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Unmanned Aerial Vehicle Control System

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Abstract
This article analyzes the state of control systems for unmanned aerial vehicles (UAVs), and considers problematic issues. Tendencies in the development of UAV control system are highlighted. Conclusions are made about the efficiency of using UAVs with the corresponding level of development of control systems.

Keywords: Unmanned aerial vehicle (UAV), control systems, autonomous control, group control, technical vision system (TVS), equipment of radio-electronic warfare (ERW), technical vision (TV).

Introduction

An unmanned aerial vehicle is an aircraft without a crew on board. UAVs can have varying degrees of autonomy - from remotely controlled to fully automatic, and also differ in design, purpose and many other parameters.

We present to your attention the areas of application of the UAV control system:

The most important component of unmanned aerial vehicles (UAVs) is the control system, which provides control over the movement and operation of the UAV subsystems during its interaction with the environment. The indicators of the control system characterize the level of functionality, autonomy and safety of the UAV.

As a rule, two main UAV control loops are distinguished:

- internal;
- external.

The internal control loop is designed to control the UAV subsystems.

The external control loop is designed to ensure the functioning of the payload and the use of the UAV for its intended purpose.

In recent years, the development of the UAV control system has shown a tendency to accelerate the transition from the simplest forms of interactive control based on remote exchange of data and commands between the operator-commander and the onboard part of the UAV, to supervisory control and the subsequent implementation of autonomous operation modes of the UAV. A mandatory requirement for the organization of supervisory control is to increase the autonomy of the onboard UAV systems by transferring some functions, for example, ensuring the movement of the UAV, to the onboard control system. Autonomous UAVs do not need an operator who constantly controls the movement of the vehicle. The operator's functions are performed by an

autonomous control system located directly on board the mobile UAV. The remote control system is used exclusively to transmit the task to the UAV and receive telemetry data from the UAV systems on the progress of its execution of the assigned tasks. The design of modern UAV control systems often combines a set of computers, navigation systems, actuators, environmental sensors, and the necessary software and algorithms, including a technical vision system (TVS), installed on board. Currently, UAV and system control technologies are being developed abroad in several directions, ranging from remote control options to fully autonomous modes of group control of UAV.

The main types of control correspond to the technologies:

- remote and supervisory control;
- autonomous control of the movement of single and group UAVs;
- autonomous control of movement and execution of tasks as intended by single UAVs;
- autonomous group control of movement and execution of tasks as intended.

Problematic issues of control systems development:

1. Weak points of science and technique reserve in the field of autonomous control methods and tools, insufficiently developed theory of self-learning systems, applied sections of the theory of adaptive and self-adjusting systems.
2. Insufficient development of UAV group control methods, especially in conditions of uncertainty, counteraction, functioning in conflict environments in terms of technologies:

- creation of hardware and software for informational interaction of UAVs in groups and UAV groups among themselves;
- group identification, target designation and target tracking; - decentralized decision-making and UAV operation management;
- planning and control of UAV group movements;
- research into the efficiency and optimization of UAV use, using modeling and decision support systems.

3. Susceptibility of the control system to external interference (spoofing) in UAV control by intercepting control, disrupting the integrity of transmitted information in conditions of interference and the use of radio-electronic warfare equipment, interrupting communications between control points and on-board UAV control systems.
4. Insufficient level of development of the elemental and technological base necessary for the effective hardware and software implementation of UAV control algorithms that take into account their hierarchical and interspecific interaction with other types of special equipment.
5. Insufficient development of issues of automation of decision-making processes when controlling UAVs.

Prospects for the development of control systems:

1. Increasing the autonomy of UAV control through the development of the following technologies:

- software and algorithmic support for control and forecasting of UAV behavior with adaptation to an uncertain environment;

- assessing the characteristics of a complex dynamic environment, autonomous planning of UAV movement with decision-making, for example, on choosing the best route in conditions of changing obstacles;
- automatic targeting (stationary, mobile, moving) in conditions of a changing background without operator participation;
- development of intelligent control systems with dynamic adaptation, learning, self-learning;
- recognition of objects and processes based on the use of neural network algorithms with elements of self-learning based on the latest achievements in the field of deep learning and reinforcement learning;
- training of neural networks associated with intelligent agents operating in a virtual environment;
- deep learning of neural networks using knowledge bases (ontologies) and logical inference programs;
- decision-making in multi-criteria conditions and the presence of multiple solution options, resolving conflicting problems;
- obtaining and extracting knowledge from accumulated information.

2. Creation and application of biofeedback control systems in UAVs. Such technological solutions allow a person to interact with technical devices, converting brain activity signals into control commands. An important feature of BC systems is that they must operate in real time, generating control signals with minimal delay. Electroencephalographs are currently used as a rule as tools for obtaining information about the bioelectrical activity of the brain.

3. Increasing the level of control intellectualization at all levels, including:
- goal-setting level, ensuring the formation of target functions, criteria for their implementation, assessment of task feasibility, interaction with the strategic management level and goal adjustment;
- action planning level;
- movement control level; - target task performance level.

4. Creation of a UAV control system with a distributed architecture, including levels of movement planning and control, control of subsystems for processing and integrating sensory information, actuators, power supply control, payload control, diagnostics and safety tools, while ensuring simplicity and ease of maintenance and operation.

5. Development of hardware for advanced UAV control systems, including:
- development of high-performance computers that can solve real-time problems of modeling and predicting UAV behavior in complex environments;
- improving the accuracy of actuators, navigation systems and environmental sensors considering with technical vision;
- creation of control technologies that ensure the necessary survivability reserve, i.e. the specified quality of UAV operation in the event of a sudden deterioration in equipment characteristics, failures, damage;

6. Development of anti-spoofing methods and means that ensure automated and subsequently:
- automatic monitoring of the state of the cyber environment, adaptation of control command formats and characteristics of their transmission channels in order to ensure the integrity and stability of control in the event of cyber-attacks.

Effective use of UAVs is possible with an appropriate level of development of the information, hardware and software of the control system, which can be achieved by implementing activities in the following areas:

- development of promising technologies for processing, analyzing and distributing information using standardized tools for processing it and transmission formats;
- development of technologies for constructing automated and information-control systems of UAVs, technologies for informational interaction of single UAVs and groups of UAVs;
- development of technologies for information and software support of UAV control systems;
- creation of technologies for highly secure communication and data transmission systems;
- development of technologies for integrating UAVs into the general system of control of troops and weapons;
- development of technologies for ensuring the security and protection of information of UAV control systems.

The following can be identified as priority areas for the development of UAV control technologies:

1) within the framework of the development of technologies for remote and supervisory control of UAVs:

- improvement of methods and means of interaction between operators and UAVs;
- search for and implementation of methods for freeing operators from routine operations when controlling UAVs and reducing the number of controling crews for UAVs;
- construction of three-dimensional models of the movement environment and support systems for the UAV operator in order to improve his situational awareness;

2) within the framework of the development of technologies for autonomous control of single UAVs in specified modes:

- methods of automatic planning and adaptive change of the UAV route using a digital terrain map and in interaction with the technical vision (TV);
- methods of automatic bypass of stationary and non-stationary obstacles;
- methods of automatic landing of the UAV on a site of limited size without special equipment or on a moving platform (for example, on the deck of a ship);

3) as part of the development of autonomous control technologies with target setting and adaptation to the environment:

- increasing the accuracy and speed of methods and algorithms for assessing the state of the environment;
- development of methods for predicting the development of conditions of the UAV operating environment;
- development of methods for intelligent planning of UAV movement and behavior in conditions of environmental uncertainty and / or limited sensory information;

4) as part of the development of UAV group control technologies:

- methods and algorithms for decentralized group control of UAV movement and behavior;
- methods and algorithms for group goal setting and target distribution in a dynamic environment;
- multi-agent control technologies;
- methods and algorithms for forming UAV groups using a single information and navigation field in the task execution area.

Conclusion:

Unmanned aerial vehicle (UAV) control systems are the foundation for the efficient and safe operation of these devices in various fields, including military, commercial and civil applications. These systems not only ensure the precise execution of tasks, but also minimize the risks associated with the control of the device.

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