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Method of parametric adjustment of the digital system of automatic stabilization of an unmanned aerial vehicle

The report is devoted to the method, which consists of complex application of the Ziegler-Nichols method and zero-order numerical methods for adjusting the parameters of the digital automatic control system of unmanned aerial vehicles, which are used as a flying platform on which precision target devices are located.

Method of parametric adjustment of the digital system of automatic stabilization of an unmanned aerial vehicle.

As initial data we will consider a scalar linear stationary mathematical model of a separate channel of digital system of precision automatic stabilization of the UAV (fig.1) [1]. The control action in a separate control channel is created by a separate propeller. That is, the number of control channels is equal to the number of screws. The mathematical model of the control object in a separate channel describes the dynamics of changes in the speed of small movement of the UAV along the direction of the axis of the propeller (Fig.1., Transfer Fnc4).

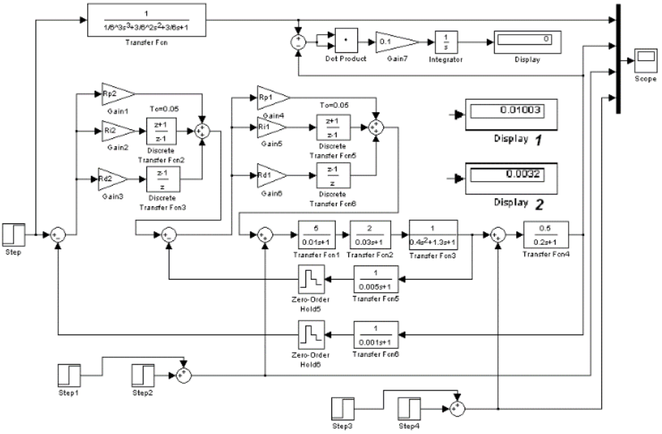

Fig. 1. Computer mathematical model of a separate channel of the digital system of precision automatic stabilization of the UAV: T_0 sampling period over time (T_0=0.05c, selected in accordance with the recommendations [2-5]).

In general, the computer mathematical model of a separate stabilization channel consists of the following blocks (Fig.1):

Gain1, Gain2 and Discrete Transfer Fnc2, Gain3 and Discrete Transfer Fnc3 – mathematical model of DPID - external circuit controller with parameters Rp2, Ri2, Rd2;

Gain4, Gain5 and Discrete Transfer Fnc5, Gain6 and Discrete Transfer Fnc6 – mathematical model of DPID - internal circuit controller with parameters Rp1, Ri1, Rd1;

Transfer Fnc1, Transfer Fnc2, Transfer Fnc3 – mathematical models of the DC amplifier, power amplifier and DC drive, respectively;

Zero-Order Hold5 together with Transfer Fnc5 and Zero-Order Hold6 together with Transfer Fnc6 – mathematical models of digital speed sensors, respectively, rotation of the rotor of the propeller drive and small movement of the UAV;

Step, Step1 together with Step2, and also Step3 together with Step4 – mathematical models of input action, pulsed electromagnetic and wind perturbations, respectively.

The parameters that need to be adjusted are the transmission factors of the DPID controllers Rpj, Rj, Rdj; respectively on the proportional, integral and differential signals for the first (j = 1) and second (j = 2) controllers.

As the criterion of optimality, we choose the integral of the deviation the output signal of the mathematical model of UAV motion $X(t)$ square averaged over the observation interval $T\ \Delta_x(t)$ along a separate degree of mobility from the reference (desired) change in time of this signal $X_b(t)$:

$$\mathrm{I(Rp1,\ Ri1,Rd1;Rp2,\ Ri2,Rd2)}=\frac{1}{\mathrm{T}}\int_0^{\mathrm{T}}(\Delta_{\mathrm{x}}(\mathrm{t}))^2\mathrm{dt}, \qquad (1)$$

where $\Delta_x(t)=X_b(t)-X(t)$; reference (desired) signal $X_b(t)$ and the criterion of optimality I(Rp1, Ri1, Rd1; Rp2, Ri2, Rd2) are calculated (set algorithmically) using blocks respectively Transfer Fnc and Dot Product, Gain7, Integrator (Fig.1); duration of simulation time *T*=10 c. In general, the method of setting up a separate channel of the digital system of precision automatic UAV stabilization consists of two types of settings: virtual - on the computer mathematical model of the digital UAV automatic control system channel and real - performed on a real UAV, for the control channel (mobility), which was previously configured according to the method of virtual configuration.

The method of virtual configuration consists of three stages:

1st stage – choose a reference (desired) model of change in time of the transient process at the output of the control system;

2nd stage – we use the Ziegler-Nichols method to find the values of the parameters Rp1o, Ri1o, Rd1o; Rp2o, Ri2o, Rd2o, which we use in the next step as initial values in numerical methods of finding the minimum criterion I(Rp1, Ri1, Rd1; Rp2, Ri2, Rd2).

The second stage consists of two substages:

Setting the first DPID controller only for the internal circuit and storing the values found Rp1o, Ri1o, Rd1o;

Setting up a second DPID controller (i.e., search Rp2o, Ri2o, Rd2o) provided that the first DPID controller uses previously found and stored parameter values Rp1o, Ri1o, Rd1o.

3rd stage – we apply any numerical method to find the minimum criterion (1):

$$I \rightarrow \min_{Rp1,Ri1,Rd1;Rp2,Ri2,Rd2} \tag{2}$$

It should be noted that during the performance of the 3rd stage, the found optimal solution is checked for sensitivity to the change of the parameters of the control object. These changes can be both deterministic (occur at certain points in time and at known quantities) and random.

Method of real adjustment allows to carry out (if necessary) specification of values of parameters of the digital controller received at virtual adjustment. Both types of configuration techniques should be part of the general methodology for the synthesis of digital UAV automatic control system in general. This article is devoted to the presentation of the method of virtual adjustment of a separate channel of the digital system of precision automatic stabilization of the UAV. Consider the result of applying the technique of virtual configuration, i.e., the technique that uses computer mathematical models (Fig.1).

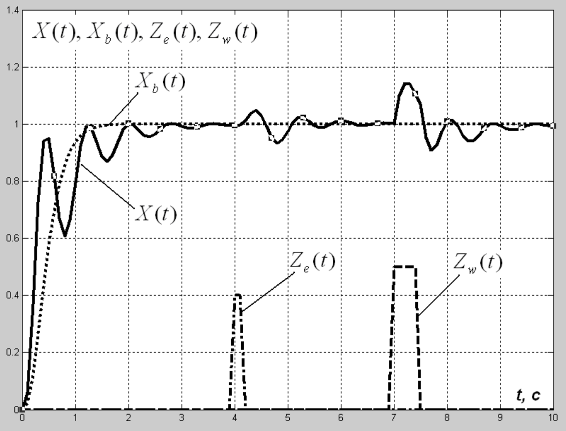

Fig.2. Transients at the output of the reference (desired) mathematical model $X_b(t)$ and a mathematical model of a separate channel of the digital system of precision automatic stabilization of the UAV X(t)

First stage. As a model of the reference (desired) change in signal time at the output of a separate channel of the digital system of precision automatic stabilization of the UAV, we choose the signal acting at the output of the model of the standard binomial form of the 3rd order [2-5]. times.

Second stage:

1st substage: We apply the Ziegler-Nichols method and obtain the following values of the parameters of the first DPID controller Rp1o=1.5; Ri1o=0.0882; Rd1o=3.1875.

2nd substage: We apply the Ziegler-Nichols method and obtain the following values of the parameters of the second DPID controller Rp2o=1.5; Ri2o=0.1; Rd2o=2.8125.

The result of computer simulation obtained using a computer mathematical model (Fig.1) shows that the output signal of the channel X(t) significantly different from the signal at the output of the reference (desired) model $X_b(t)$ (Fig.2). The numerical value of the optimization criterion is 0.01003 (Fig.1).

Third stage. For the final optimization (adjustment) of the parameters of DPID-controllers (Fig. 1) we solve problem (2) using the numerical method of zero order, which is called the Hooke-Jeeves method [11, 12].

As a result, we get the optimal: the transition process X(t) at the output of the mathematical model of a separate channel of the digital system of precision automatic stabilization of the UAV (Fig. 3); point (Rp1opt=1, Ri1opt=0.07, Rd1opt=3.18; Rp2opt=0.3, Ri2opt= =0.08, Rd2opt=2.85) in the six-dimensional space of the parameters that were configured; the value of the criterion is Iopt(Rp1opt, Ri1opt, Rd1opt; Rp2opt, Ri2opt, Rd2opt)=0.0032. As you can see (Fig.2 and Fig.3), we managed to improve the quality of the transient process (the transient process was oscillating and became aperiodic, which almost coincides with the reference (desired) process), and also managed to reduce almost three times 0.01003/0.0032=3.1344 standard error.

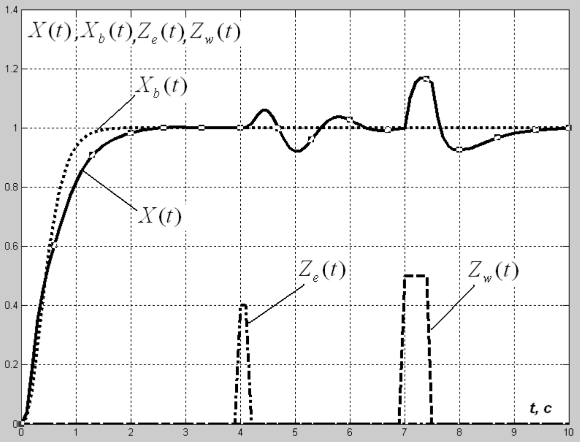

Fig.3. Transients at the output of the reference (desired) mathematical model $X_b(t)$ and mathematical model of a separate channel of the digital system of precision automatic stabilization of the UAV X(t) with optimal parameters of DPID - controllers

The proposed technique can be used at the stage of preparation of the UAV for flight (preliminary parametric synthesis of the digital automatic stabilization system) or for reconfiguration of the digital automatic stabilization system in real time (operational parametric synthesis).In the preliminary parametric synthesis, it is possible to take into account all deterministic changes in the parameters of a single channel of the digital system of precision automatic stabilization of UAVs and to remember the best values of the parameters of the DPID controllers corresponding to these changes.

At operative parametric adjustment in the conditions of uncertainty concerning knowledge of moments of time and size of change of parameters of control object (CO), it is offered to carry out the following actions:

before applying the technique to quickly identify the parameters of CO; to apply the mathematical model of CO updated as a result of identification in the given technique.

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