ISSN NO: 2770-0003
Date of Publication: 26-03-2022

Synthesis of Nonlinear Automatic Systems

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Abstract. Modern technical systems, as a rule, operate in essentially nonlinear modes, are multicomponent and are described by a large number of state variables. When synthesizing regulators for such systems, one has to face a lack of available control strategies and analysis methods. Traditional (developed for linear systems) methods of design and analysis, when faced with non-linearities, in most cases turn out to be untenable. The theory of designing nonlinear regulators is still under development. Individual methods are very "fragmented", they focus on their own rather narrow class of systems and have individual limitations that do not allow them to be considered from a single point of view.

In this regard, it is very difficult to create a more or less universal algorithm for the automated synthesis of control systems for nonlinear objects. At the same time, the requirements for automatic control systems are constantly growing. All these circumstances, as well as the complexity and wide ranges of changes in the characteristics of the regulatory objects used, make it necessary to search for new widely applicable methods and means of building control systems.

Nonlinear systems have been the subject of research for quite a long time. First of all, it should be noted the work of Russian scientists N.M. Krylov, H.H. Bogolyubov and A.A. Andronov, who created methods for solving a wide class of nonlinear differential equations, on the basis of which many methods of designing automatic control systems were subsequently developed. The works of such scientists as A.F. Filippov, E.A. Leontovich, H.H. Bautin, J. Palis, V. Di Melu, M. Kholodniok and others were devoted to nonlinear systems.

Since the 90s of the XX century, there has been an even more noticeable increase in interest in research in the field of nonlinear systems theory in the world scientific literature, in particular, in the field of nonlinear dynamics of physical and technical systems and nonlinear control theory. For example, at the XIII World Congress of the IFAC (International Federation for Automatic Control), held in San Francisco in 1996, the share of meetings of participants devoted to these aspects was 13%, which exceeded similar figures (5% and 6%) for the two previous congresses (1990 and 1993) combined. The number of monographs published on this subject abroad only in the 90s has reached several dozen and continues to grow now.

In connection with the development and widespread introduction of electronics, systems containing key elements with pronounced nonlinearity inherent in them have recently acquired special importance. Power supplies, drives, various electromechanical actuators, etc. have penetrated into all industries. All of them belong to the class of systems with a variable structure (SPS). This class is characterized by its own behavioral features and methods of analysis. Generally speaking, ATP from the point of view of operating modes can be considered as a generalized class of systems, since they are a combination of switchable systems of other types, i.e., in the simplest case, they can be completely limited to a single system.

A large number of works have been devoted to the study of ATP. Among the early publications on this topic, the works of E.A. Barbashin, I. Flugge-Lotz, Bigot, Fossar occupy an important place. C.B. Yemelyanov was one of the first to carry out a general analysis of the principles of the construction of the ATP from a single position. In his works, a study of various modes of operation of the ATP was carried out, important features and advantages of systems of this class were identified, and methods for synthesizing controls for objects operating under conditions of continuously operating external disturbances were described. However, C.B. Emelyanov noted that the practical use of the ATP methods is largely hampered by the large dissociation of the theoretical results published on this topic. This fragmentation has not been fully overcome so far, despite the fact that the theory of ATP has become more orderly.

V.I. Utkin made a very significant contribution to the study of the principles of construction and methods of synthesis of ATP. He developed a mathematical apparatus for the study of discontinuous dynamical systems and considered various cases of its application. V.I. Utkin paid the main attention in his

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works to control and optimization systems with discontinuous control actions operating in the so-called sliding modes, which have a number of very attractive properties and have now turned out to be the main modes of operation of the ATP. V.I. Utkin conducted quite fundamental research and found solutions for a wide range of tasks. However, it should be noted that sliding modes are not the only possible type of movements in the ATP, and it is not always possible to organize work in such modes. Other modes of operation have their own advantages, and neglecting them can deprive the designed system of certain useful qualities, or make it impossible to build a workable system that meets the specified requirements. Since in the research of V.I. Utkin considers exclusively sliding modes, the algorithms obtained by him are quite difficult to use for the synthesis of control strategies using a combination of different types of movements.

Interest in the ATP has not weakened so far, and research in this area is being conducted quite intensively. In this regard, the works of K.D. Yang-ga, Yu. Stepanenko, A.S.I. Zinobera, A.D. Koshkui, Chun-Yi Su, P. Matavelli, J. Spiazi, etc. can be noted.

With the development of computer technology, developers and engineers have received the means to overcome the difficulties associated with taking into account non-linearities. It has become possible to create complex high-quality control systems based on numerical methods for studying nonlinear systems without the use of linearization. However, despite advances in computer technology, nonlinear systems are still quite difficult to analyze and synthesize. First of all, this is due to the lack of design techniques that take into account the features of non-linearities, and the lack of appropriate software tools that allow full use of the performance of modern computing systems. Most techniques are still reduced to iterative procedures for modeling the behavior of the system by numerical methods. At the same time, it is often necessary to face the lack of strictly formulated criteria for the optimality of the designed systems, and the main role in decision-making in this process is assigned to a human expert. The resulting regulators can be called specialized, they are not universal, suitable only for specific conditions (control objects) and require a lot of time and human effort.

The first attempts to automate the process of designing nonlinear control systems were made by foreign scientists F. Zhao, C.S. Su, T. Nishida, K. Mizutani, E. Sachs, W. Lee, D.B. Kuipers and others. Anyway, all of them were based on the use of geometric analysis of phase portraits or spaces and have a common drawback -poor adaptability to work with high-order systems. Most of these techniques are focused exclusively on two-dimensional systems, while others face difficulties due to the increase in computational complexity when processing significant data arrays for multidimensional phase spaces. In addition, none of the methods takes into account sliding modes, which are a very important type of movement in the ATP, without which the capabilities of such systems are significantly reduced.

So, there are still no general universal methods for studying nonlinear systems - the variety of nonlinearities is too great. Effective methods of analysis and synthesis have been developed only for certain types of nonlinear systems. Thus, the search for systematized and automated methods of analysis and synthesis of nonlinear systems is a very urgent task, which is currently not fully solved

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