New methods developed for designing dynamic object controllers

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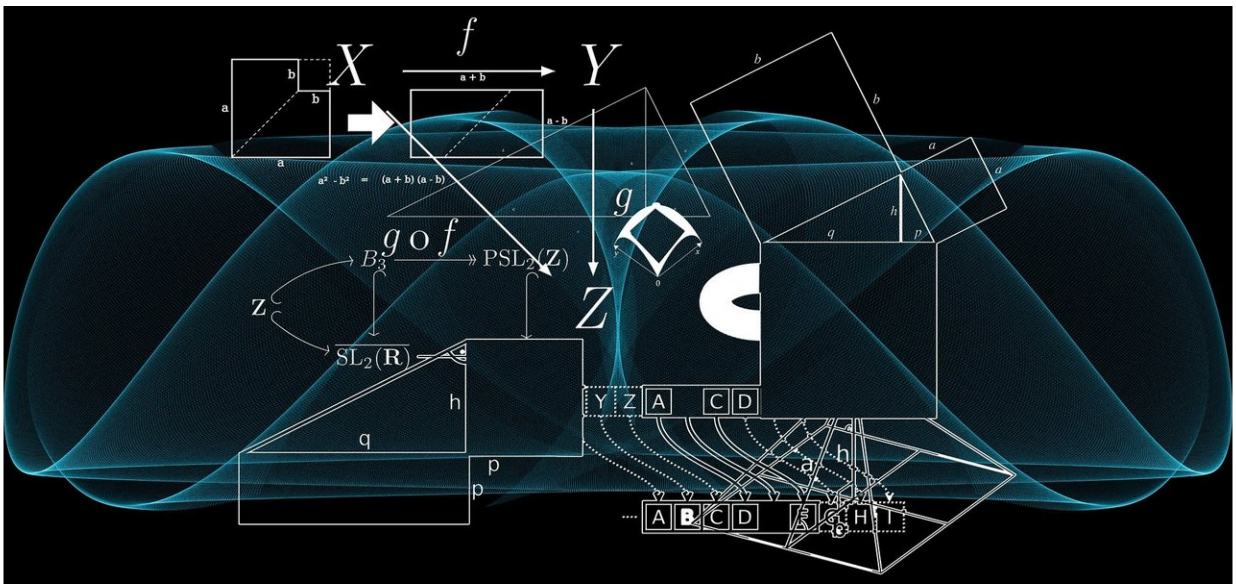

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The words "uncertainty" and "multiple criteria" characterize the relevance and complexity of modern problems related to the control of dynamic objects and processes. In fact, any mathematical model describing complex controlled processes inevitably includes inaccuracies in the description of the perturbations and parameters of the control object. Ignoring such "uncertainty" often leads to fatal errors in the functioning of real control systems.

On the other hand, the requirements for the control system are quite often contradictory, which naturally leads to the formulation of multicriteria problems, which, if successfully solved, eliminate at least those solutions that are obviously "inefficient." It is well known that multicriteria control problems are very difficult to solve. These difficulties acquire a much greater scale when there is an uncertainty in setting the parameters of a system and disturbances; therefore, any progress in the development of the theory and methods for solving such problems is very valuable and relevant both in the theoretical and applied aspects.

According to Dmitry Balandin, chief researcher of the Laboratory of Information Systems and Technical Diagnostics, professor of the Department of Differential Equations, Mathematical and Numerical Analysis at the UNN Institute of Information Technologies, Mathematics and Mechanics, the main result of the work performed by his research team consists of developing new methods for designing dynamic object controllers in the form of feedback. These methods have been developed on the basis of modern achievements of control theory, the theory of linear matrix inequalities and the theory of convex optimization.

"The object of our investigation is a system of ordinary differential or difference equations describing the dynamics of the object under study. It is assumed that the dynamic object is subject to various types of external effects. In particular, they may include the effects represented by arbitrary square integrable vector functions of time, the effects of random nature that are described as Gaussian white noise with an unknown covariance matrix, pulsed effects with an unknown impact intensity, harmonic effects with an unknown frequency and amplitude," says Balandin.

The aim of the control is to design a feedback (either from the measured state or from the measured output), which provides the quenching of the disturbance arising in the system and generated by these effects. The quality indicators of transient processes, further referred to as disturbance quenching levels, are determined for each class of external effects and are the maximum (for all effects from a given class) of the ratio of the norm of the system controlled output to the norm of the external effect. The natural tendency of improving the transient processes leads to optimal control problems consisting in minimizing the disturbance quenching levels.

Some simple examples show that the control law that minimizes the level of quenching for one class is far from being the best for another class. Thus, for example, the control providing the best quenching of a disturbance generated by periodic effects differs significantly from the control laws that ensure the quenching of a disturbance generated by shock effects. Thus, the problem arises of finding a compromise in the synthesis of the control laws for the object that is subject to effects from various classes. This problem is essentially a multi-criteria control problem.

In the optimization theory, multi-criteria problems, even in a finite-dimensional formulation, are traditionally very hard to solve. This is even more true for multi-criteria optimal control problems, and setting multi-criteria control problems with the account of uncertain factors further complicates the problem. In recent decades, significant progress has been made in solving optimal control problems with criteria that have clear physical interpretations in the form of quenching levels for deterministic or stochastic disturbances from different classes. However, the treatment of multicriteria problems with these criteria still causes considerable difficulties. These difficulties are due, in the first place, to the complexity of characterizing the Pareto set and finding the corresponding scalar multi-objective function that would determine this set.

It also turns out that the problem is even more complicated, since each of the criteria is characterized by its quadratic Lyapunov function, and the scalar optimization of the multi-objective function in the form of a standard linear convolution leads in the general case to a hardly solvable bilinear system of inequalities with respect to the matrices of these Lyapunov functions and the feedback matrix of the regulator. To construct an approximate solution of such a system, as a rule, an additional condition of the equality of all the Lyapunov functions among themselves is imposed, which introduces a certain deal of conservatism into the problem. Until now, the main question has remained unanswered: To what extent do the resulting control laws differ from the Pareto optimal ones?

In their latest publications, Lobachevsky University scientists, in co-authorship with their colleagues from the Nizhny Novgorod State University of Architecture and Civil Engineering, answered this question and provided numerical estimates of the deviation of suboptimal solutions in multicriteria problems from Pareto optimal ones, and also give new exact Pareto optimal solutions for some types of criteria.

An important application considered in the recent papers is the problem of controlling the motion of a rotor in active magnetic bearings (AMB). The idea of controlling the magnetic field to suspend ferromagnetic bodies has long been widely applied in modern technical devices, especially in rotor systems. Theoretical and applied studies in this field have a history of several decades in Russia and abroad.

In Nizhny Novgorod, theoretical and applied research in the field of rotor systems with active magnetic bearings for many years has been conducted at the Research Institute of Applied Mathematics and Cybernetics of the Lobachevsky University and at the Afrikantov OKBM.

Despite the great number of publications on active magnetic bearings, the issues of improving the automatic control system for AMB remain in the focus of attention of researchers and engineers. The technical requirements for such systems are extremely demanding, the main of them being the high rotor speed and unattended trouble-free operation of the system "rotor in active magnetic bearings" for quite a long time.

To ensure that these requirements are met, it is necessary to significantly improve the system reliability, which is only possible by greatly simplifying the control algorithms in the AMB. Mathematically, this problem is formulated as a multicriteria optimal control problem, where the criteria reflect various, sometimes conflicting requirements to the reliable operation of the control object.

"As a result of applying the above theory, it was possible to synthesize new laws governing the motion of the rotor in active magnetic bearings to ensure reliable operation of the system when rotor parameters and disturbances acting on the rotor are not precisely known," concludes Professor Balandin.

More information: D. V. Balandin et al, Multicriteria Robust Generalized H2 and γ0 Controllers with Application to Stabilization of a Rotor in Electromagnetic Bearings, *Automation and Remote Control* (2018). DOI: 10.1134/s0005117918060024

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