Evaluation of the impact of recovery subsystem parameters on the efficiency of a special purpose information system

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Abstract

The analysis of the tendency of information systems development as well as problems of quality management shows that now intensively developing managed systems with dynamically changing structures. Reconfiguration of such systems largely depends on the parameters of incoming requests and the internal state of the elements that are part of the control object. In order to provide the qualitative management of such systems, it is necessary to obtain information about their technical condition. The technical condition of the system is determined by the internal structure of the control object, the magnitude of the influences coming to its input and the area of acceptable behavioral strategies in the space of possible states.

High requirements for the accuracy and reliability of the operation of a special purpose information system with random changes in structure, makes it problematic the traditional use of average values of random parameters to identify the state of the system based on known distribution functions. This approach to evaluation can lead to undesirable decisions to change the structure of the system in terms of reliability. This is possible due to the scatter of parameters relative to their average value, the shift of distributions that are significantly different from Gaussian white noise. In practice, such distributions are found with a shifted mathematical expectation.

Key words: technical operation, diagnostic system, the effectiveness of functioning.

Introduction

The analysis of operation and recovery processes shows that the ability to assess the state of its elements is important for solving a wide range of tasks for managing the functioning of a special purpose information system. The solution of this problem is entrusted to the subsystems of technical management and technical support, which are part of the monitoring system, with the help of which the diagnosis of the state of the special purpose information system is organized. This means that the quality of operation of a complex system significantly determined by the organization level of its diagnostic support. We will mean by diagnostic support a set of interconnected rules, methods, algorithms and means necessary for implementation of diagnosing at all stages of a life cycle of system.

Since the application of a particular method or method of diagnosis is significantly determined by the type of object, their choice requires approaches that provide a solution to a set of problems for the rational organization of diagnostic support. It is important to note that the methods should take into account the possibility of solving the problem of assessing the state of the information system with both external and built-in diagnostic tools, which, in turn, can be automatic or automated.

Material and methods

The aim is to analyze the process of operation and restoration of the special purpose information system. Factors influencing the efficiency and quality of functioning of a complex system are considered. Approaches are proposed that would take into account and adequately reflect the impact of the recovery subsystem on the functioning of the information system.

Results and discussion

To identify the most significant parameters that affect the productivity of a special purpose information system, consider the process of its operation, which in the form of states and events are shown in Fig. 1 and corresponds to the generalized form of the set of states shown in Fig. 2. In fig. 1 numbers indicate the following events: 1 – damage; 2 – refusal; 3 – restoration of correct functioning; 4 – recovery; 5 – restoration of serviceability.

The transition of a special purpose information system from state to state is due to defects. All of them can be divided into defects, which are fixed by the built-in diagnostic subsystem and cause the transition of the system to a faulty but operational state; defects that are fixed by the diagnostic subsystem and lead to the transition of the information system to one of the partially operational states (characterized by a decrease in productivity); defects that are not fixed and they do not directly affect the facility operability; defects that cause complete failure of the system or put it in a "non-functioning" state.

The first group of defects is characteristic of the information system, which has a reserve in its structure. When failures occur, the backup set is automatically turned on after identifying the damage and the time to eliminate it.

System performance losses for this group are determined by the transition time (T_s) from the main set to the backup set.

The second group of defects puts the information system in a faulty state and does not directly affect its performance, but reduces the quality of operation, as well as increases the loss of system performance.

Failures of the built-in diagnostic subsystem make it difficult to solve damage search problems. Failures are not always detected during the exploitation of the information system, and, therefore, in the case of defects, lead to a significant increase in the recovery time (T_r) of the system performance which entails a decrease in system performance.

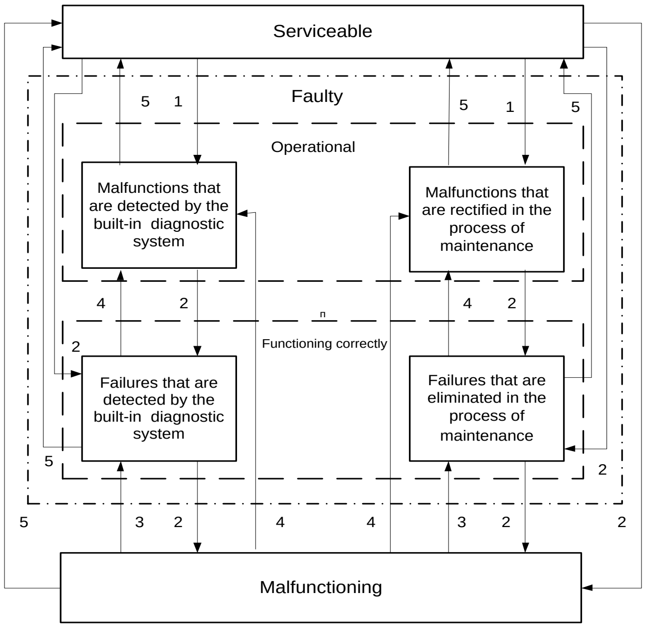

Fig. 1. Scheme of the main states of the information system

The third group of defects causes the transition of the special purpose information system to emergency mode (that is, switching to the emergency multitude). In this case, the performance losses of the system are defined as the time of transition from the main set to the backup set (T_s), and the recovery time of the main set (T_r). In some cases, the failure of the information system elements (for example, line equipment)lead to the emergence of partially operational conditions and then the losses depend only on their T_r.

The fourth group of defects puts the constituent parts of the special purpose information system in a "non-functioning" state, ie there is a complete failure – an event that consists in the temporary cessation of the intended use. In this case, the performance loss of the system depends on the recovery time of the information system main set. The result is the occurrence of one of the states: either functioning properly or working.

Thus, the average performance loss of a special-purpose information system depends on a large number of factors that affect change of the T_r and T_s. In the papers (Glazunov L. P., 1984; Druzhinin G. V., 1986; Nadezhnost', 1988) a sufficiently detailed classification of such factors is given. The most important of them are:

the level of units (nodes), which are replaced in case of failures;

types of spare parts and their compliance with the accepted level of aggregation;

types of damage and failure of information system elements;

the presence of a built-in diagnostic subsystem and the degree of completeness of its verification of the correct operation;

the presence of a subsystem for external diagnostics of the information system state, which allows you to manually search for defects;

availability of diagnostic programs that provide the ability to restore elements of the information system by operators with insufficient qualifications and others.

The nature of the dependence of the average recovery time of the system elements is determined by many factors, and above all - the type of basic design, which is used to build specific samples of equipment. It is important to note that to solve the problem of recovery at each of the levels of operation of the information system, the different modular elements can be used.

From fig. 1 it follows that to reduce the average loss of performance you need to increase the completeness of the automatic check of the correct operation. This in turn reduces the number of uncontrolled failures in the system and allows to achieve a reduction of the T_s and T_r. However, the improvement of T_s and T_r due to the automation of defect retrieval processes, leads to the complexity of the diagnostic subsystem, the reliability of which affects the quality of application of components in the information system. If we exclude the possibility of the operator's participation in the recovery process using the external diagnostics subsystem, then the failure of the built-in diagnostic subsystem, the loss function will dramatically increase by increasing Tr. In general, the division of the restoration process of the component part into the process of restoring the correct operation (the ability of the complex to process information flows) and the process of restoring efficiency and serviceability,allows to reduce equipment downtime while increasing the total time to bring the system into working order.

The complex nature of the relationship between the individual parameters requires a more detailed study of issues such as the division of tasks between internal and external diagnostic subsystems, the choice of completeness of automatic performance testing, identifying ways to reduce system performance losses due to failures.

There are two main types of control over the state of the information system: – checking the correct operation; – search for defects (Nadezhnost', 1987). The means and methods of their implementation are partially or completely the same. The first of them is carried out in the operating mode of the information system and has such quantitative characteristics as the coefficient of completeness of the correctness of functioning and the probability of conducting control. The second is designed to search for defects using the built-in diagnostic subsystem, ie to determine the location and nature of the fault. Its quality is assessed by the depth of automatic defect search and the average diagnosis time.

To assess the impact of various parameters of the built-in diagnostic subsystem on the average performance of the object under study, consider the model of the information system. Imagine that the object is covered by the built-in diagnostic subsystem (type 2) with full coverage α2 (provides automatic search for the element that failed) and is controlled by the built-in diagnostic subsystem (type 1) (checks the correct operation of the main set in operation). In addition, the object has some emergency set (in some cases a backup set).

In the study we will proceed from the following assumptions:

failure of the built-in diagnostic subsystems (type 1 and type 2) does not directly affect the efficiency of the main set, but lead to an increase in the time to restore the correct operation (T_{ro}) and the time to restore efficiency (T_{re});

after the emergency set is turned on, the failure of the built-in diagnostic subsystem (type 1) will lead to the need to re-enable the emergency set manually;

the built-in diagnostic subsystem in the case of failure does not recover;

the probabilities of uninterrupted operation of the elements of the main set, covered and not covered by the built-in diagnostic subsystem (type 2) with completeness of control α2, accordingly are determined as:

$$P_{40} = P_{40}^{\alpha_2}, \qquad P_{50} = P_{40}^{(1-\alpha_2)}$$

when $\alpha_2 = 1$ in good condition, the built-in diagnostic subsystem (type 2) implements fully reliable control;

the probability of no-failure operation of the built-in diagnostic subsystem (type 1) is associated with the probability of failure-free operation of the main set through the parameter

$$a_1 \geq 0, \qquad P_{20} = P_{OM}^{a_1}$$

the probability of trouble-free operation of the built-in diagnostic subsystem (type 2) is associated with the probability of failure-free operation of the main set due to the completeness of the inspection a_1 and the complexity factor

$$a_2 \geq 0, \qquad P_{30} = P_{OM}^{\alpha_2 a_2}$$

the probability of failure of the emergency set is associated with the P_{OM} ratio

$$P_{10} = P_{OM}^{C}, \text{де } 0 \leq \mathrm{C} \leq 1$$

it is considered that the element of the information system does not allow breaks in work. Under its complete refusal the event which puts the investigated object in an inoperative condition and necessary break in the course of transfer of information flows is understood.

The total number of states in which an element of an information system can be formed is a space of elementary events Ω. Herewith one of 11 incompatible complex events may occur A_i :

A_0 – good condition, A_1 – operable condition; A_2 – inoperable condition with automatic switching to the emergency set and recovery of the main set only with the help of the built-in diagnostic subsystem (type 2), A_3 – inoperable condition with automatic switching to the emergency set and recovery of the main set both by means of the built-in diagnostic subsystem (type 2), and the operator; A_4 – inoperable condition with automatic switching to the emergency set and recovery of the main set only by the operator; A_5 – inoperable condition with manual shifting to the emergency set and recovery of the main set with the help of the built-in diagnostic subsystem (type 2); A_6 – inoperable condition with manual shifting to the emergency set and recovery of the main set both by the built-in diagnostic subsystem (type 2), and the operator; A_7 – inoperable condition with manual shifting to the emergency set and recovery of the main set only by the operator; A_8 – system failure with main set recovery using built-in diagnostic subsystem (type 2); A_9 – system failure with main set recovery both with the help of the built-in diagnostic subsystem (type 2) and by the operator; A_{10} – system failure and recovery of the main set only by the operator.

Each of A_i leads to certain losses in the performance of the information system during peak load, and their combination$\{A_i\}$ generates a finite set

$$A = \{\emptyset, \Omega, A_1, A_2, \dots, A_{10}, A_0, A_1 + A_3 \dots\}$$

To build a probabilistic space (Ω, A, P) you need to find $P(A_i)$. We use the topological method of calculating the reliability of complex systems (Nadezhnost', 1985; Nadezhnost', 1987) and, in particular, the logical-probabilistic method. It is recommended to use a tabular description method to examine objects that contain less than 10 state variants.

Let's write: $P_{i0} = x_i$, $Q_{i0} = \overline{x_i} = 1 - P_{i0}$

All possible combinations of state conjunctions of model elements are grouped into complex events $\{A_i\}$. Using Boolean algebra (Glazunov

L. P., 1987; Nadezhnost', 1988), we transform them into complete conjunctive normal forms.

$f(A_0) = x_1x_2x_3x_4x_5$; $f(A_1) = \overline{x_1x_2x_3}x_4x_5$;
$f(A_2) = x_1x_2x_3\overline{x_4}x_5$ $f(A_3) = x_1x_2x_3\overline{x_5}$;
$f(A_4) = x_1x_2\overline{x_3x_4x_5}$; $f(A_5) = x_1\overline{x_2}x_3\overline{x_4}x_5$
$f(A_6) = x_1\overline{x_2}x_3\overline{x_5}$; $f(A_7) = x_1\overline{x_2x_3x_4x_5}$
$f(A_8) = \overline{x_1}x_3\overline{x_4}x_5$; $f(A_9) = \overline{x_1}x_3\overline{x_5}$
$f(A_{10}) = \overline{x_1x_3x_4x_5}$

In fig. 2 shows all possible states of the system in the form of a graph, where the edges are events that transfer the system from state to state.

Based on expressions (1) it is possible to find the probability functions (P) of each of the states of the studied object: $P(f(A_i) = 1)$.

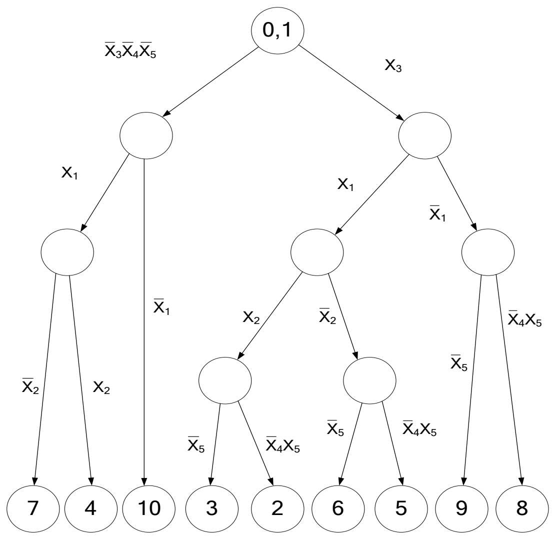

Fig. 2 Graph of system states

Since all $f(A_i)$ are unique, and the failures of the elements of the information system are independent, we pass from x_i to $P_{i0} = f_o(P_{OM})$ for each $A_i \subset \Omega$.

$P_0 = P(A_0) = P_{OM}^{(C+a_1+a_2\alpha_2+1)}$;
$P_1 = P(A_1) = P_{OM} - P_{OM}^{(C+a_1+a_2\alpha_2+1)}$;
$P_2 = P(A_2) = P_{OM}^{(C+a_1+a_2\alpha_2-\alpha_2+1)} - P_{OM}^{(C+\alpha_1+a_2\alpha_2+1)}$;
$P_3 = P(A_3) = P_{OM}^{(C+a_1+a_2\alpha_2)} - P_{OM}^{(C+a_1+a_2\alpha_2-\alpha_2+1)}$;
$P_4 = P(A_4) = P_{OM}^{(C+a_1)} - P_{OM}^{(C+a_1+a_2\alpha_2)}$;
$P_5 = P(A_5) = P_{OM}^{(C+a_2\alpha_2-\alpha_2+1)} + P_{OM}^{(C+a_1+a_2\alpha_2+1)} -$
$-P_{OM}^{(C+a_1-a_2\alpha_2-\alpha_2+1)} - P_{OM}^{(C+a_2\alpha_2+1)}$;
$P_6 = P(A_6) = P_{OM}^{(C+a_2\alpha_2-\alpha_2+1)} - P_{OM}^{(C+a_1-a_2\alpha_2-\alpha_2+1)}$;
$P_7 = P(A_7) = P_{OM}^{(C)} + P_{OM}^{(C+a_1+1)} + P_{OM}^{(C+\alpha_1+a_2\alpha_2)} +$
$+P_{OM}^{(C+a_2\alpha_2+1)} - P_{OM}^{(C+a_1)} - P_{OM}^{(C+1)} - P_{OM}^{(C+a_2\alpha_2)} -$
$-P_{OM}^{(C+a_1+a_2\alpha_2+1)}$;
$P_8 = P(A_8) = P_{OM}^{(a_2\alpha_2-\alpha_2+1)} + P_{OM}^{(C+a_2\alpha_2+1)} -$
$-P_{OM}^{(C+a_2\alpha_2-\alpha_2+1)} - P_{OM}^{(a_2\alpha_2-\alpha_2+1)}$;
$P_9 = P(A_9) = P_{OM}^{(a_2\alpha_2)} + P_{OM}^{(C+a_2\alpha_2-\alpha_2+1)} -$
$-P_{OM}^{(C+a_2\alpha_2)} - P_{OM}^{(a_2\alpha_2-\alpha_2+1)}$;
$P_{10} = P(A_{10}) = 1+P_{OM}^{(C+a_2\alpha_2)} + P_{OM}^{(C+1)} +$
$+P_{OM}^{(a_2\alpha_2+1)} - P_{OM}^{(a_2\alpha_2)} - P_{OM}^{(C+a_2\alpha_2+1)} - P_{OM}^{(C)} - P_{OM}$.

According to the calculated probabilities, you can determine the probability space $(\Omega, \mathrm{A}, \mathrm{P})$ and obtain an analytical expression of the average productivity loss:

$$\overline{\Delta \mathrm{K}} = \sum_{i=1}^{10} \Delta K_i \; P_i,$$

where ΔK_i – the productivity loss of studied system.

To assess the impact of the parameters of the recovery subsystem on the quality of the information system, we specify the function of the average recovery time. Whereas the information obtained by the built-in diagnostic subsystem (type 2) should be used to automate the diagnosis or reduction of T_{re} to $\mathrm{T_{ro}}$, then the latter must be related to α_2:

$$\alpha_2 = \mathrm{L}(\alpha_2)/\mathrm{L} \ ,$$

where $\mathrm{L}(\alpha_2)$ – the number of diagnostic parameters that ensure the methodological reliability of the verification;

L – the total number of diagnostic parameters that implement a given depth of diagnosis (performance monitoring) of the main set with the required reliability.

Obviously, L varies according to the properties of the structure of the diagnostic object and depends on the tasks assigned to the built-in diagnostic subsystem (type 2). If, for $\alpha_2 = 1$ the search depth to the component (L+1), then T_{re} of the basic set is calculated by the formula:

$$\mathrm{T_{re}} = \alpha_2 \mathrm{t_b} \mathrm{K_m} + \mathrm{t_0}(1-\alpha_2)\mathrm{K_m} + \mathrm{t_z} \, ,$$

where t_{b} – average time of check of one diagnostic parameter by means of the built-in subsystem of diagnostics (type 2);

t_0 – the average time to check one diagnostic parameter, using a person who measures the parameters;

K_{m} – maximum number of search operations (depends on the failure localization procedure);

t_z – the average time to troubleshoot one fault.

In case of single failures, it is possible to build diagnostic algorithms that are close to the minimum form [5, 7]

$$K_m = \log_2 L,$$

where L – the number of radio electronic modules in the system.

Given that (50...80)% recovery time is the time of troubleshooting (Nadezhnost', 1987; Kovtunenko, A. P., 2007) with timely replenishment of a set of spare parts, we determine

$$t_z = 0{,}5 \cdot t_0 \cdot \log_2 L = 0{,}5 \cdot t_0 \cdot K_m$$

Using the obtained expressions, we find the loss functions $\varphi(A) = \Delta K_i \cdot P_i$ in each of the possible states of the sample.

$$\overline{\Delta \mathrm{K}} = \sum_{i=2}^{10} \varphi(A_i)$$

Analysis of loss functions shows that $\overline{\Delta \mathrm{K}}$ depends on the average performance loss of the information system by switching ΔK_s and by restoring the efficiency of ΔK_r of the main set $\overline{\Delta K_i}$, that is

$$\overline{\Delta \mathrm{K}} = \overline{\Delta K_s} + \overline{\Delta K_r}$$

$$\overline{\Delta K_i} = \left(\sum_{i=1}^{4} t_{s1} P_i + \sum_{i=5}^{10} t_{s2} P_i\right) \cdot B$$

where B – throughput of the information system when the main set is operational

t_{s1}, t_{s2} – the time of transition to the main and backup set of elements, respectively.

The obtained expressions allow to carry out research of influence of primary parameters of system on $\overline{\Delta \mathrm{K}}$ for various variants of the organization of control of the main set which can change depending on type of elements of information system.

Conclusions

The proposed approach allows to assess the change in the efficiency of the special purpose information system from the impact of the subsystem to restore the efficiency of the system elements. It allows to consider indicators of depth of the built-in subsystem of diagnosing, and also a possibility of transition to reserve (emergency) elements of system by means of the operator. The given expressions allow to carry out an estimation of productivity at the expense of influence of primary parameters of elements of information system.

In further researches with use of the proposed approaches it is offered to consider expediency of increase of depth of control of elements of difficult system by means of the built-in subsystem of diagnostics and efficiency of its work depending on reliability of the used elements.

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