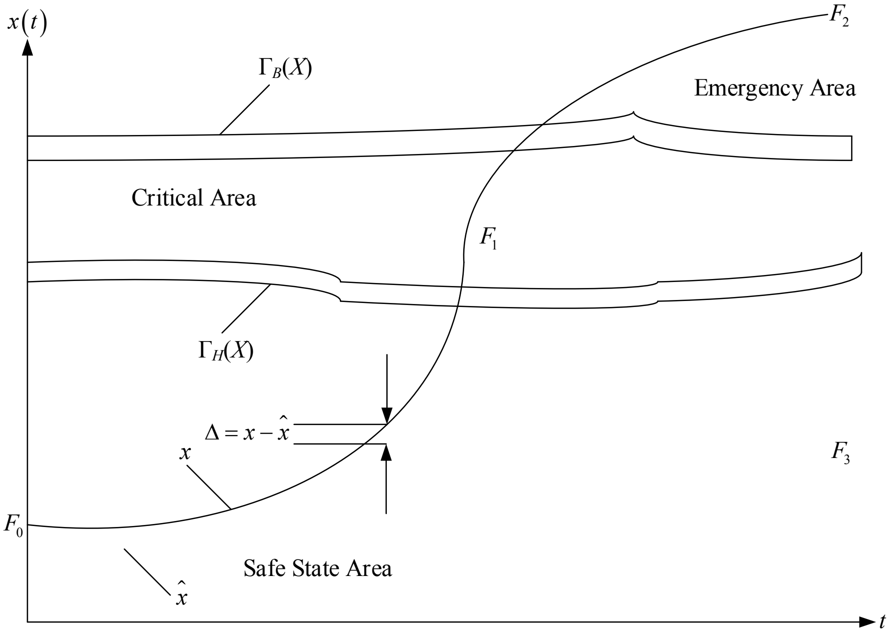

Fig. 1. Security and the critical states of the object

Operation of an aircraft engine TV3-117 as a complex dynamic object in critical modes characterized in that the selected object state variables in the dynamics exceed their critical values corresponding to their values at the border of $T(X)$. We select from a set of variables that make up the vector object's state $\overline{X}(t_i)$ a subset of $X_k \subset X$ state variables that may change in its reach critical (invalid) value X_k^{Cr}. Then $X_k^{Cr} \in \Gamma(X)$, a $X \setminus X_k^{Cr} \in \Theta(X)$. For an aircraft to such variables include, for example, the motion parameters. For aircraft engine compressor TV3-117 the degree of compression, the gas temperature before the turbine, the magnitude and the rate of change of fuel flow in a combustion chamber, a turbocharger speed, etc.

Let $I_k\left[y_i(t) \in Y(t)\right]$ be the amount of information required to recognize a class of critical situations from the measured values of the output variables $\{y_i(t)\}$. For the formation of the administrative decision $d_k(\Omega_k)$ also need to know a lot of resources R_k, suitable for taking the object out of critical situations.

Thus, the critical situation is characterized by a violation of maximum permissible values of one or multiple object state variables (Fig. 1).

Such violations can be described by the predicate $P_j(E_{obj})$, where P_j – predicate symbols, E_{obj} – events violations of the boundary $\Gamma(X)$, denoted by binary relations $x_{ki} = X_{ki}^{Cr}$, $x_{kr} < X_{kr}^{Cr}$, $x_{kl} > X_{kl}^{Cr}$ etc., where $x_{ki}, x_{kr}, x_{kl} \in X_k, X_{ki}^{Cr}, X_{kr}^{Cr}, X_{kl}^{Cr} \in \Gamma(X)$. Detection of events and analysis of critical situations needs to install disorders facts limit values of state parameters of the object, as well as the possible causes disorders (e.g., any current state of individual subsystems of the helicopter maneuvers and external disturbances can lead to disturbance).

Let $\Omega_k(t) = \{u_i(t)\}$ be a set of admissible controls in a critical situation, belonging to the set $U(t)$ control actions, i.e, $\Omega_k(t) \subset U(t)$. Let $\varphi_k(X)$ be function of monitoring in a critical situation, connecting the output variables to the state variables:

$$\varphi_k : T_H \times X \to Y. \quad (1)$$

Let $h_k(t)$ be a function of the transition of object region $\Gamma(X)$ to $\Theta(X)$ under the action of the set of permissible controls Ω_k:

$$h_k(t) : T_H \times X_k \times \Omega_k \to X \subset \Theta(X). \quad (2)$$

The function $h_k(t)$ describes the function of the object control (system) in critical situations.

To form the control function $d_k(\Omega_k)$ in critical situations, it is necessary to know the time reserve $\Delta t_{\text{рез}}$ in critical situations, the deviations of the variables $x_k(t)$ from the boundaries of the $\Gamma_B(X)$

and/or $\Gamma_H(X)$: $\delta_H = x_{ki} - x_{ki}^{Cs}\left(\Gamma_H\right)$ and $\delta_B = x_{ki}\left(\Gamma_B\right) - x_{ki}^{Cs}$.

Exogenous factors $\xi \in \Xi$ (external influence) and endogenous factors $f \in F$ (component failures of the control object, data conversion and transmission errors, subjective operator error) form a plurality of reasons $\phi \in \Phi$, that lead to the emergence of critical situations at the facility. It should be noted that some types of these reasons (e.g., adverse effects of the environment, equipment failures) is deformed region $\Gamma(X)$ and $\Theta(X)$, change the set of permissible controls Ω_k. For example, in case of failure of the power plant or at some strong turbulence of the atmosphere above, the safe flight of the aircraft modes become invalid. Changes of $X(t)$, $\Theta(X)$, $\Gamma(X)$ and $\Omega(t)$ – is a random process, the specific implementation of which depends on the phase of the object, environmental changes, the characteristics of that particular object, indications of measurement noise.

However, despite the variety of possible concrete manifestations of critical situations, decision maker, it has a limited set of management solutions for the withdrawal of an object from critical situations. For aircraft, for example, a change of mission, or the path of movement, change of aerodynamic configuration of the aircraft, turn off the failed subsystems.

The human operator decides based on the identification of critical situations together the specific characteristics of the management class with some critical situations. Thus, suppose that the area $\Gamma(X)$ can be divided into disjoint regions compact plaster $\Gamma_i(X)$, each of which corresponds to a particular class of critical situations:

$$\Gamma(X) = \bigcup_i \Gamma_i(X) \cap \Gamma_j(X) = \varnothing; i \neq j. \quad (3)$$

Classification is done in such a way that each class corresponds to the same or similar set of control solutions and action for their implementation. The problem of decision making on $d_k(\Omega_k)$ facility management in critical situations is to form the allowable time period such algorithm impact on the parameters of the state of the object controls, a change which clearly would translate an object from a critical to a safe state.

Let the object as a result of the adverse effects $\phi_k(t_1)$ be in one of the critical conditions, i.e., there was at least one event E_{obj}. The critical state is detected based on the measurement information $I_k\left[y_i\left(t_1\right) \in Y\right]$. It is necessary, taking into account available resources R_k for a specified time interval $t_2 - t_1 < \Delta t_{рез}$ d_k to decide and implement the impact on bodies $\Omega(t_1, t_2)$ control to the object at the time t_2 was in safe condition $\Theta(X)$:

$$d_k = D\left[t_1, t_2, \Delta t_{рез}, X_k\left(t_1\right), J_k\left(y, \delta_B, \delta_H\right), \phi_k\left(t_1, t_2\right), \Gamma_i\left(X\right) \subset \Gamma\left(X\right), \Theta\left(X\right), \varphi_k, h_k\right]. \quad (4)$$

This definition of decision-making in critical situations is methodological in nature and gives an idea of the complexity of the problem being solved. The decision-making algorithm for transferring an object from a critical to a safe state can be represented in a simplified form:

$$d_k\left(\Omega_k\right): \Gamma\left(X\right) \in X_k\left(t\right) \xrightarrow{\Omega_k(t)} X\left(t\right) \in \Theta\left(t\right). \quad (5)$$

The boundary of $\Gamma(X)$ cannot be expressed directly in a measured parameter. In general, you can apply three basic approaches to reflect the tolerance range borders of the states of complex dynamic object:

– selection of a single variable $x_i(t)$, a critical value which is taken as the main feature, and fixation (or regulation) of the values of other variables in the form of limiting conditions;

– approximation hypersurface boundary separating the area of the security status of the system and the area of critical states, as a function of the critical values of multiple variables of the system state;

– building integrated (generalized) characteristics of several variables or their critical values as a safety indicator state complex dynamic systems.

For complex dynamic objects, as a rule, ~~tend~~ analytical expressions for separating $\Gamma_H(X)$ and $\Gamma_B(X)$ are missing, since the vector X contains both instrumental (quantitative), and not instrumental components (logic, linguistic variables, character terms). In most cases, only some functions of $\Gamma_H(X)$ and $\Gamma_B(X)$ on the finite set of points $X^K \subset X$ or experimentally derived partial dependence of the critical values of the state variables from some arguments are known. To construct dividing functions using heuristic methods, such as methods of assessing the formalization of human capabilities and the formation of expert judgment.

In determining the violation of the boundary of permissible states the time of an emergency is detected. The next stage of the process control in critical situations is the decision point for the management of complex dynamic system output of an emergency.

Thus, the overall cycle model of decision-making in critical situations can be presented in the form of spatial multidimensional structure of the system of knowledge: $S' = \{S, M, A, E, D, X, G\}$, where S – initial critical situation, S' – situation resulting from the decision made, M – plurality of models of the critical situation, A – set of alternatives of a critical situation development, E – set of evaluation criteria, D – set of solutions, X – plurality of states of the object, G – purpose management object.

Classical formulation and management problem solving of complex dynamic systems based on continuous mathematical models in the form of certain equations of the dynamics of the controlled process. Many of the technical management of objects identified by experts in the relevant subject areas, and are described by mathematical models which permit the study in order to achieve stable and sustainable functioning of objects and solving optimal control problems [2, 7–10].

Complex systems management process in critical situations is characterized by: the uncertainty and lack of knowledge about the characteristics of the object in critical situations, goals and management of resources, including time, and other types of uncertainties; the problem of choosing the most informative features of critical situations of a large number of state parameters of the object, which can be prepared and analyzed for a limited time; the need to analyze a large number of signs of critical situations qualitative nature, poorly amenable to analytical processing; lack of time to make decisions and significant psychological stress on the operating personnel.

To solve the management problems of dynamic systems under uncertainty, scarcity of resources and unforeseen emergencies, methods for identification management of inaccurately specified object, methods of the theory of adaptive systems and adaptive control techniques to prevent critical conditions of dynamic objects in conditions of uncertainty [2] have been developed. Conceptual bases of the organization of intelligent control of complex dynamic objects are presented in [11]. Situational management tasks for complex systems "at variance" with the current state of the system in critical situations are discussed in [2, 12, 13]. However, as to the management of complex dynamic systems, there are unsolved problems, conditioned by the necessity of active and purposeful accumulation, analysis and application of variable knowledge about management processes in critical situations.

In-depth analysis of a number of accidents has shown that 80 % of the guilt of the flight personnel is actually a measure of the share of disasters and accidents in which pilots were able to fend off the emergence and deepening particularly dangerous situation, but they failed [4–6]. Consequently, in many critical situations do exist management resources, the use of which, subject to the timely and correct management decisions would remove a critical situation, preventing it from escalating into an emergency situation, and to transfer control system to normal operation. Making the right and timely decisions by the operator must be supported by the provision of information, containing a possible alternative solutions, developed as a result of instrumental analysis of the critical situation arising, as well as based on the knowledge in the management objects accumulated experts. It is therefore very urgent problem of decision support in critical situations using Intelligent decision support system based on the principles of engineering knowledge in the subject area.

3. Materials and methods of research

A promising approach to the organization of decision support in the management of the operation of an aircraft engine TV3-117 in flight modes is the use of knowledge representation standards, based on Semantic Web.

As a result, the problems of system analysis support decision-making in the governance process in emergency situations developed a methodology for object-cognitive analysis [3], including the principles, model structure for the creation of information decision support system. Methods of development of an information decision support system, in accordance with the principles of object-cognitive analysis, including the main stages (fig. 2): Development of the process of object-oriented model of managing a complex dynamic object in critical situations; ontological analysis and development of an ontological knowledge base; formalization of ontological knowledge base using the descriptive logic; Data Mining for the purpose of classification of precedent critical situations; implementation of information decision support system, including the development of algorithms and software develop recommendations for decision-making in critical situations and user interface; assessment of the effectiveness of information decision support system.

Based on the analysis results of evaluating the effectiveness of decision support, improvement of the quality of knowledge of information systems is made to support decision-making through the evolution of the knowledge contained in the case law of the critical situations in the management rules, which allows to improve the understanding of evolutionary problems and make effective management decisions. In the simulation, the information decision support system special methods and tools for object-oriented modeling domain are used, designed for the design of information systems, to recreate a conceptual model of the experts in formal knowledge representation model. The principles of knowledge representation using UML object-oriented modeling language (Unified Modeling Language) [3]. Models allow for the early stages of design to form a kind of formalized knowledge base of the processes occurring within the subject area. During the simulation set paradigmatic relations between the cognitive elements of the process of managing a complex dynamic object in critical situations (cause and effect, similarity relations), as well as relations of generalization, association, dependency and implementation necessary for the development of a set of object-oriented model management process. model structure. During the simulation set paradigmatic relations between the cognitive elements of the process of managing a complex dynamic object in critical situations (cause and effect, similarity relations), as well as relations of generalization, association, dependency and implementation necessary for the development of a set of object-oriented models of management process. During the simulation, paradigmatic relations between the cognitive elements of the process of managing a complex dynamic object in critical situations (cause and effect, similarity relations) are set, as well as relations of generalization, association, dependency and implementation necessary for the development of a set of object-oriented model of management process. Model structure $DClass = \left\{ C\left(A^C, O \right), R^X \left(Role, Mult \right) \right\}$ contains descriptions of abstracted concepts and entities $C_i \in E$, which are the basic objects of the subject area and determine the relationship between them. Fig. 2 shows the architecture model of information decision support system.

Developed for a specific domain class structure (Fig. 3) includes meta-knowledge (knowledge about knowledge stored in the knowledge base, defining what is meant by rules and precedents, which classes of situations they are designed as interconnected and how to find them) and specific subject knowledge (management knowledge in specific emergency situations). Specifics charts database classes knowledge meets the prevalence of certain types of relations between classes, logical and associative (to speed up the search for relevant knowledge). Modeling of such a relationship is achieved as a built-object modeling means (Introduction of generalization relationship, dependence and association) and the introduction of special designations for paradigmatic relationship between domain concepts (causal relationship, similarity relationships).

The advantage of the model is to describe the relationships between classes of objects, allows the formalization of knowledge representation. On the basis of the data mining describing preceding critical situations (Fig. 3), attribute list (informative attributes) of selected classes of critical situations has been set. As a result, we developed a model for the class hierarchy situational knowledge base with baseline values and specifying the types of objects attributes. Thus, the class attributes are precedent emergency signs, weight characteristics, the units and the time limit within which the actual set values of attributes and the associated operations (methods) comparing the signs of the current situation and the precedents methods of obtaining an emergency signs, of standardization of signs and so on.

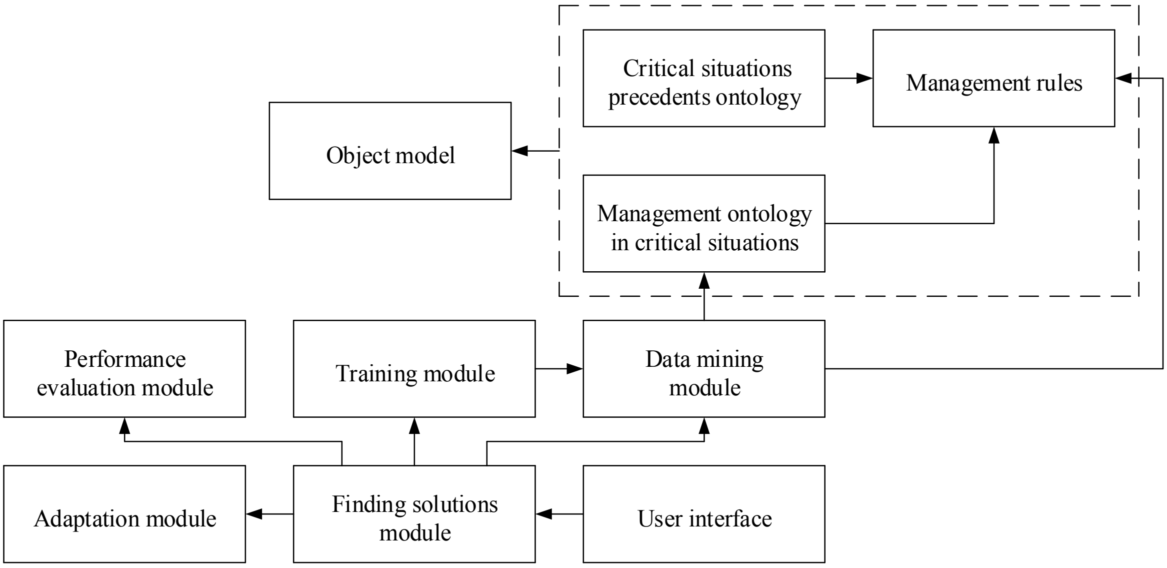

Fig. 2. A model of architecture of information decision support system

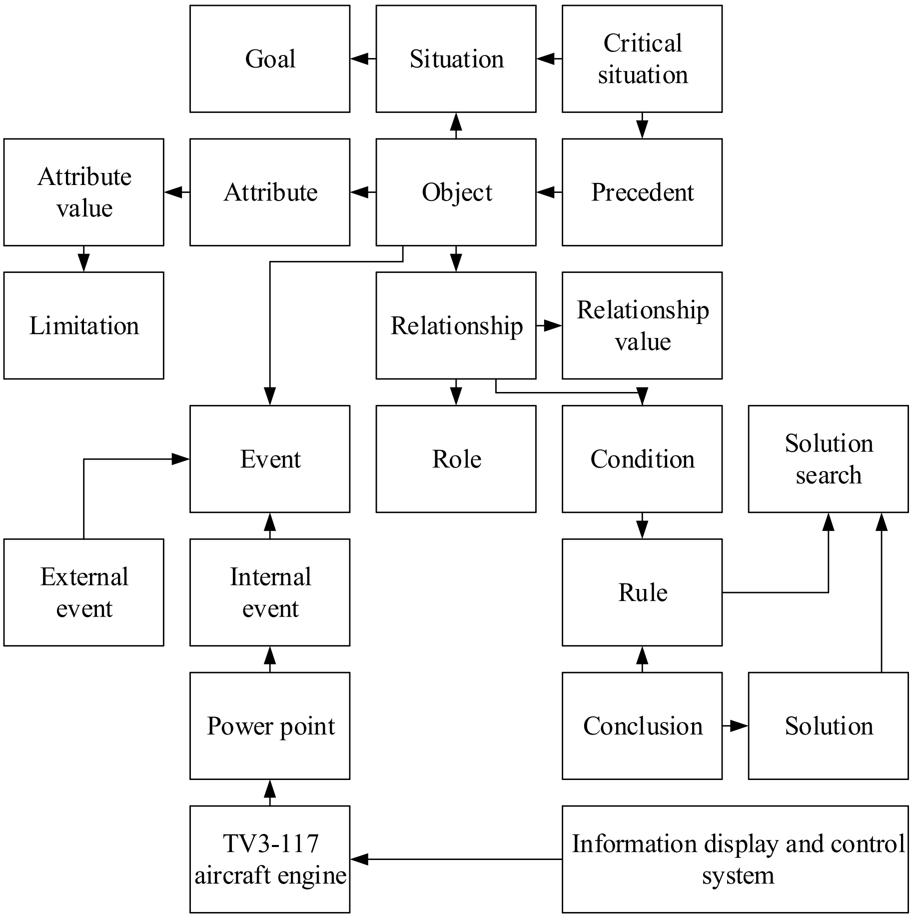

Fig. 3. Model ontology management in an emergency

For a description of intellectual decision support system dynamics behavior diagrams were used, which are divided into: state diagrams, activity diagrams, interaction diagrams (consisting of diagrams and sequence diagrams of the cooperative). Design of information decision support system should take into account the timing requirements of its functioning. In [3] a method based on allocation in the expert system of four levels of search solutions is proposed. The first level uses a conventional logic signal generation on failures or trespass the area safe state of the control object, and subsequent levels work with the knowledge base, and the data used at each level, require more time for processing. Such an approach can provide characteristics acceptable for real-time performance. The proposed approach is characterized by the fact that knowledge of the search hierarchy built not only on time but also on the degree of abstraction and the level of confidence in knowledge: the rules to individual cases.

The result of the object-oriented analysis is a set of operations acquisition, processing and presentation metaknowledge and problem-oriented knowledge $\Phi = (\varphi_1,...,\varphi_m)$, the operation φ_i are encapsulated into respective objects as their own resources.

The complex models is the basis for the formalization of the interaction of the components knowledge base of information decision support system, which includes the following components: ontology, rules and precedents. Functioning of knowledge is seen as the interaction of objects (situations, rules and case law), which is associated with knowledge of processing methods: deductive inference-making, rule-based, or a procedure to establish the similarity of objects (precedents and current problem situations).

It is proposed to develop a base of precedents on the basis of precedents in accordance with the classification of a plurality of types of output management solutions of the problem situation. With each class associated information structures domain, describing the knowledge about a particular subdomain – the rules and precedents that inherit properties of their class.

Rules management in critical situations, there are many $\Re = \{Rul_C, Rul_D, Rul_A, Rul_E\}$, where Rul_C, Rul_D, Rul_A, Rul_E – sets a critical situation recognition rules, decision-making, the choice of control actions, and evaluate the effectiveness of the implementation of decisions, respectively, that model identified logical patterns. Rules $R \in \Re$ defined in the following form: $\langle S, a_1, U_1, ...a_n, U_n; P_1, ..., P_m; b, U_b, S' \rangle$; S' – situation arising as a result of the decision; S – initial critical situation; $a_i \in A$ – preconditions critical situation; $U_i \in U$ – assess the extent required confidence in the premises; $b \in B$ – finally, with the assessment of the degree of confidence U_b; $P \in P^M$ – predicates, $M \geq 1$, $m \geq 0$. U_i marks are determined in accordance with a predetermined evaluation method of uncertainty of knowledge. Matches if all prerequisites are proven (with some degree of certainty) and all predicates are true, that is chosen alternative solutions contained in the conclusion of the rule:

$$R = \langle S, a_1, U_1, ...a_n, U_n; P_1, ..., P_m; b, U_b, S' \rangle \Leftrightarrow \forall (1 \leq i \leq n) \exists \tilde{a}_i$$

$$\left[\text{set}\left(\tilde{a}, \widetilde{U}_i\right) \wedge d_i \in d_i \wedge \widetilde{U}_i \in U_i \right] \wedge \forall (1 \leq j \leq m) P_j \left(\tilde{d}_1, ..., \tilde{d}_m\right). \tag{6}$$

Search based on precedents, is applied in critical situations, the complexity of which does not allow for their constructive formalization, but for which there is experience (precedents) for their successful resolution [2, 17, 18]. Precedents of critical situations are specific instances of objects or events that belong to this subdomain. Thus, there is a precedent $Case^{Cs}$ combination of the following objects: <*Case_name*, Z, X^m, D, E>, where *Case_name* – name of a precedent, Z – set of classes precedents of critical situations, X^m – set of attributes describing precedents in the class $Z^m \in Z$, D – a plurality of control of the decisions contained in the case law, E – set of assessments of the effectiveness of decisions. For each i-th attribute j-th precedent of $x_{ij} \in X^m$ determined are: feature type $type\_x_{ij}$ and weight feature w_x_{ij}; $i = 1, ..., n$; $j = 1, ..., J^m$ – number of attributes describing precedent for a specific class Z^m; J^m – class Z^m number of precedents in the base use case. Weight characteristics are determined for a particular subject area by analyzing the hierarchies or other known methods of processing expert evaluations.

Search algorithm of nearest precedents can be implemented using both deterministic and fuzzy approaches. A deterministic model search algorithm *Retr* of nearest precedents: $Retr$: $Case^{Cs} \times Q^{Cs} \times Case^{Cs} \rightarrow \{0, 1\}$. Stochastic model: $Retr$: $Case^{Cs} \times Q^{Cs} \times Case^{Cs} \rightarrow P_r(Case^{Cs})$, where $P_r(Case^{Cs})$ – class of probability distributions in the set *BCase*. The fuzzy model: $Retr$: $Case^{Cs} \times Q^{Cs} \times Case^{Cs} \rightarrow [0, 1]$.

The algorithm consists of the following procedures. First, when the search procedure of the nearest precedents is initiated, vector X of describing the current critical situation is formed. Preparation of emergency signs is carried out on the basis of monitoring and diagnosing the technical condition of aeroengine TV3-117 or by request recommendations comprising "forming" characteristic values.

Information space for knowledge representation in critical situations is organized on the basis of ontology management. Ontology – a model of knowledge, formally submitted on the basis of conceptualization [14]. Conceptualization involves description of the set of objects and concepts, knowledge about them and the relationships between them. An ontology provides a common vocabulary for control tasks, defines the semantics of messages and is responsible for the interpretation of the message context. Ontology analysis – analytical work to determine associations and relevant information and logical and functional aspects of the system under investigation in the corresponding ontology content [14]. The basis of ontological analysis is the structure of concepts of information decision support system developed in the form of class diagrams. For clarification and development of ontological analysis, a complex method of extracting concepts is proposed, integrating the analysis of complex object models based on the knowledge and experience of experts and automated linguistic analysis. Methods of extraction of terms of entities and relationships between them were analyzed and the basic: extracting terms and their relationships and refinement based graphic hierarchies of object-oriented model; extraction of relations based on inductive logic, a term taken from the glossary of object-oriented model of the dictionary and may be adjusted manually; automatic selection of terms and relations based on linguistic properties and the inheritance hierarchy of nouns; clustering compatibility terms describing the nature, heuristics, based on linguistic dependence relation, general rules of association based on machine learning.

An ontology defines a common information space in which the various models of representation of knowledge about the management processes are integrated, of complex dynamic management of a specific area of the object in the critical situations, presented in the form of ontology $Onto^{control}$ and $Onto^{app}$, rules of management in critical situations and use cases specific emergencies that require action . Ontology decision support includes a top-level ontology (metaontologies) $Onto^{meta}$, ontology management in critical situations $Onto^{control}$ and ontology stages of analysis of critical situations, find solutions, the choice of control actions, their implementation and evaluation of the effectiveness of the various subsystems of the control object $Onto_i^{app}$:

$$Onto = \left\langle Onto^{meta}, Onto^{control}, \left\{Onto_i^{app}\right\}, InfD \right\rangle; \quad (7)$$

where $InfD$ – conclusions models recommendations associated with the ontology Onto system.

Entities are metaontology $Onto^{meta}$ terms such as "object", "attribute", "value", "attitude", etc. Ontology $Onto^{control}$ describe the management process in critical situations include classes such as "reliability", "security", "critical situation", "Tag", "reason", "Aftermath", "Resolution", "Action", "Failure" "failure Rate", "Fault", "Status", "Control" et al., and is organized on the model of metaontology $Onto^{meta}$.

Subject $Onto^{app}$ ontology concept comprises characterizing features of the process management semantics complex dynamic object in an emergency ("Information Display System", "sensor", "Controls" et al.), Structured according to a hierarchy established for a particular object. The structure of the subject area assumes the presence in the ontology of inheritance relationships, static aggregation, as well as several types of associative paradigmatic relations: relations of aggregation, cause-and-effect relations, relations of similarity, semantic similarity relations. Filled objective $Onto^{app}$ ontology can be considered as a knowledge base component to work with a particular subject area and is, in turn, is the template for constructing a dynamic knowledge base component,

The domain ontology is represented as a set of elements: $Onto^{app} = \langle C, Pr, V, I, R, Ax, D \rangle$, where C – plurality of grades $\{C_1, C_2, \ldots, C_n\}$; Pr – properties; V – property values; I – plurality of instances of a class, or examples $\{I_1, I_2, \ldots, I_n\}$, R – set of relations $\{R_1, R_2, \ldots, R_n\}$; Ax – set of axioms $\{Ax_1, Ax_2, \ldots, Ax_n\}$; D – plurality of output algorithms ontology $\{D_1, D_2, \ldots, D_n\}$.

Description is made in the language of ontology OWL DL (Ontology Web Language based on Description Logic). The main content of the ontology is represented as a logical theory that is reflected in the facts and axioms that provide information about the classes, properties and instances. The ontology applied several kinds of facts. The first type describes information about a specific instance in the form of classes to which it belongs, the instance properties and property values.

Axiom identifiers associated classes and properties by partial or complete specification of their characteristics, providing information about the classes and properties, on which to determine the consistency, the withdrawal ontology. The ontology axioms $Onto^{app}$ contains the class hierarchy, axioms describe the relationship of association, the axioms imposed on the property.

Completeness and accuracy of the developed ontology is necessary to assess, for which logic modeling of knowledge presented in ontology is done. Translation Ontology in the descriptive logic of the Horn can be carried out using special software – translators with RDF and OWL languages ontological knowledge base of the Editor ontologies Protege in one of the languages {Prolog logic programming, Classic, SHOE) or by writing a program that contains the axioms of conceptual ontology scheme and axioms of description of specific situations and rules. The specificity of the developed ontology is the definition of a generalized axioms.

Conceptual axiom schema (set of *T*-axioms) are descriptions of classes taxonomic generalization relationship, representative examples of classes. The axioms that describe the specific situation of the subject area and the rules that describe the causal relationships (set of *A*-axioms) is displayed in the rules generated in Protege on SWRL language (Semantic Web Rule Language). In order to take into account the numerical values of the properties of the ontology classes software, except the axioms and facts used by developed production rules necessary to recognize the FS, in accordance with the form (6). The resulting rules are written in the language of ontological rules SWRL a Horn clause.

$$RuleA_n : C_1(?x) \wedge C_2(?y) \wedge P_1(?x,?y) \wedge C_3(?x,?z) \rightarrow C_2(?z,?y); \qquad (8)$$

where $(C_1, C_2, C_3) \in C$. $P_1 \in P$, *x*, *y* – copies of the variables, the *z* – variable or value.

Precedent $i\left(^{cbr}_{i}\right)$ represented by the formula:

$$i\left(^{cbr}_{i}\right) = \left(category_b i\_name_i, Ds_i, Sl_i, Sc_i\right). \qquad (9)$$

To form chains conclusions on the ontology, leading to the desired goal, e.g., to the recognition of a critical situation a class as a result of failure diagnosis used inference. The logical conclusion is working on the basis of the rules of the resolution.

Existing algorithms for the organization of the process of reasoning on the ontology does not allow for analysis and comparison of the properties of type specimens. Therefore, the proposed form of the unprecedented critical situations ($Case_{Cs}$) in the base use case as a class examples of "critical situation" (*Cs*) a special kind: $Case_{Cs} \subset I_{Cs}$. The set precedents are classified according to the result of data mining on $CatCs_g$ classes of a plurality of categories $CatCs = \{CatCs_1, ..., CatCs_k\}$, *G* = 1, ... *k*, where *k* – cardinality of the set of classes of critical situations, $CatCs = \bigcup CatCs_g$; $CatCs_i \bigcap CatCs_j = \varnothing$; $i \neq j$. On the set precedents ratio defined as a binary classification of the ratio between the elements of *CaseCs* and *CatCs*, which determines the classification in examples *I* against categories *CatCs*. Categories precedents determined so that each category corresponds to a specific $CatCs_g$ example solutions in the class "Resolution". The circuit connections between the nodes, categories and use cases is a diagram of switching nodes properties, in which case each class inherits the properties to which it belongs. Accumulation of experience in problem situations and its actualization occur by adapting the decisions contained in the case law, to the new situation.

Modeling of the interaction of various forms of knowledge representation was made on an example of failure detection information display system elements of the aircraft. Monitoring and diagnostics of elements of information display systems and controls is essential to ensure the safety of the aircraft. Failures of these elements lead to a complete or partial loss of spatial orientation and handling of objects, so the timely detection of failure makes it possible to avoid accidents due to the reorientation of the management of the remaining indicators.

4. Conclusions

1. Studies show that more analysis is needed of all the potential of its knowledge representation models for specific tasks in the given problem area.
2. The methodology of object-cognitive analysis is the basis for the creation of information decision support system comprising an intelligent component acquisition, storage, processing, providing, updating and dissemination of knowledge. The resulting object-oriented domain ontology system and support decision-making model is the basis for the development of methods and algorithms of search of solutions in critical situations management.

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Розробка інформаційної системи підтримки прийняття рішень і автоматизації управління авіаційним двигуном ТВ3-117 в критичних ситуаціях на основі інженерії знань

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Мета: Метою даної статті є розробка інформаційної системи підтримки прийняття рішень і автоматизації управління авіаційним двигуном ТВ3-117 в критичних ситуаціях на основі інженерії знань. **Методи:** У статті застосовано наступні методи: метод імітаційного моделювання на етапі проектування інформаційної системи підтримки прийняття рішень; спеціальні методи і засоби об'єктна-орієнтованого моделювання предметної області, що розроблені для проектування інформаційних систем з метою відтворення концептуальної моделі експертів у формалізованій моделі представлення знань; метод ієрархічного пошуку задля пошуку прецедентів; онтологічний аналіз з метою визначення та об’єднання релевантних інформаційно-логічних і функціональних аспектів досліджуваної системи. У процесі моделювання встановлюються парадигматичні відносини між когнітивними елементами процесу управління складним динамічним об’єктом в критичних ситуаціях (причинно-наслідкові, відносини подібності), а також відносини узагальнення, асоціації, залежно та реалізації, необхідні для розробки комплексу об’єктно-орієнтованих моделей процесу управління. **Результати:** Проведені дослідження показують, що необхідно додатковий аналіз всіх можливостей застосовуваних моделей подання знань для вирішення конкретних завдань в даній проблемній області. Методологія об’єктно-когнітивного аналізу є основою розробки інформаційної системи підтримки прийняття рішень, що включає інтелектуальну компоненту придбання, накопичення, обробки, надання, поновлення і поширення знань. Отримані об’єктно-орієнтовані моделі предметної області і онтології системи підтримки прийняття рішень є основою для розробки методів і алгоритмів пошуку рішень з управління в критичних ситуаціях. **Обговорення:** Отримані результати застосовуються в рамках концепції інтелектуалізації процесу контролю і діагностики технічного стану авіаційного двигуна ТВ3-117 в польотних режимах, одним з пунктів якої є інтелектуальна обробка і зберігання інформації результатів льотних випробувань та експлуатації авіаційного двигуна ТВ3-117 на основі вимог сучасних баз даних і баз знань, з можливістю їх інтеграції в сучасні CASE-технології.

Ключові слова: авіаційний двигун, інформаційна система, об’єктно-орієнтовані моделі, критичні ситуації, онтологія

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Разработка информационной системы поддержки принятия решений и автоматизации управления авиационным двигателем ТВ3-117 в критических ситуациях на основе инженерии знаний

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Цель: Целью данной статьи является разработка информационной системы поддержки принятия решений и автоматизации управления авиационным двигателем ТВ3-117 в критических ситуациях на основе инженерии знаний. **Методы:** В статье применены следующие методы: метод имитационного моделирования на этапе проектирования информационной системы поддержки принятия решений; специальные методы и средства объектно-ориентированного моделирования предметной области, которые разработаны для проектирования информационных систем с целью воссоздания концептуальной модели экспертов в формализованной модели представления знаний; метод иерархического поиска с целью поиска прецедентов; онтологический анализ с целью определения и объединения релевантных информационно-логических и функциональных аспектов исследуемой системы. В процессе моделирования устанавливаются парадигматические отношения между когнитивными элементами процесса управления сложным динамическим объектом в критических ситуациях (причинно-следственные, отношения сходства), а также отношения обобщения, ассоциации, в зависимости от реализации, необходимые для разработки комплекса объектно-ориентированных моделей процесса управления. **Результаты:** Проведенные исследования показывают, что необходим дополнительный анализ всех возможностей применяемых моделей представления знаний для решения конкретных задач в рассматриваемой проблемной области. Методология объектно-когнитивного анализа является основой создания информационной системы поддержки принятия решений, включающей интеллектуальную компоненту приобретения, накопления, обработки, предоставления, обновления и распространения знаний. Полученные объектно-ориентированные модели предметной области и онтологии системы поддержки принятия решений являются основой для разработки методов и алгоритмов поиска решений по управлению в критических ситуациях. **Обсуждение:** Полученные результаты применяются в рамках концепции интеллектуализации процесса контроля и диагностики технического состояния авиационного двигателя ТВ3-117 в полетных режимах, одним из пунктов которой является интеллектуальная обработка и хранение информации о результатах летных испытаний и эксплуатации авиационного двигателя ТВ3-117 на основе требований современных баз данных и баз знаний, с возможностью их интеграции в современные CASE-технологии

Ключевые слова: авиационный двигатель, информационная система, объектно-ориентированные модели, критические ситуации, онтология

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