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Control of Multiobjective Complex Systems

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Abstract

Defined the approaches to solving the multicriterial problem in the quality assessment of complex technical systems. Confirmed the effectiveness of the approaches in the design of training facilities for the preparation of transport system operators.

Keywords: complex system, multi-criteria assessment of the quality, the problem of uncertainty, normalization and ranking criteria, modeling

Introduction

Currently, the analysis and synthesis of complex systems in the vast majority of sectors (not an exception, and transportation) with the rare exception of the vector optimization criterion is almost never used. Usually, most of the authors are limited to a one-criterion optimization; ranking of criteria and minimization of dimension of criterion space is not performed. Hardly used and known formal methods for solving problems with constraints (in particular, the method of successive concessions [1, 2]). Therefore, so far the definition of approaches to solving problems related to multicriteria is relevant.

Opinion on the effectiveness of complex systems can not be done on the basis of the registration of a single indicator; assessment, as multiobjective, can not be reduced to a standard quality assessment by one criterion. But even setting the entire set of criteria is often not enough to highlight the most important of them without additional information about the relative importance of each of them. Consider only deterministic control problem, where multiple criteria is completely determined by the quality of governance.

Problems of uncertainty, normalization and prioritization criteria

Typically, the criteria $K_i, i = \overline{1,n}$ are numerical functions defined on the set of control strategies. Strategy u preferable strategy v, if

$$K_i(u) \geq K_i(v), i = \overline{1,n};$$

at least one of the inequalities – strict. Strategy u and v are considered equal, if $K_i(u) = K_i(v)$. The most serious in assessing the quality of processes and systems - is the problem of uncertainty in the formulation of the original problem. With this the problem is directly related to the normalization of the quality criteria and task priority (importance) for each member of the set criteria.

In some cases, the evaluation of a process or system can be performed using a generalized global quality criterion K (function local criteria K_i). In this evaluation two methods are commonly used.

In the first case, the estimate is reduced to solving a problem with constraints; has two modifications. In the first modification of the whole set of criteria is determined the main criterion K_m. Other criteria K_i $i \neq m$ are limited to the conditions: «not less than» or «not more than». In another modification of the set of criteria can be represented as ordered by the degree of importance of the set, and then consistently estimate quality. Optimality criterion of the whole set of criteria is chosen subjectively.

The second method is to form a global quality criterion as the sum of local, combined with their weights (scalarization, clotting criteria). The effectiveness of the method depends on the degree of objectivity of these constants.

Criteria have different dimensions, therefore is made their normalization. Taking into account the optimum values K_{i0} each of the local criterion and interval deviation $K_i - K_{i0}$. A successful solution to the problem of normalization depends on how accurately the optimal values of the local criteria.

Some applications

The above procedure was used to solve a number of practical problems: traffic safety systems, identification and valuation of risk, objectification of evaluation operator of ergatic transport system technical characteristics of the object in terms of control; the definition of simulation characteristics [3] simulators. Evaluation of simulation characteristics directly related to the problem of the objective quality control simulation facility and reduces to a comparison of control actions in the «operator-object» and «operator-model of the object». Here, a set of indicators characterizing the activity of the operator included:

- keeping accuracy specified parameters of motion, conservation of safe driving modes with equipment failures;
- quality perform additional tasks that are not directly connected with the movement: the reliability of perception, the execution of motor actions, etc .;
- the structure of the collection of information (frequency and duration of fixation, migration routes and the transfer view, discrete perception);
- options mental processes of detection, identification and decision-making;
- parameters defining psychophysiological tension of the operator;
- subjective operator opinions (survey data, interviews).

At present, none of the issues raised above (from the point of view of practical application methods) not solved until the end; are at the level of cognitive modeling. Despite the abundance of publications on the identification of ergatic systems according to the normal functioning of probably the most appropriate decision should be regarded as a particular problem identification using an iterative method. Thus, if a choice of the block diagram of the control object, everything is more or less successfully, then the choice of the block diagram of the human operator and its relation to the object depending on the parameters of the environment and the psycho-physiological condition of the operator is not so. Especially important is a good choice of block diagram. It for each operator of the control channels is represented in the form of three units: first describes the motor (motor) system of the person; other - the formation of a mental image output coordinates; third - "comparing device" of the central nervous system and the formation of control errors.

The greatest difficulties are related to the formalization of the latter. Difficulties in the development of simulators is largely related to the action in the human-machine system organismic principle: the object determines the behavior of the operator. The definition of operator control actions (stabilization program motion without fluctuations in his behavior) is only possible using an iterative procedure. This also applies to the determination of the transfer functions of the object and the operator according to normal operation. Direct identification integrated Human-machine system, because of its closed through a man almost impossible

As some approximation for the transfer function of the object (human involvement in the system is not considered) used generalized transfer function of the system

$$W_c^{ob}(j\omega)=\frac{S_{yx}(j\omega)}{S_{xx}(j\omega)}$$

(determined from simultaneous measurements x and y during normal opera tion). Inputs $x(t)$ include component, correlated with $y(t)$. When $W_c^{ob} \equiv W_c$ ($W_{oc}(p) \equiv 0$) operator manipulates the object with open channel; the opposite is true, if the operator controls with open channel, then $W_c^{ob}(p) \equiv W_c(p)$.

When the preliminary evaluation of the transmission system operator determines the deviation from the set of motion parameters in a fixed time or the maximum deviations on some interval (for example, the deviation from the desired path for manual landing, take-off, maneuver, etc.). The data obtained were built [4,5] functions or density distributions, the defining moments of the distribution (expectation, variance, kurtosis, skewness, etc.). Assessment of quality control in an emergency is determined by the maximum deviation from the nominal values; assesses the likelihood of falling outside the limits of safe values. Is performed correlation and spectral analysis of motion parameters. This made it possible to determine not only the average and standard deviations in maintaining a given parameter $x_i(t)$, but also the degree of vibrational process. To ensure the accuracy of the obtained characteristics used implementation processes of long duration, what is requiring large amounts of computational work. Is made rapid assessment of control (using the mean m_i, standard deviation σ_i, and the degree of vibrational $\aleph_i = \int_0^T x_i^2 dt \Big/ \int_0^T (x_i - m_i)^2 dt$).

Under certain amplitude a_n of the harmonics ω_n in the Fourier series expansion in the interval $[0,T]$ estimation of oscillatory processes taken in the form of:

$$\aleph_i = \frac{\sum_n \omega_n^2 a_n^2}{\sum_n a_n^2}.$$

Integral assessment made by value:

$$\aleph_i = f(x_i)\sqrt{m_i^2 + \sigma_i^2}.$$

Deciding isoperimetric problem of variational calculus, we obtain:

$$\aleph_i = \sqrt{m_i^2 + \sigma_i^2}\left(1 + T_i\sqrt{x_i - \frac{\pi^2}{T^2}}\right);$$

σ_i^2 - predetermined dispersion, $x_{i\,\min} = \frac{\pi^2}{T^2}$, T_i - the transition process in the circuit stabilize a given parameter x_i (when operating in a steady state j-th operator typically maintains no more than three parameters ($i \le 3$ and in level flight - speed, heading, altitude, when the spiral - speed, roll, vertical speed)). In the simultaneous evaluation of control (in all parameters for each of the steady-state modes) used a dimensionless additive global criterion:

$$K_j = \sum_{i=1}^{3} \frac{\aleph_{ij}}{c_{ij}} = \sum_{i=1}^{3} \frac{\sqrt{m_{ij}^2 + \sigma_{ij}^2}}{c_{ij}} \left(1 + \sqrt{x_{ij} - \frac{\pi^2}{T^2}} \right).$$

Note, in fact the choice of values c_i for each exposure of i -th parameter is equivalent to the introduction of the weighting constants (with their inherent elements of this subjectivity).

Conclusion

As experience shows the development of simulators transport systems, to solve multicriteria problem in the analysis and synthesis of complex technical systems it is advisable to use the above approaches.

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