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REVIEW

of a member of the dissertation council on the dissertation of Nikolay Nikolaevich Litvinov on the topic "Construction of control algorithms for nonlinear controlled systems", submitted for the degree of candidate of physical and mathematical sciences in specialty 2.3.1. System analysis, control and information processing, statistics.

Relevance of the research topic.

The dissertation is devoted to one of the important areas of development of mathematical control theory related to the study of issues of transferring controlled systems of ordinary differential equations from the initial state to a given final state for various classes of control functions. This class of problems is called boundary value problems for controlled systems. Boundary value problems for controlled systems have been studied quite well for linear and nonlinear systems of a special type. However, the theory of solving boundary value problems for nonlinear systems of a general type has not yet been sufficiently developed. On the other hand, algorithms for solving boundary value problems can be used in the creation and modeling of autonomous intelligent control systems for robotic manipulators, unmanned aerial vehicles. unmanned surface and underwater vehicles, as well as other mobile objects. In view of the above, the relevance of the topic of the dissertation research is beyond doubt.

Contents of the work.

The dissertation consists of four chapters, a conclusion, a list of references and two appendices. The volume of the work is 104 pages, the list of references includes 82 sources.

The introduction substantiates the relevance of the dissertation topic, provides a fairly detailed excursion into the history of the development of the theory of boundary value problems for controlled systems of ordinary differential equations, and formulates the goals and objectives of the dissertation. The theoretical and practical significance of the obtained results and their reliability are confirmed. In addition, a list of publications on the topic of the dissertation and information about its testing are provided.

In the first chapter, the object of study is a nonlinear non-stationary system of ordinary differential equations with limited control. A method has been developed for constructing a discrete control function that ensures the transfer of the system from the initial state to the origin. A constructive sufficient condition has been found under which this transfer is possible. Estimates of the reachability domain and the discreteness step have been obtained. The second chapter is devoted to the analysis of the computational complexity of the discrete control algorithm, numerical modeling of various control

options for a robot manipulator using the discrete control algorithm. The constructed algorithm is also compared with the optimal control method.

The third chapter proposes a method for constructing a differentiable control function that guarantees the transfer of a wide class of nonlinear stationary systems of ordinary differential equations from the initial state to the origin in such a way that one of the corresponding functions of the phase coordinates is in the form of a known polynomial. The latter circumstance allows one to control the accuracy of the computational process and the proper functioning of computing systems. A Kalman-type condition is found that guarantees the specified transfer. An estimate of the reachability region is obtained. The efficiency of the algorithm is demonstrated using numerical modeling of the interorbital flight problem.

The fourth chapter is devoted to solving the problem of optimal control of ODE systems that describe arrays of identical and non-identical Josephson junctions, numerical modeling and analysis of the dynamics of these models in the presence of control. The appendices present the program code for solving problems of discrete and optimal control of a robot manipulator.

Main scientific results:

1. Algorithm for constructing piecewise constant control functions that ensure the transfer of an ODE system from the initial state to a given final state for a sufficiently wide class of nonlinear nonstationary systems over a finite time interval.

2. Algorithm for solving a boundary value problem for a nonlinear stationary system taking into account the control of computing complexes.

3. Finding constructive sufficient conditions that ensure the transfer of a nonlinear stationary system to the origin from a certain neighborhood of the origin in the class of continuous and discrete controls.

4. A package of applied programs for solving discrete control problems in the Python programming language.

5. Solution of the problem of optimal control of arrays of identical and non-identical Josephson junctions.

Theoretical and practical significance of the work. The dissertation develops new methods for solving boundary value problems for controlled systems of ordinary differential equations, which are of independent scientific interest and can be used in the design of autonomous control systems for various mobile objects.

The reliability of scientific results is confirmed by the correct use of the mathematical apparatus and the results of numerical modeling of the obtained algorithms in solving specific practical problems. The presented conclusions were tested during presentations at scientific conferences. Litvinov N.N. published 5 scientific papers.

Conclusion.

The dissertation of Litvinov Nikolay Nikolaevich on the topic: "Construction of control algorithms for nonlinear controlled systems" meets the basic requirements established by Order dated 11/19/2021 No. 11181/1

"On the procedure for awarding academic degrees at St. Petersburg State University", applicant Litvinov Nikolay Nikolaevich deserves to be awarded the academic degree of candidate of physical and mathematical sciences in specialty 2.3.1. Systems analysis, management and information processing, statistics. Violations of paragraphs 9 and 11 of the specified Procedure were not found in the dissertation.

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