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# Unmanned Helicopter Autopilot Design Based on Active Disturbance Rejection Control

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**Abstract.** This paper presents the design of three channel controller based on active disturbance rejection control (ADRC). The final aim is to develop a robust tracking control scheme which ensures that the outputs of closed-loop system track the given expectations. The results of simulations show that the control system has satisfactory tracking performance, and the great ability to suppress disturbances.

**Keywords: U**nmanned helicopter, ADRC, autopilot design

## 1 Introduction

Many experts and scholars have begun to research and develop the small unmanned helicopter, but its system is very complex, especially its control system, with multivariable, strong coupling, time-varying and non-linear characteristics, make it unusually difficult to control [1-3].

To solve this problem, this paper puts forward a idea that applies active disturbance Rejection controller (ADRC) which has a fast response, high control precision, good robustness, strongly adaptability and does not need accurate mathematics model to the small unmanned helicopter control system. Whether control system is a system of linear or nonlinear is not important. This has laid a good foundation for the development of ideological ADRC[4-6].

First, this paper gives a brief introduction about small-scale unmanned helicopter's structures and characteristics. Then we analyze in detail the unmanned helicopter platform, each components' forces and moments, their mathematical expression. Secondly based on the research of ADRC algorithm and its characteristics of small unmanned helicopter, we design the three-channel decoupling ADRC, and set the parameters of the controller. Finally, we use simulation tool to build a small unmanned helicopter close-loop control system simulation model. Simulation tests include unmanned helicopter attitude control test.

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## 2 Helicopter nonlinear model

We just take it for granted that is the 6-DOF rigid model. According to Newton-Euler equations, the helicopter rigid body dynamics equations are given by

(1)

(2)

(3)

(4)

(5)

(6)

where, , ,

are three-component velocity in body-fixed reference frame. ,

, are The three-components of the angular velocity , , are angle attitude. The relation between attitude angles and angular velocities is described by:

(7)

(8)

(9)

We can see from the above equations a coupling between these attitude angles.

## 3 The controller design outline

Input-output feedback linearization is intended primarily for the system output and system control input to establish a direct relation, and remove the coupling portion of the system. Under different experimental conditions, the linearized results are different, but the process is the same, here for small unmanned helicopter attitude control as an example. Choose three unmanned helicopter attitude angle as system output: Roll angle 、yaw 、pitch angle .

*Problem statement:* to develop a robust tracking control scheme which ensures that the outputs of closed-loop system track a given expectations ( ).

According to (7),(8),(9), here we perform input-output feedback linearization[7]. Small unmanned helicopter flight dynamics nonlinear mathematical model is described by

 

$$f(x) \quad g(x)\, g(x)\, g(x) \qquad (10)$$

$$f(x) \quad G(x)u$$

$$f(x) \quad g(x) \quad g(x) \quad g(x)$$

where the controller and the states of the dynamics system is shown as follows:

,

For the ADRC, its control objects are generally SISO systems. Here the control

$z$

objects(3-15) is a MIMO system, So you want to use ADRC algorithm to design a controller, first equation (3-15) treated as follows

Then (3-15) is rewritten as

(1)

(2)

(3)

Where are the inputs, and ( , , ) are new output. We can respectively design the ADRC controller for the second-order system (11). is the unknown parts including three-channel coupling. In addition, we make the following assumption. Small unmanned helicopter during the flight of the various state variables are bounded, meanwhile is bounded as well. We have separately ADRC tracking differentiator, the extended state observer and the nonlinear state error feedback control law for a detailed description. here we will directly give the designed ADRC in the following discrete forms:

$(k+1) = v(k) + hv(k)$

$(k+1) = v(k) + hfhan((v(k) - v(k), v(k), r, h)$

$(k) = z_{i1}(k) - y_i(k)$

$(k+1) = z_{i1}(k) + h(z_{i2}(k) - fl_{i1} e_i(k))$

$U$

$U \quad i$

$(k) = z_{i1}(k) - v_{i1}(k), e_{i2}(k)$

$(k) - v_{i2}(k)$

$(k) = -fhan(e_{i1}(k), e_{i2}(k), r_{i1}, h_{i1})$

where, $y_{id}$ ( $i$ =1,2,3 ) respectively denote 、 $e_d$ 、 $w_d$ . According to, the following controller is ultimately applied to the control object

$0(k) - z_{i3}(k)$

(15)

# 4 Simulation results

In this section, the purpose of numerical simulation is to demonstrate the performance of the proposed control system.

## 4.1. Adjustment of the parameters of SDRC

There are many parameters in active Disturbance Rejection Controller, including the parameters , in tracking differentiator, , , the parameters , in extended state observer, the parameters , in Nonlinear state error feedback control law. They are very difficult to be adjusted Simultaneously. Since we can follow the principle of separation, every parts can be designed individually.

Based on the experience, is given by ________ , where is Integration step. The main parameters , , are taken as the following forms:

, , ____

The parameters of NLSEF are given directly in the form , .

The simulation is a small unmanned helicopter attitude control test. UAV is based on the initial state of a certain height, the rated speed of the rotor to hover. Unless controller achieves effective attitude control, we can make UAVs more difficult action.

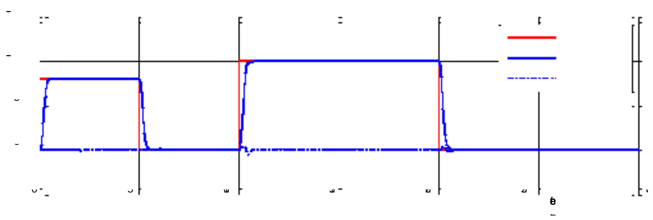

**Fig.1**. Results of the pitch angle and yaw angle tracking

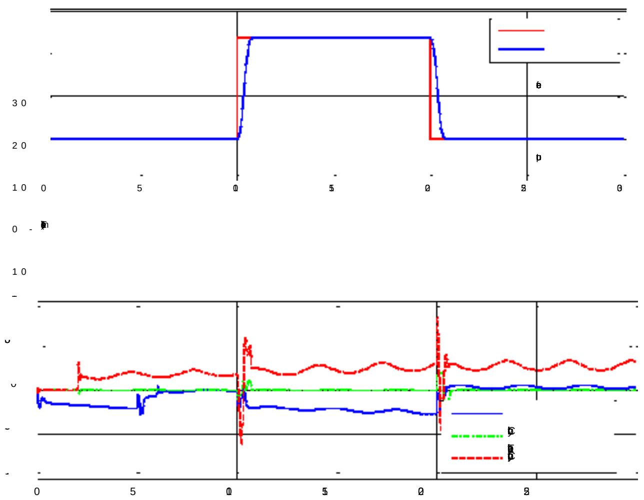

**Fig.2**. Results of roll angles tracking

**Fig.3.** Controller output signals to the actuators

The reference signal applied to each channel separately. Then the results of the attitudes tracking are given in Fig. 1 and Fig. 2. We can see the effect of its track is still very desirable Attitude angles will regulate along with the reference signal. Fig.6 shows that servo-actuators signal regulate along with the attitude angles. Although the peak of the differential output and tracking slight deviation, but the size of the deviation is within the allowable range, and almost no effect on the controller. This causes that the nonlinear state error feedback laid a good foundation.

 

## 5 Conclusion

We completed the design of ADRC controller for small unmanned helicopter. Through the ADRC algorithms, the work of anti-rejection controller tuning comes true by the three-channel decoupling ADRC controller. The three-channel controller based on active disturbance rejection control has a fast response, high control precision, good robustness, strongly adaptability and does not need accurate mathematics model to the small unmanned helicopter control system. The test results show that ADRC applied to the control system of small-scale unmanned helicopter is entirely feasible.

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