

ABSTRACT

on the dissertation on the topic: "Development of algorithms and control programs for unmanned aerial vehicles", PhD student in the specialty "8D07116 – Intelligent control systems", Mazakova Aigerim

The dissertation is devoted to the development of algorithms and control programs for unmanned aerial vehicles of the aircraft type.

Relevance of the dissertation. In recent decades, there has been significant progress in the development and application of unmanned aerial vehicles (UAVs) to solve various problems. Currently, attention is shifting to the potential use of unmanned aerial vehicles in various areas of civil application, such as emergency situations, natural disasters and communications.

This is due to several reasons. Firstly, UAVs are usually cheaper to operate compared to traditional manned aircraft. They are also easier to maintain and can provide long periods of flight. In addition, they are capable of operating in conditions of limited visibility and darkness, making them a valuable resource in emergency situations, when pilot participation may be dangerous.

An important aspect of using UAVs is their control. Currently, many missions are carried out using remote control, which is often limited by the quality of communication and weather conditions. Therefore, methods for increasing the autonomy of these devices are currently being actively developed.

One of the key areas of research is the development of automatic flight control algorithms that will allow UAVs to carry out missions without human intervention. This requires the creation of methods and algorithms for constructing trajectories that take into account the environment in real time.

The complexity of the UAV control task is due to many factors, including the dimensionality of mathematical models, as well as the need for continuous data on motion parameters to make optimal decisions.

Thus, the development of mathematical models, control algorithms and the study of UAV controllability are important areas of work that are highly relevant.

The purpose of the dissertation is to develop algorithms for studying the controllability of UAVs, analyzing mathematical models of dynamics, as well as finding optimal control solutions. To achieve this goal, the following tasks are solved in the work:

- 1) Study of a mathematical model of UAV dynamics.

- 2) Development of a UAV controllability criterion.
- 3) Development of algorithms for finding optimal UAV control.
- 4) Creation of software for determining controllability and calculating optimal control.
- 5) Development of an algorithm for controlling a group of UAVs.

The scientific novelty of the work is manifested in the following aspects:

- obtaining a new controllability criterion for unmanned aerial vehicles based on the application of interval mathematics methods;
- automation of testing the stability of UAV dynamics based on the application of computer algebra using interval mathematics;
- development of an algorithm for selecting the optimal flight path based on the penalty function method;
- creation of an algorithm for distributing targets between a group of UAVs.

The research methods used in the work include interval mathematics, numerical analysis, controllability and optimal control theory, as well as modern design and software development systems.

The object of the study is the UAVs themselves, and the subject of the study is mathematical models and algorithms for determining controllability and optimal control over them.

The practical significance of the work lies in the possibility of using the developed algorithms both for controlling single UAVs and for controlling a group of such devices.

The scientific significance of the work is manifested in the creation of new controllability and stability criteria based on interval mathematics, as well as in the development of optimal control algorithms for UAVs.

The scientific provisions, conclusions and recommendations presented for defense are supported by the correct use of the mathematical apparatus, the correct setting of experiments and their processing, as well as the correspondence of the results of theoretical studies and experimental data. The reliability of the conducted research is confirmed by proven theorems and numerical calculations on model problems.

Connection of the topic with the plans of scientific research programs

The dissertation work was carried out in accordance with the calendar plan of scientific research grant works on priority: 4. Information, telecommunication and

space technologies on subpriority: 4.1 Artificial intelligence and information technologies: 4.1.1 Intelligent control and decision-making systems (including in real time) on the topic of the project: AP19678157 "Development of a software and hardware complex for monitoring the state of the reservoir filling level" of Al-Farabi Kazakh National University.

The structure of the dissertation includes an introduction, 5 sections, a conclusion, a list of references and appendices.

The introduction provides a justification for the relevance of the chosen topic of the dissertation. The purpose, object, subject and objectives of the research work are formulated. The results of the studies are described, their scientific novelty and practical significance are shown. Data on the testing of the main results of the dissertation are provided.

The first section analyzes the global flow of scientific papers in this area, which allows us to see an objective picture of the development of this scientific area and assess its relevance and potential applications. Domestic and foreign achievements in the field of UAV development and application are noted. The statement of the problems studied in the dissertation is given.

The trends in the development of modern technologies for the development and practical application of UAVs are identified, which proves the relevance of scientific research in this area.

The second section is devoted to the analysis of existing solution methods and the formulation of the problem of controllability of an autonomous UAV flight. A general description of the problem and the statement of research objectives are given. The problem is analyzed and the main problems that may arise during its solution are identified. The advantages and disadvantages of the described methods are highlighted.

Based on the application of interval mathematics, a criterion for UAV controllability is obtained. A program has been developed that allows for effective verification of controllability conditions.

The third section is devoted to the analysis of conditions that ensure the stability of the selected trajectory of the autonomous flight of the UAV. A program has been developed that allows for effective verification of stability conditions.

The fourth section is devoted to determining the optimal control for an autonomous UAV flight. A program has been developed that allows finding optimal control for an UAV flight.

The fifth section is devoted to the development of an algorithm for distributing targets between a group of UAVs.

The conclusion presents the main results and findings of the dissertation.

Approbation of the work. The results of the dissertation were presented at international scientific conferences, annual scientific conferences of the Institute of Computing and Information Technologies, scientific conferences of young scientists and specialists of the Kazakh National University, as well as at scientific seminars of the Department of Artificial Intelligence and Big Data of Al-Farabi Kazakh National University. This made it possible to discuss and test the obtained results in the scientific community, as well as receive feedback and additional recommendations from colleagues and experts.

In addition, an internship abroad was conducted, which contributed to the exchange of experience with researchers from other countries, deepening knowledge in the field of research and expanding international scientific contacts (Appendix A).

It is important to note that the results of the work were recognized and were formalized in 17 certificates of state registration of rights to an object of copyright (Appendix B). This confirms the originality and significance of the research.

Publications. On the topic of the dissertation, 22 printed works were published, including 6 in publications recommended by the Committee for Control of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, 9 works in a journal included in the international citation database "Scopus" (confirmed by a certificate from JSC NCGNTE on the presence of a publication in a journal included in the Scopus database – Appendix C). The h-index in "Scopus" is 3.

Scientific publications:

1. Mazakova A., Jomartova S., Mazakov T., Shormanov T., Amirkhanov B. Controllability of an unmanned aerial vehicle //2022 IEEE 7th International Energy Conference (ENERGYCON), Riga, Latvia. – 2022. – P. 1-5. doi: [10.1109/ENERGYCON53164.2022.9830244](https://doi.org/10.1109/ENERGYCON53164.2022.9830244)
2. Mazakova A., Jomartova S., Wójcik W., Mazakov T., Ziyatbekova G. Automated Linearization of a System of Nonlinear Ordinary Differential Equations // INTL Journal of Electronics and Telecommunications. – 2023, vol. 69, N 4. – P. 655-660. doi: 10.24425/ijet.2023.147684.
3. Mazakova A., Jomartova Sh., Mazakov T., Brzhanov R., Gura D. The Use of Artificial Intelligence to Increase the Functional Stability of UAV Systems //

International Review of Aerospace Engineering (IREASE). – 2024, vol 17, № 3. – P.98-106. doi: <https://doi.org/10.15866/irease.v17i3.25067>

4. Mazakova A.T., Jomartova Sh.A., Mazakov T.Zh., Ziyatbekova G.Z., Dosanaliyeva A.T. Automation of the linearization process of a nonlinear model described by ordinary differential equations // Bulletin of KazUTB. – Astana. – 2023, No. 1 (18). – P.7-23.

5. Mazakova A.T., Jomartova Sh.A., Mazakov T.Zh., Toikenov G.Ch., Aliaskar M.S. Parametric stability of an unmanned aerial vehicle // Bulletin of KazUTB. – Astana. – 2024, No. 3 (24). – P. 43-51.

6. A.T. Mazakova, Sh.A. Jomartova, T.Zh. Mazakov, G.Ch. Toikenov, M.S. Aliaskar. Optimal Control of An Unmanned Aerial Vehicle // Bulletin of KazUTB. – Astana. – 2024, No. 3 (24). – P. 64-71.

Certificates of entering information into the state register of rights to objects protected by copyright:

1. Certificate No. 45318 dated May 2, 2024 "Determination of UAV stability" (computer program), authors: Mazakov A.T., Mazakov T.Zh., Jomartova Sh.A.

2. Certificate No. 45324 dated May 2, 2024 "Determination of UAV controllability" (computer program), authors: Mazakova A.T., Mazakov T.Zh., Jomartova Sh.A.

3. Certificate No. 45572 dated May 10, 2024 "Determination of optimal control of UAV" (computer program), authors: Mazakova A.T., Jomartova Sh.A., Mazakov T.Zh.