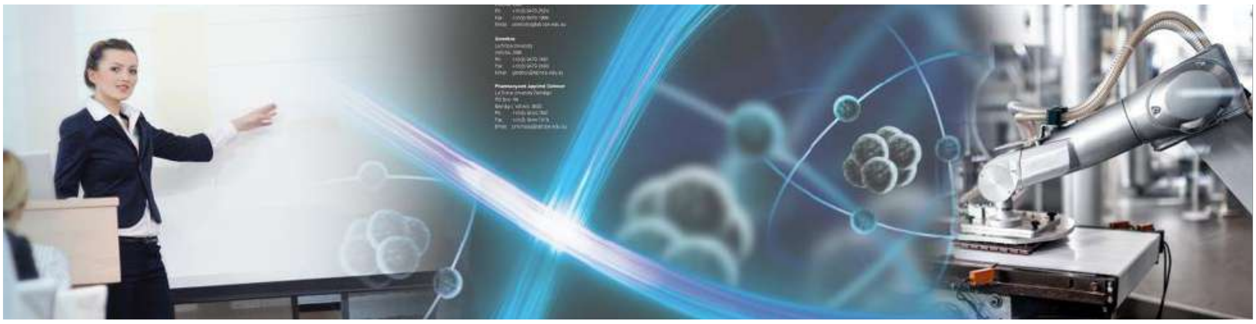
Міністерство освіти і науки України

Харківський національний університет радіоелектроніки

Кафедра комп'ютерно-інтегрованих технологій, автоматизації та робототехніки

VIII Міжнародна Конференція
ВИРОБНИЦТВО
&
МЕХАТРОННІ СИСТЕМИ 2024



VIII International Conference
MANUFACTURING
&
MECHATRONIC SYSTEMS 2024

M&MS

2024

VII International Conference

25-26 October

Kharkiv

M&MS 2024, 25-26 October, Kharkiv, Ukraine

УДК: 005:004.896:62-65:338.3

Виробництво & Мехатронні Системи 2024: матеріали VIII-ої Міжнародної конференції, Харків, 25-26 жовтня 2024 р.: тези доповідей / [редкол. І.Ш. Невлюдов (відповідальний редактор)].-Харків: [електронний друк], 2024. – 135 с.

У збірник включені тези доповідей, які присвячені сучасним тенденціям розвитку технологій та засобів виробництва та мехатронних систем, передовому досвіду та впровадженню їх в галузях систем промислової автоматизації та керування виробництвом; системній інженерії; CAD/CAM/CAE системах; мехатроніці (електро-механічних системах, електронних інструментах систем керування, механічних CAD системах); робототехніці та засобахм інтелектуалізації; MEMS (сучасних матеріалів та технологіях виготовлення MEMS) та компонентах і технологіях автоматизації видобутку, переробки та транспортування нафти та газу.

Manufacturing & Mechatronic Systems 2024: Proceedings of VIII st International Conference, Kharkiv, October 25-26, 2024: Thesises of Reports / [Ed. I.Sh. Nevlyudov (chief editor).] .- Kharkiv .: [electronic version], 2024. - 135 p.

The collection includes the thesises of reports on modern trends in the development of technologies and means of production and mechatronic systems, top experience and implementation of them in fields of: industrial automation and production management systems; systems engineering; CAD/CAM/CAE systems; mechatronics (electrical and mechanical systems, electronic control tools, mechanical CAD systems); robotics and intellectual toolls; MEMS (modern materials and manufacturing technologies MEMS) and components and technologies for the automation of oil, gas and oil extraction, processing and transportation.

Міністерство освіти і науки України (МОНУ)
Харківський національний університет радіоелектроніки (ХНУРЕ)
Варшавський університет сільського господарства (WULS - SGGW)
Азербайджанський державний університет нафти і промисловості
Національний університет «Львівська політехніка»
Festo Didactic Україна
Jabil Circuit Ukraine Limited
ТОВ «Науково-виробниче підприємство «УКРІНТЕХ»»
Факультет автоматики і комп’ютеризованих технологій (АКТ)
Кафедра комп'ютерно-інтегрованих технологій, автоматизації та робототехніки (КІТАР),
Державне підприємство «Харківський науково-дослідний інститут технології машинобудування»
Державне підприємство «Південний державний проектно-конструкторський та науково-дослідний інститут авіаційної промисловості»

МАТЕРІАЛИ

VIII-ої Міжнародної Конференції

ВИРОБНИЦТВО & МЕХАТРОННІ СИСТЕМИ 2024

(25-26 жовтня 2024)
Харків, Україна

ЗМІСТ

Basic principles of building aerial robots

Igor Zarubin, Svetlana Sotnik

Department CITAR, Kharkiv National University of Radio Electronics, Ukraine,
Kharkiv, av. Nauki. 14., email: svetlana.sotnik@nure.ua

Anotation: The study covers key principles of building aerial robots, including those related to construction, aerodynamics, navigation and data acquisition systems. The focus is on integration of modern technologies, such as sensors, GPS modules, and specialized software, which ensure efficient task performance in challenging environments. The paper analyzes benefits of implementing intelligent control systems, including algorithms for automatic route planning, flight correction, and obstacle detection. Particular attention is paid to the aerodynamic design of the body and choice of materials that ensure lightness, durability, and resistance to external factors such as wind, rain, and high temperatures. The study offers practical examples of implementation of design principles on example of modern agricultural aerial robots used for monitoring and data collection. A critical analysis of design and operational challenges provides deep understanding of potential of these technologies. Visual elements of work contribute to better understanding of complex technical solutions.

Key words: aerial work, design, aerodynamics, navigation, sensors, data collection.

I. INTRODUCTION

In today's world, aerial robots (drones) have become indispensable tools for performing wide range of tasks, from environmental monitoring to data collection for agriculture. The fundamental principles of their construction determine their effectiveness and reliability in executing tasks, particularly in complex and often unpredictable conditions. Developing aerial robots requires comprehensive approach that includes both engineering solutions and the integration of advanced technologies [1-7].

The design of aerial robot is crucial for ensuring its stability and maneuverability. Key aspects include selection of materials for chassis, which must provide necessary strength and lightness, as well as aerodynamic shape, which affects flight efficiency. Navigation and control systems, including sensors and management algorithms, play a vital role in ensuring accuracy and autonomy. The integration of advanced technologies, such as GPS modules, LIDAR, and various sensors, ensures high precision in data collection and adaptability to changing conditions.

This work explores fundamental principles of aerial robot construction, including their design, material selection, aerodynamic characteristics, and modern navigation and data collection systems. Practical examples of these principles in contemporary models used for various tasks, such as agronomic monitoring and mapping, are examined. This research provides better understanding of how technical and technological aspects impact the effectiveness and reliability of aerial robots, as well as the challenges faced by developers in this rapidly evolving field.

Automation is an ever-present topic in development of aerial robots, as it provides increased task efficiency and adaptability to changing conditions. Thanks to automated control and data collection systems, drones can perform complex tasks with minimal human intervention, making them indispensable in many areas of activity [8, 9].

II. THE ROLE OF BASIC COMPONENTS AND TECHNOLOGIES IN CONSTRUCTION OF AERIAL ROBOTS

In modern design of aerial robots, role of various components and technologies is critical to ensure efficiency, reliability, and functionality of devices. Different design elements and technological solutions not only determine technical characteristics of robots, but also affect their ability to perform complex tasks in real world. The table below provides detailed overview of key components and technologies that play important role in design and operation of aerial robots.

Table 1. The role of main components and technologies in construction of aerial works

Component/ Technology	Role in construction of aerial robots
Body and frame	Ensuring strong and lightweight design for optimized aerodynamics.
	Use of modern materials to reduce weight and increase durability.
Management systems	Flight control and stabilization using GPS and inertial measurement units (IMU).
	Intelligent algorithms for autonomous control and navigation.
Engines and propellers	Impact on maneuverability and flight efficiency. Selection of engine and propeller types.
	Aerodynamic characteristics for optimal lifting power.
Energy systems	Selection of power sources to ensure long flight time.
	Optimize energy efficiency and reduce battery weight.
Sensors and cameras	Expanding data collection and environmental monitoring capabilities.
	Integration of sensors to collect information and improve autonomy functions.

III. THE PROCESS OF DESIGNING AERIAL ROBOTS USING MODERN TECHNOLOGIES

The design process for aerial robots is complex and multi-stage, involving numerous steps and technologies to maximize efficiency and reliability. Modern technologies, such as computer-aided design, simulation, data-driven optimization, and intelligent systems integration, play critical role in each stage of design process. The concept of design process is shown in Fig. 1.

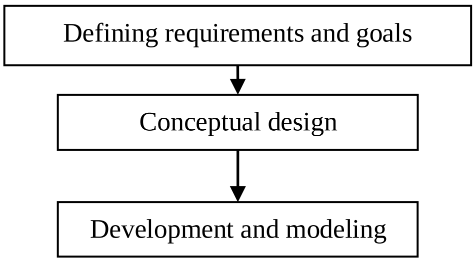


Fig. 1. Design process concept

At «Define Requirements and Objectives» stage, main functions to be performed by aerial robot (e.g., surveillance, data collection, monitoring) are established.

The target characteristics can be presented in form of defining technical parameters, such as maximum flight altitude, duration of operation, maximum payload. Assessment of operating conditions should be made, namely:

1. Environment analysis. Evaluation of environment in which robot will be used (e.g., urban environments, agricultural lands).

2. Protection requirements Determination of protection requirements against weather, dust, and other factors.

The «Conceptual Design» phase should consider development of concepts, ideas, technologies and materials. Decisions need to be made to determine type of structure (quadcopter, hexacopter, flying drone) according to objectives, and basic aerodynamic characteristics need to be developed to optimize lift and stability. Responsible consideration should be given to selection of lightweight and strong materials, such as carbon fiber or composites, to increase strength and reduce weight, and to consider opportunities to integrate latest technologies, such as brushless motors and high-performance sensors.

3. The final stage of design process is called development and modeling, during which CAD system is used to create 3D models, i.e. to develop detailed models of structure using computer simulation for accurate planning of all elements, analysis and verification (checking model for compliance with technical requirements and operating conditions). After these steps have been completed, we move on to design optimization.

The process of design optimization based on testing Fig. 2.

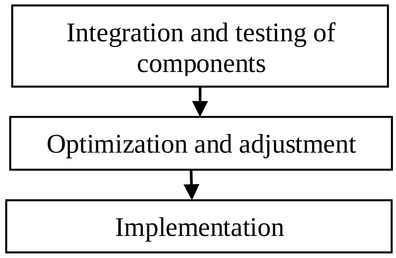


Fig. 2. Design optimization process based on testing

1. Integration and testing of components. The choice of sensors for navigation, such as GPS, barometers, or LiDAR, helps robot better understand its location and environment, just as transformers help systems recognize context of query. Video surveillance cameras can be selected with high resolution and night vision capabilities to ensure accurate data collection, and installing motors, sensors, and cameras according to designed model ensures that robot will have all necessary functions and capabilities. This includes correct placement of components to ensure optimal stability and flight efficiency. Testing involves ground and flight tests to verify operation of control systems, integration of components and their interaction, and to identify any problems before conducting flight tests. Flight tests, in turn, evaluate flight efficiency, stability, and accuracy of robot's control in air. This helps to identify and correct any problems that may arise in real-world use.

2. Optimization and control is broken down into several steps, such as: collecting data on robot's performance, including flight time, sensor performance, and stability, is critical for further analysis and adjusting system design performance assessment based on information obtained. If necessary, design and component changes are made based on results of analysis and testing to improve overall performance and reliability of aerial robot. Machine learning models can help adapt the system to different flight conditions and improve overall performance of robot.

3. The implementation stage also includes several points, namely:

- final testing. Conformance checks and final tests to confirm that robot meets all technical requirements and can operate in real-world environments. Final testing includes checking all systems and components and ensuring that quality standards are met before going into mass production;
- preparation for production. Includes setting up production processes, ensuring required quality standards and preparing production facilities.
- implementation. Launching aerial robot in real-world conditions to test its functionality and reliability in actual use, supervising the robot's operation and ensuring its efficient operation, identifying and eliminating any problems that may arise during use;
- user training. Conducting training for operators and technicians on use of aerial robot, its setup and maintenance, providing support to users to resolve any issues or problems that may arise during operation.

This approach provides clear picture of designing and implementing aerial robots process, with emphasis on importance of each stage and its role in ensuring robot's efficiency and reliability.

IV. TECHNOLOGY AND INNOVATION

In today's world, where technology is evolving at incredible pace, innovations in development and use of aerial robots are becoming critical to improving their efficiency and functionality. Continuous progress in aerospace technology, computing, and materials science opens up new opportunities for improving aerial robots, which significantly expands their capabilities and reduces limitations they face.

This section is dedicated to analyzing advanced technologies and innovations that affect design, manufacture, and operation of aerial robots. We will review latest advances in areas such as sensor technology, control systems, data processing algorithms, materials and structures, as well as latest approaches to automation and artificial intelligence. Special attention will be paid to how these innovations contribute to accuracy, reliability, and efficiency of aerial robots, as well as benefits they provide in practical applications such as environmental monitoring, agronomic research, and more.

The purpose of this section is to present current technologies underlying development of new models of aerial robots and to assess their impact on future trends and opportunities in this dynamic and promising industry. The presentation of latest technologies and innovations can be seen in Table 2.

Table 2. Technologies and innovations in aerial robot development

Section	Subject	Description
1. Technologies and innovations	Sensor technologies	Modern sensor technologies used to ensure accurate navigation, environmental monitoring, and task completion.
The development of sensory systems	High-resolution cameras	Innovative cameras provide detailed images and video, including thermal imagers and variable focus cameras.
LiDAR and its application	Laser systems for distance detection	LiDAR systems create 3D maps of terrain using laser pulses. The latest technologies ensure high accuracy and speed of data collection.
Integration of sensor data	Processing data from different sensors	Integration of data from cameras, LiDAR, and other sensors to obtain comprehensive information.
2 Control and automation systems	Development of management systems	Control systems include powerful processors and specialized software for data processing and robot control.
Autonomous systems	Autonomous route planning and obstacle avoidance	Innovative AI algorithms allow robots to make decisions and perform tasks without human intervention.
Extended use of AI	Intelligent algorithms for object recognition	AI algorithms are used for object recognition, route planning, and flight control.
Programmable systems	Specialized platforms for software development	Programmable systems allow you to customize robot's operating parameters and use specialized programming languages.
3. Materials and structures	Newest materials	Using composites and nanomaterials to create lightweight and durable structures.
3D printing and its application	3D printing technologies for manufacturing parts	3D printing allows you to quickly produce parts and components, reducing costs and providing flexibility in design.
Aerodynamic structures	Modeling of aerodyne mic characteristics	Use of simulations to optimize wing and body shapes to ensure flight efficiency.
Innovations in power supply systems	Increased battery capacity and charging speed	Developing new types of batteries and power sources, such as solid-state batteries and supercapacitors, to improve energy efficiency.
4. Automation and data processing	Process automation	Reduce need for manual intervention by automating flight planning and data collection.
Big data processing [10]	Storage and analysis of data from various sources	Using cloud platforms and specialized programs to process and store large amounts of data.

Continued Table 2

Real processing time and speed	Real-time data processing	Powerful computing systems for processing sensor information and real-time navigation control.
Real processing time and speed	Real-time data processing	Powerful computing systems for processing sensor information and real-time navigation control.
Real processing time and speed	Real-time data processing	Powerful computing systems for processing sensor information and real-time navigation control.
Intelligent algorithms	Machine learning and deep learning	Use of intelligent algorithms to improve data processing and automate processes.
5 Latest approaches and trends	Integration with IoT	Connecting aerial robots with the Internet of Things (IoT) for distributed monitoring and control.
Use of blockchain technologies	Data security and transparency	Blockchain to ensure security and protection of data collected by aerial robots from fraud and unauthorized access.
Development of new form factors	Hybrid systems and new designs	Development of new form factors for aerial robots, including hybrid systems and compact designs.
Improving energy efficiency	The impact of technology on development	Innovations and latest technologies contribute to expansion of their capabilities and areas of application.

Together, these technologies and innovations open up new opportunities for development of aerial robots, making them more functional, reliable and efficient in various applications. The development of these areas ensures continuous improvement of the quality of robots and expansion of their capabilities.

V. CONCLUSIONS

The development of aerial robots has undergone significant advances due to introduction of advanced technologies and innovations. Modern sensor systems, such as high-resolution cameras and LiDAR, have significantly increased accuracy of data collection and detail of information about environment. This allows us to create accurate 3D maps of area and provides reliable navigation and real-time monitoring. Important component is development of control systems, where intelligent algorithms and autonomous systems provide high level of automation. Independent route planning and automated control reduce need for manual intervention and increase flight efficiency.

Materials and designs of aerial robots have also undergone significant improvements. The latest composites and 3D printing technologies contribute to lightweight and durable structures that optimize performance and stability during flight. Innovations in data processing and process automation enable rapid analysis and adaptation to changing conditions, and use of machine learning allows for continuous improvement of algorithms and robot performance based on data obtained.

Recent trends include integration with Internet of Things (IoT) and use of blockchain technologies to improve data security, which opens up new opportunities for expanding robot functionality. The development of new form factors and improvements in energy efficiency through new batteries and energy recovery systems also contribute to durability and reliability of aerial robots.

Thus, modern technologies and innovations not only improve functionality and efficiency of aerial robots, but also ensure that they can adapt to new challenges and requirements in various applications. The development of these technologies ensures that aerial robots will continue to improve and be introduced into new practical areas in future.

LIST OF REFERENCES

[1] І. С. Зарубін, “Огляд сучасних повітряних роботів,” *Автоматизація та Приладобудування («Automation and Development of Electronic Devices» ADED-2024) [Електронний ресурс]: збірник студентських наукових статей / Харківський національний університет радіоелектроніки.* 2024, pp. 144-149.

[2] S. V. Sotnik, I. S. Zarubin, “Modeling design of mobile robotic platform,” *Стан, досягнення та перспективи інформаційних систем і технологій / Матеріали XXIV Всеукраїнської науково-технічної конференції молодих вчених, аспірантів та студентів.* 2024, pp. 481-482.

[3] І. С. Зарубін, та інш., “Ефективність використання роботизованих систем у виробництві,” *Computer-integrated technologies, automation and robotics CITAR-2024.* 2024, pp. 150-153.

[4] S. V. Sotnik, “Safe cobots in development of industrial robotics,” *European scientific congress. Proceedings of the 8th International scientific and practical conference. Barca Academy Publishing.* 2023, pp. 80-84.

[5] Y. M. Al-Sharo, et al., “Generalized Procedure for Determining the Collision-Free Trajectory for a Robotic Arm,” *Tikrit Journal of Engineering Sciences.* 2023, 30 (2), pp. 142-151.

[6] AJA Tahseen, et al., “Access Control to Robotic Systems Based on Biometric: The Generalized Model and its Practical Implementation,” *International*

Journal of Intelligent Engineering & Systems. 2023, pp. 313-328.

[7] V. Lyashenko, et al., "Modern walking robots: a brief overview," *International Journal of Recent Technology and Applied Science*. 2021, vol 3, no. 2, pp. 32-39.

[8] S. V. Sotnik, et al., "Modeling of potting greenhouse design," Стан, *досягнення та перспективи інформаційних систем і технологій / Матеріали XXIV Всеукраїнської науково-технічної конференції молодих вчених, аспірантів та студентів. 2024*, pp. 483-484.

[9] A. Y. Hubar, et al., "Impact of automation and cals technologies on human factor in production," *The 5th International scientific and practical conference "Perspectives of contemporary science: theory and practice" (June 24-26, 2024) SPC "Sci-conf.com.ua*", 2024, pp. 243-249.

[10] V. G. Kaponkin, et al., "The role of big data in improving functionality of search engines," *The 8th International scientific and practical conference "European congress of scientific achievements" (August 12-14, 2024) Barca Academy Publishing, Barcelona, Spain*. 2024, pp. 69-76.