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I.S. Azarov
(National Aviation University, Ukraine)

Flight control system of unmanned aerial vehicle along predetermine trajectory

The thesis is devoted to the investigation of the automatic control system of an unmanned aerial vehicle (UAV), which can be used to construct a given aircraft aircraft (LA) trajectory. An improved algorithm for control of UAVs along a given trajectory using the MATLAB environment is proposed. The analysis of existing methods of automatic control of aircraft, their advantages and disadvantages is carried out.

Introduction and analysis of the problem. The incentive for the development of unmanned aircraft throughout the world was the need for light, relatively cheap aircraft with high maneuverability characteristics and capable of performing a wide range of tasks. UAV successfully perform military and civilian tasks. To date, most of the existing UAV have been piloted manually, using remote controls operating on radio channels. With the manual control of the UAV, difficulties arise in the preparation of pilots, inadequate operating range, restrictions related to weather conditions. UAV management is a task for a well-trained professional. For example, in the US Army UAV operators become active Air Force pilots after a year of training and training. In many respects, this is more complicated than piloting the aircraft and, as is known, the majority of UAV accidents, due to pilot mistakes - operators and mechanical failures. According to official data provided for the period 2012-2017, the Air Force of the United States for all time, were destroyed 70 aircraft drones. These circumstances determine the relevance, practical significance and expediency of performing research on the justification of technologies for the development of inexpensive, available software and hardware systems as a universal tool for conducting scientific and technical research and automated development of flight control systems for UAV.

The purpose of the thesis: The investigation of the automatic control system of the UAV in the flight mode along a given trajectory.

The tasks of the thesis:

- Analysis of existing UAV control algorithms;
- Statement of quality management requirements;
- Analysis of modeling systems and selection of the environment for creating a dynamic UAV model;
- Visualization of the simulation model;
- Study of model dynamics in the chosen modeling environment;
- Development of algorithms for the UAV control model;
- Estimation of the results obtained during the model experiments in different flight conditions.

Determination of requirements for the automatic control system of UAV

During the control of the movement of the UAV, aerodynamic forces and moments arise. As the regulating factors allowing in fluencing the aircraft to control its movement, angles of deviation in pitch, yaw, roll and thrust of the engine are used. UAV as a control object is a complex dynamic system due to the presence of a large number of interconnected parameters and complex cross-interactions between them. Complex movement is often broken down into the simplest kinds: angular motions and movements of the center of mass, longitudinal and lateral motion. Controls that create control actions can be divided into two groups: organs of longitudinal control, providing movement in the longitudinal plane; lateral movement control bodies, providing the necessary character of changes in the angles of heel, slip and yaw. Such a division of controls is conditional, since it is possible to bring flight regimes in which the controls have cross effects on other movements. At the same time, this approach allows us to identify the main functions of specific bodies and control channels and independently solve a set of relatively simple and practical problems. To provide full automation of flight control, four control channels are necessary:engine control channel (traction);pitch control channel;control channel roll; yaw control channel. The engine control channel regulates the thrust in accordance with the specified flight program. The next three control channels provide the required angular position of the device in space. Information about the movement of the UAV comes to the appropriate channels, where commands are formed on the rudders, ailerons and the engine control lever, which provide the desired flight control. Stable flight control is impossible without creating an acceptable quality control system. The task of synthesizing the flight system is to select the structure and parameters of the control channels that provide a given quality of flight control, based on dynamic properties. An integral part of the automatic control systems for the movement of UAV are actuators. Inclusion of mathematical models of these devices in the control object allows taking into account their dynamic and static properties. The executive drives of the steering organs are selected from the condition that their load characteristics ensure the necessary dynamics of the control processes, in other words, they require the provision of movement with a given speed of the steering organ, loaded with external forces or external moments. For the UAV in question, the classical regulation of the control channels is not suitable, because of the non-standard flight control design. There is a need to broadcast a standard control system through channels to control four elevons. On the basis of this, the problem arises of composing algorithms for controlling elevatorons on the channels of roll, pitch, and yaw. The main task is to create a fully automatic ACS that will adjust the deviations of the control surfaces for the UAV flight along the desired trajectory.

Requirements for the construction of a mathematical model of a UAV

Basis in creation of a control system of flight on a trajectory is the development of the UAV mathematical model in MATLAB counting all aerodynamic forces and the moments which are used for working off of an algorithm of a control system.

In the course of modeling of the UAV is considered as a dynamic object at which change of a state in time is described by the differential equations.

In the thesis to be considered only the rigid design of the UAV of plane type.

One of highlights in drawing up the UAV mathematical model is acceptance of various assumptions simplifying real process [1,2]:

- invariable weight;
- lack of the moving masses;
- rigid design;
- the main axes coincide with axes of the related system of coordinates;
- the vector of force of draft lies in the plane of symmetry and passes through the center of masses under some corner with an axis OX;
- vectors of the total kinetic moment of the rotating parts of the engine are directed along an axis OX;

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Debugging the algorithm of the simulation model of UAV

In process of debugging of the program of the UAV imitating model and their systems, the land surface, the atmosphere the main efforts were directed to observance of conditions of adequacy of the developed models to real objects of researches.

We divided process of debugging of the program of imitating model into the following main stages[3-5]:

1. development of three-dimensional models of a glider of the UAV and its elements by 3D methods - design;
2. formation of a databank of aerodynamic characteristics of UAV on the basis of calculations of its three-dimensional model in the environment of ANSYS CFX;
3. creation of imitating model of dynamics of flight of the UAV in MATLAB/Simulink;

4. creation of imitating models of elements of a complex of management of UAV in MATLAB/Simulink;
5. development of a complex of control calculations and working off of functioning of model;
6. creation of visualization tools and conclusion of results.

Development of program imitating models of dynamics of flight of LA, elements of a complex of management of the UAV, the land surface and the atmosphere is executed with use of means of imitating modeling of MATLAB/Simulink on the basis of aerodynamic calculation of three-dimensional models of a glider in a complex of aero hydrodynamic calculations ANSYS CFX. It allowed to refuse expensive researches with use of purges in a wind tunnel, however was sufficient for creation of adequate bank of aerodynamic data of the considered glider. In fig. 1 the function chart of a hardware and software system for performance of imitating modeling of the operating software of the autopilot is submitted.

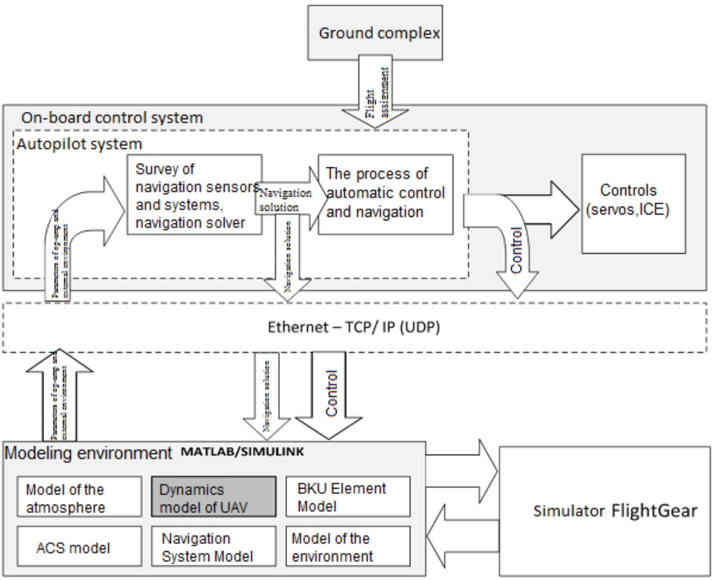

Fig. 1. Functional diagram of the simulation complex of the control object for the development of the aircraft software.

The scheme assumes hardware-software interface of an onboard complex of management of the UAV (autopilot) to software of imitating modeling, visualization and documenting of results. Thus, the closed hardware-software cycle (hardware-in-the-loop) allowing carrying out debugging of functioning of control algorithms of SAU at design stages, tests and modernizations of the UAV is formed.

The structure of model UAV loudspeakers (fig. 2) consists of blocks of calculation of forces and the moments, calculation of draft of the engine, the equations of the movement, models of sensors of primary information, steering drives, the system of navigation and automatic control (SNAC).

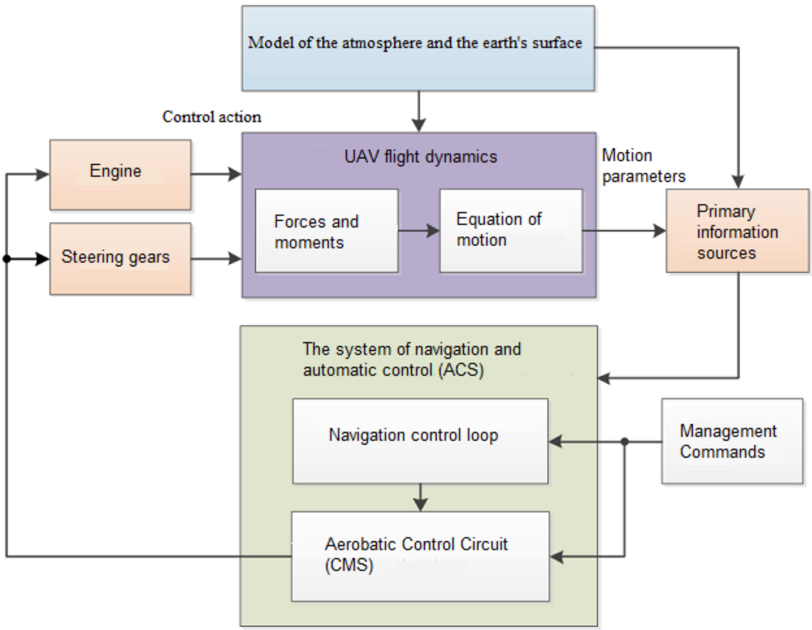

Fig. 2. Flowchart of full model UAV loudspeakers

The model LA loudspeakers were complemented with nonlinear models of elements of a complex of management of the UAV: power plant, sensors of primary information and steering drives. The mathematical model of the aircraft power plant was based on the static characteristic of the engine and related the position of the throttle as a percentage of the thrust of the propeller-driven installation in newtons through the rotor speed. Also in the model is the hourly fuel consumption. The mathematical model of the steering drive takes into account the quality of the drive, the nonlinearity of the "drive limitation" type of drive, the limitation of the drive's "speed", the "dead zone", and the hinge moment associated with the effect of aerodynamic forces on the steering surface in flight. Results of calculation of model are presented in the form of schedules of output parameters of model (speed, height, coordinates, corners of position of the UAV, angular speeds, etc.). After the end of modeling there is an opportunity to choose the interesting site of flight and, using ample opportunities of means of Simulink according to the analysis of graphic information (including the analysis of transitional characteristics, the frequency analysis, etc.), to conduct a research according to an objective.

For visualization of results the 3D model of the UAV is imported to the virtual environment of the FlightGear simulator, data transmission about spatial movement, evolutions, speeds of flight and deviations of wheels of the UAV from model in the simulator and also data transmission about height over the spreading surface from the simulator in model is organize.

Modeling of the spreading surface was provided by a podgruzka from FlightGear in Simulink through the UDP protocol of information on parameter H_{relief}. At the same time the preliminary binding of the district map of FlightGear to the electronic district map of the Atlas system by the indication of initial values of geographic latitude and longitude and also initial height and an initial azimuth was carried out.Using the obtained mathematical model, the balancing positions of the steering surfaces, the coefficients of the UAV flight controllers, the flight performance of the vehicle were specified, and the restrictions on heights and flight speeds were determined. The required and available thrust of the power plant, the maximum and minimum permissible values of heights, speeds of the flight and pitch angles, calculation of take-off and landing on the runway (runway) were also determined.Calculations were carried out by giving test input effects, modeling and subsequent processing of its results, and performing test flight missions to develop appropriate flight regimes.Results of modeling of the UAV with the set coordinates of ways of a trajectory are given in fig.3, it is obvious that the UAV passed the set coordinates with the minimum course deviation.

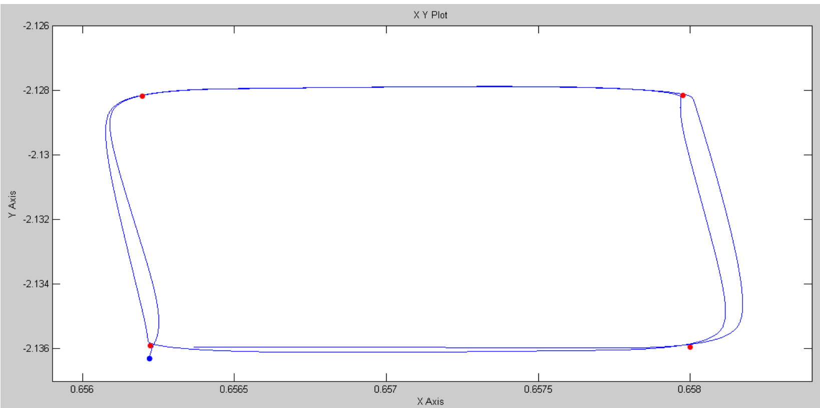

Fig. 3. Weeds the UAV on a circular trajectory from four points

Conclusions The design features of UAV are studied, the goals and technical requirements for the control system of UAV are defined. An improved algorithm for controlling a UAV on a given trajectory were proposed and analyzed in MATLAB environment. The dynamics of UAV flight in various control modes was investigated .An evaluation of the results obtained during the maneuvers (turning, changing echelon, avoiding a head-on collision, turning and dropping altitude) under various UAV flight conditions was obtained. In the future, the results of this work can be used to construct more complex algorithms for automatic control systems of UAV in flight mode along a given trajectory.

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