Optimization of the Quality Assessment of the Information Security System Functioning

Volodymyr Khoroshko [1], Serhii Zybin [2], Yuliia Khokhlachova [3], Ahmad Ayasrah [4], Abduiiah Al-Dalvash [5]

[1,2,3,4,5] *National aviation university, 1, Liubomyra Huzara ave., Kyiv, 03058, Ukraine*

Abstract

The paper proposes a method for solving the problem, which was formulated. The solution to this problem is based on comparing the characteristics of the functioning of the system under study. Characteristics compares with similar characteristics of a reference on a variety of criteria. This solution can be used when testing systems of various types, purposes and arbitrary level of complexity. This method of presenting the assessment results makes it possible to quickly navigate the totality of the data obtained. And also to carry out a quick search for unsatisfactory functioning elements of the system under study.

This technique can be used to select the optimal mode of functioning of the system, to select from a certain class of functional elements to build an optimal system and to consistently modernize the system under study by improving the unsatisfactory functioning elements identified during the assessment process, etc.

Keywords

Information security systems, quality of systems functioning, optimization of quality assessment.

1. Introduction

The study of the functioning laws for complex dynamic systems of various types (technical, economic, and social) has attracted the attention of researchers for a long time [1,2,3,4,5,6,7,8,9].

Among the eternal problems that arise in this case, the following problems can be singled out as especially important: the choice of optimal modes of operation for such systems, the choice of an optimally functioning system from a certain class of equivalent systems, the quality assessment of complex dynamic systems functioning.

The paper proposes a method for solving the problem, which was formulated. It is based on comparing the characteristics of the system's functioning under study with similar characteristics of a certain reference system according to a number of criteria.

2. Main purpose

Obviously, only a versatile, multi-criteria and multi-level assessment will be sufficiently objective. At the same time, its manual acquisition for complex dynamical systems is impossible in practically admissible periods of time. This is impossible even for any particular case due to the large volumes of processed information. One or a little territorial analysis will give only one-sided assessments, while important features of the laws of the systems functioning that are being investigated are often ignored. Therefore, a problem arises related to the development of methods for optimal processing of this

ISIT 2021: II International Scientific and Practical Conference «Intellectual Systems and Information Technologies», September 13–19, 2021, Odesa, Ukraine
EMAIL: professor_va@ukr.net (A.1); zysv@ukr.net (A.2); hohlachova@gmail.com (A.3); ahmadaesr@gmail.com (A.4); abduiiah.dalosh@gmail.com (A.5)
ORCID: 0000-0001-6213-7086 (A.1); 0000-0002-2670-2823 (A.2); 0000-0002-1883-8704 (A.3); 0000-0003-4392-1806 (A.4); 0000-0002-1003-9182 (A.5)

information in order to quickly obtain the required estimates.

3. Study of the dynamic system functioning

Let's consider a dynamic system, the functioning of which is described by a set of characteristics

$$A(t) = [A_j(t)]_{j=1}^{m}, t \in [0, T],$$

where T is the time during which the test study was carried out. We assume that each characteristic

$$A_j(t) = [A_j^i(t)]_{i=1}^{n}, j = 1, 2, 3 \dots,$$

represents a vector of constant values or a vector – a function that describes individual aspects of the system functioning under study (initial, intermediate and final state, phase vector, control vector, etc.) [5].

Let us assume that the system can operate in l modes $R_q, q = 1, 2, \dots 3, \dots, l$. The characteristics of the functioning laws for an information security system (ISS) can be obtained both as a result of experimental research and by means of mathematical modelling of the dynamics of its functioning.

Let us assume that five criteria are used to assess the functioning quality of the system that is being investigated $K_p, p = 1, 2, 3 \dots, p$. It is necessary to determine the limits of change of indices and *t* values. If there is no special need for this, it is omitted. We denote $L_{ji}^{kp}(t)$ as the area of reference values of the component $A_j^i(t)$ when the system operates in the *k*-th mode according to the *p*-th evaluation criterion.

Equivalent systems are understood as systems of the same type and purpose, the law of functioning of which is described by a set of characteristics A(t). We denote by G_N-class of equivalent dynamical systems, which includes *N* elements.

An example of a complex dynamic system is an information security system. Let's simulate the dynamics of the functioning of a ISS, which is a system with many links.

The functioning of the ISS can be described by dynamic, energetic and a number of other characteristics [2, 5]. Each of these characteristics is a multidimensional scalar vector or vector-function, the components of which describe the duration of individual phases of the system's functioning or its behaviour characteristics under various external influences. Among the evaluation criteria, one can point out the deviation from work tolerances, the effectiveness of information protection, the effectiveness of absorption, etc. The areas of their variation are used as the areas of reference values of the characteristic components. The class of equivalent systems in this case can be a reference system that functions under optimal conditions. In general, the amount of information that needs to be analysed for a sufficiently substantiated objective assessment of the functioning quality of an ISS can clearly exceed that available for non-automated processing [10,11,12,13].

Let us assume that the investigated dynamic system (ISS) is a new (*N* + *1*)-th element of the G_N class. It is necessary to formulate the problem based on a numerical analysis of the characteristics of the system $A(t) = [A_j(t)]_{j=1}^{m}$. It is necessary to form a sequence of qualitative local estimates for the behavior of the components of these characteristics $A_j(t) = [A_j^i(t)]_{j=1,i=1}^{m,n}$. This must be done according to a set of criteria $K_p, p = 1, 2, 3 \dots, 5$, for a given set of operating modes $R_q, q = 1, 2, \dots 3, \dots, l$. Based on the resulting set of local estimates, it is necessary to form a sequence of weighted averaged estimates of varying degrees of generality. These assessments make it possible to analyse the features of the behaviour of both individual characteristics of the system and the quality of its functioning as a whole.

Consider a solution technique for the formulated problem. Let us assume that the system under study is assessed according to the *p*-th criterion when it is operating in the R_q-th mode. To solve the formed problem, we introduce an auxiliary function

$$\alpha_j^i(t) = 0, \forall A_j^i(t) \in \theta_{ji}^{kp}(t);$$

$$\alpha_j^i(t) = A_j^i(t) - max\, \theta_{ji}^{kp}(t), \forall A_j^i(t) > \\ > \theta_{ji}^{kp}(t);$$

$$\alpha_j^i(t) = min\, \theta_{ji}^{kp}(t) - A_j^i(t), \forall A_j^i(t) < \\ < \theta_{ji}^{kp}(t).$$

Let us introduce the numerical parameters of the local assessment for the *i*-th component and the *j*-th characteristic of the system according to the *p*-th criterion in the *k*-th mode of operation by the relations

$$c(A_j^i, K_p, R_q) = ||\alpha_j^i||_{c[0,T]} = \max[\alpha_j^i(t)],$$

$$l(A_j^i, K_p, R_q) = ||\alpha_j^i||_{L2[0,T]} = \\ = [\int_0^T (\alpha_j^i(t))^2 dt]^{\frac{1}{2}}.$$

The system for which $c\left(A_j^i, K_p, R_q\right) = l\left(A_j^i, K_p, R_q\right) = 0\ \forall\, j, i, R, q$ will be considered a reference system.

Obviously, direct analysis of the entire totality of the numerical parameters of local assessment is a complex problem. This analysis is complicated by the analysis of behaviour for the functioning of the system and functional dependences of $A_j^i(t)$, in the form of graphs, in order to obtain generalized estimates of the functioning of the system under study, which is a dynamic system. The reason for this complexity is in the amount of parameters, which is equal to $5 = 2mnls$ and is large enough.

Suppose that for the characteristic $[A_j^i(t)]_{j=1}^m$ of systems for class G_N certain values

$$c_{min}\left(A_j^i, K_p, R_q\right) = \min c\left(A_j^i, K_p, R_q\right),$$
$$c_{max}\left(A_j^i, K_p, R_q\right) = \max c\left(A_j^i, K_p, R_q\right);$$
$$l_{min}\left(A_j^i, K_p, R_q\right) = \min l\left(A_j^i, K_p, R_q\right),$$
$$l_{max}\left(A_j^i, K_p, R_q\right) = \max l\left(A_j^i, K_p, R_q\right).$$

We introduce for each function $A_j^i(t)$ under study (*N+1*)-th for the dynamic system the illogical arrays of local qualitative estimates:

1) $C_{ji}^{qp} = 1, \forall\, c\left(A_j^i, K_p, R_q\right) < c_{min}\left(A_j^i, K_p, R_q\right) + \left[c_{max}\left(A_j^i, K_p, R_q\right) - c_{min}\left(A_j^i, K_p, R_q\right)\right]/4$, we consider this assessment is unsatisfactory;
2) $C_{ji}^{qp} = 2, \forall\, c\left(A_j^i, K_p, R_q\right) \epsilon \{\, c_{min}\left(A_j^i, K_p, R_q\right) + \left[c_{max}\left(A_j^i, K_p, R_q\right) - c_{min}\left(A_j^i, K_p, R_q\right)\right]/4,\ c_{max}\left(A_j^i, K_p, R_q\right) - \left[c_{max}\left(A_j^i, K_p, R_q\right) - c_{min}\left(A_j^i, K_p, R_q\right)\right]/4 \,\}$, we consider this assessment is satisfactory;
3) $C_{ji}^{qp} = 3,\ \forall\, c\left(A_j^i, K_p, R_q\right) > c_{max}\left(A_j^i, K_p, R_q\right) - \left[c_{max}\left(A_j^i, K_p, R_q\right) - c_{min}\left(A_j^i, K_p, R_q\right)\right]/4$, we consider this rating is good.

Similarly, arrays L_{ji}^{qp} are introduced for primary assessment parameters. Obviously, graduation of estimates depending on the needs can be narrowed or expanded. Note that when the class G_N is expanding (Introduce (*N+1*)-th element), the change in value $c(l)_{min}\left(A_j^i, K_p, R_q\right)$ in order to "unreliable recognition" limits of estimation is inappropriate, unlike $c(l)_{max}\left(A_j^i, K_p, R_q\right)$. Naturally, the wider class G_N, the score will be more objective, high-quality and accurate.

We formally form on the basis of a set of local qualitative assessments of varying degrees of generality until the final conclusion on the quality of the functioning of the studied dynamic system. Such a construction will be carried out in two directions, which can be changed vertical and horizontal, which corresponds to a method for further evaluation that facilitates their perception and qualitative analysis.

The assessment in the vertical direction makes it possible to analyse the behaviour of individual characteristics or the system as a whole according to the corresponding parameter, criterion or mode, namely:

Step 1. For the separate type of estimated parameter for a set of components of each characteristics for a digital evaluation criterion

$$V_{j,c}^{q,p} = \sum_{i=1}^{n} \rho_{A_j^i} c_{ji}^{qp} / \sum_{i=1}^{n} \rho_{A_j^i},$$
$$V_{j,L}^{q,p} = \sum_{i=1}^{n} \rho_{A_j^i} L_{ji}^{qp} / \sum_{i=1}^{n} \rho_{A_j^i},$$

where $\left\{\rho_{A_j^i}\right\}_{i=1}^{n}$ – are weight coefficients that determine the significance of the component of the system characteristics. Here and then the values of weight coefficients are determined by the experts exploring the dynamic systems under consideration in accordance with the specifics of the latter or the objectives of the study itself. The assessment of the values $V_{j,c}^{q,p}$ ($V_{j,L}^{q,p}$) are made similarly to the valuation by values. C_{ji}^{qp} (L_{ji}^{qp}).

Step 2. For the separate evaluation criterion for the set of estimated parameters

$$V_{j,}^{q,p} = \left(\rho_c V_{j,c}^{q,p} + \rho_L V_{j,L}^{q,p}\right)/(\rho_c + \rho_L),$$

where ρ_c , ρ_L – are weighing coefficients that determine the importance of evaluation parameters.

Step 3. For the certain mode, the functioning of the assessment criteria

$$V_{j,}^{q} = \sum_{p=1}^{s} \rho_{K_p} V_{j,}^{q,p} / \sum_{p=1}^{s} \rho_{K_p},$$

where $\left\{\rho_{K_p}\right\}_{p=1}^{s}$ – are weighing coefficients determining the importance of evaluation criteria.

The assessment in the horizontal direction makes it possible to analyse the behaviour of individual components of the specific characteristic or characteristics of the system as a whole according to the corresponding parameter, criterion or mode, namely:

Step 1. For the separate type of estimated parameter for the aggregate evaluation criteria separately each component characteristics

$$H_{i,c}^{j,q} = \sum_{p=1}^{s} \rho_{K_p} c_{ji}^{qp} / \sum_{p=1}^{s} \rho_{K_p},$$

$$H_{i,L}^{j,q} = \sum_{p=1}^{s} \rho_{K_p} L_{ji}^{qp} / \sum_{p=1}^{s} \rho_{K_p};$$

Step 2. For used estimated parameters for the aggregate criteria for estimating relative each component characteristics

$$H_i^{j,q} = (\rho_c H_{i,c}^{j,q} + \rho_L H_{i,L}^{j,q})/(\rho_c + \rho_L);$$

Step 3. For the separate mode of functioning by set of components. Characteristics

$$H_{j,}^{q} = \sum_{i=1}^{n} \rho_{A_j^i} H_{i,}^{j,q} / \sum_{i=1}^{n} \rho_{A_j^i}.$$

Obviously, the following statement is right

The statement 1. $H_i^q \equiv V_j^q = VH_i^q$.

Note that the assessments of the last level characterize the behaviour of individual characteristics of the system in terms of the set of parameters in specified modes and functioning.

The graphic results of the first stage of the assessment are shown in Figure 1.

The values of $C_{ji}^{qp}(L_{ji}^{qp})$ correspond to the elements of the table that are at the intersection of the rows A_j^i and the columns *C(L)*, the rest are estimates of the 1-3rd generality.

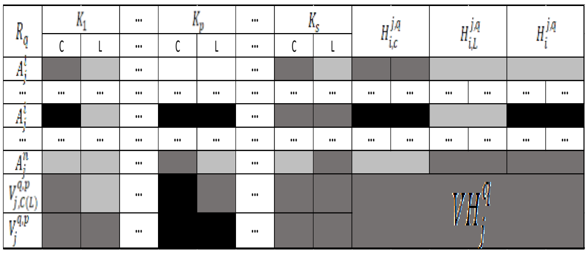

Figure 1: The graphic results of the first stage

Wherein

- good,
- satisfactorily,
- unsatisfactorily.

The main advantage of the proposed method for presenting the assessment results is the ability to track the unsatisfactory functioning of individual elements of the system in order to determine the causes of failures.

The next stage of generalized weighted estimates is determined as follows: in the vertical direction – according to the totality of characteristics for the digital mode of operation, i.e.

$$VH^k = \sum_{j=1}^{m} \rho_{A_j} VH_{j,}^{Q} / \sum_{j=1}^{m} \rho_{A_j},$$

where $\{\rho_{A_j}\}_{j=1}^{m}$ – are weighting factors that determine the significance of the characteristic of the system.

In the horizontal direction, the assessment is carried out according to the set of modes for each characteristic of the investigated dynamic protection system, i.e.

$$VH = \sum_{q=1}^{l} \rho_{R_q} VH_{j,}^{q} / \sum_{q=1}^{l} \rho_{R_j},$$

where $\{\rho_{R_q}\}_{q=1}^{l}$ – are weighting factors that determine the significance of the modes of functioning of the system.

The following statement is obvious.

The statement 2.

$$\sum_{q=1}^{l} \rho_{R_q} VH_{j,}^{q} / \sum_{q=1}^{l} \rho_{R_q} = \sum_{j=1}^{m} \rho_{A_j} VH_j / \sum_{j=1}^{m} \rho_{A_j} = VH.$$

The *VH* value makes it possible to make a final conclusion about the quality of the functioning of the investigated protection system (dynamic) as a whole. The graphically generalized results of the estimates obtained at the second stage are shown in Figure 2. The elements of the table, which are at the intersection of rows A_j and columns R_q, correspond to the values VH_j^q, the rest are estimates of the 4th level of generalization and the final conclusion about the quality of the system.

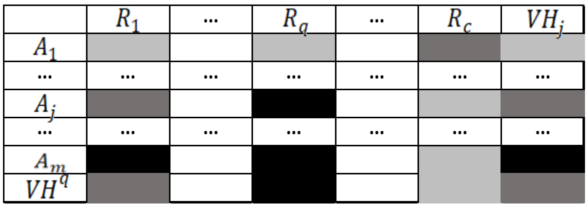

Figure 2: The graphically generalized results

Wherein

- good,
- satisfactorily,
- unsatisfactorily.

Based on the results obtained, the procedure has been developed for the transition from generalized assessments of the highest to those of the lowest level up to the possibility of a detailed qualitative and quantitative analysis of the behaviour of components for a separate characteristic of the studied protection system according to a specific criterion for a given mode of operation of the system [5, 6, 7]. This is necessary to determine the reasons for obtaining unsatisfactory quality ratings.

4. Conclusions

This article proposes the methodology for a versatile, multi-criteria and multi-level assessment of the functioning quality for the information security system. This system is dynamic. The technique can be used for testing systems of various types, purposes, and arbitrary levels of complexity.

The proposed method of presenting the results of the assessment makes it possible to quickly navigate in the totality of the data obtained, as well as to quickly search for unsatisfactory functioning elements of the system under study.

In addition, this technique can be used to select the optimal mode for the system operating, select from a certain class of functional elements to build an optimal system and consistently modernize the system under study by improving the unsatisfactory functioning elements identified during the assessment process, etc.

5. References

[1] Stefan Thurner, Rudolf Hanel, and Peter Klimek. Introduction to the Theory of Complex Systems. Oxford University Press. – 2018.

[2] Tymoshenko A.O. Methods for the analysis and design of systems to obtain information / A.O. Tymoshenko - K: Politechnika, 2007.

[3] Tomashevsky V.M. Model of systems / V.M. Tomashevsky – K: View. group BHV, 2007.

[4] Mark L. Agranovsky, Matania Ben-Artzi, Greg Galloway, Lavi Karp, Vladimir Maz'ya, Simeon Reich, David Shoikhet, Gilbert Weinstein, and Lawrence Zalcman, Editors. Complex Analysis and Dynamical Systems VII (Contemporary Mathematics). Amer Mathematical Society. – 2017.

[5] Ivakhnenko A.G. Modeling of complex systems based on experimental data / A.G. Ivakhnenko, Yu.P. Yurachkovsky – M: Radio and communication, 2000.

[6] Ho, Y. J.; Ruiz Estrada, M. A; Yap, S. F. "The evolution of complex systems theory and the advancement of econophysics methods in the study of stock market crashes". Labuan Bulletin of International Business & Finance. – (2016). Vol. 14: 68 – 83.

[7] Zgurovsky M.Z. Technological foresight / M. V. Zgurovsky, N. D. Pankratova – K: Polytechnic, 2005.

[8] Hiroki Sayama. Introduction to the Modeling and Analysis of Complex Systems. Open SUNY Textbooks. – 2015.

[9] Koval V.N. Applied systems for the analysis of multidimensional processes / V.N. Koval – K: Naukova Dumka, 2002.

[10] Khoroshko V.O. Bagatocriterial assessment of the efficiency of projects for the safety of cybersecurity / V.O. Khoroshko, M.Y. Shelest, Yu.M. Weaver // Technical sciences and technologies, No. 1 (19), (2020): 121–131.

[11] S. Zybin, V. Khoroshko, V. Maksymovych, I. Opirskyy. Effective Distribution of Tasks in Multiprocessor and Multi-Computers Distributed Homogeneous Systems. // International Journal of Computing. VOLUME 20(2), (2021): 211 – 220.

[12] I. Opirskyy, S. Zybin, V. Horoshko. Analysis of Mathematical Models of Functioning Scalar Multiprocessor Systems. // Information systems and networks. Volume 6, (2019): pp. 66 – 78.

[13] V. Khoroshko, S. Zybin, N. Brailovskyi, Y. Khokhlachova. Conflict situations and interactions of the parties. // Scientific and Practical Cyber Security Journal (SPCSJ) 5(1), (2021): 22-34. URL: https://journal.scsa.ge/papers/conflict-situations-and-interactions-of-the-parties/