OPTIMAL AND PID CONTROLLER FOR CONTROLLING CAMERA'S POSITION IN UNMANNED AERIAL VEHICLES

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ABSTRACT

This paper describes two controllers designed specifically for adjusting camera's position in a small unmanned aerial vehicle (UAV). The optimal controller was designed and first simulated by using MATLAB technique and the results displayed graphically, also PID controller was designedand simulatedby using MATLAB technique .The goal of this paper is to connect the tow controllers in cascade mode to obtain the desired performance and correction in camera's position in both roll and pitch.

KEYWORDS

Unmanned Aerial Vehicles, System Control, Servo Motor, PID Controller, Optimal Control

1. INTRODUCTION

Unmanned aerial vehicle is remotely piloted or self piloted (without pilot) aircraftwhich can carry many different types of accessories such as cameras. In many types of UAV's servo motors are using for adjusting movements, sensors and communications equipment [1].Control of the movements and flying systems in the UAV is customarily done by using the microcontrollers optimal controllers or conventional PID control techniques.The main objective of the work reported in this paper is to evaluate the performance of each of optimal and PID controllers separately and will show the characteristics of the each of PID and optimal controllers, and which controller is better for obtaining the desired response.

2. SERVO MOTORS

Using the servomotor is helpful to correct the performance of a mechanism because it uses error sensing feedback. The servo motors usually used in the systems where the feedback or error correction signals help control mechanical position or other parameters[3]. Some servos also have rotation limit of 360°, but servos do not rotate continually. The Servos are used for precision positioning. They are used in many fields like toys, cars and UAVs. Servos are commonly electrical or partially electronic in nature, using an electric motor as the primary means of creating mechanical force. Other types of servos use hydraulics, pneumatics, or magnetic

DOI : 10.5121/ijitmc.2013.1403

principles [3]. Usually, servos operate on the principle of negative feedback, where the control input is compared to the actual position of the mechanical system as measured by some sort of transducer at the output.

2.1. Modeling a Simple Servo motor

DC servo motorhas an output shaft with an inertial load(J) on it.Theamount of frictions in the bearings of the motor and load represented in our paper by the constant (b).The input voltage u(t) is transformed by the motor into a torque T(t) in the motor output shaft. If we assume that (h) is the angular position of the servo output shaft, then the torque balance can be written as:

$$J*\dot{h}+b*\ddot{h}=T(t) \quad (1)$$

Where:

($\dot{h}$)- Is the shaft velocity, ($\ddot{h}$)-is the shaft torque

The control objective is to control the shaft position (h) or the shaft velocity (h) to be some desire value. The input voltage u(t) is related to the torque T(t) by a gain (K) and the inertia load divided by the friction coefficient is referred to as the system time constant (τ) where:

$$\tau = J/b \quad (2)$$

So the system model becomes:

$$\tau * \dot{h} + \ddot{h} = K.u(t) \quad (3)$$

The linear part of the servo system model can be put in the transfer function form:

$$y(s) = \frac{K}{s(\tau s+1)} u(s) \quad (4)$$

Where y(s) is the output shaft position and u(s) is the motor input. K is the system gain and τ.

Where :(tau) is the time constant.

Let's go now to the UAV and will show and explain the scheme for controlling the rotational position of the camera for roll and pitch movements of an unmanned air vehicle (UAV).Roll error and pitch error signals obtained from gyro systems in the UAV are subtractive combined with roll and pitch position signals, to generated control signals to be applied to rotate the camera in a way that compensates for the roll and pitch movements of the UAV, and effectively isolates the camera from roll and pitch movements of the UAV and the camera will provide a good photo or video without loss in information (Fig. 1).

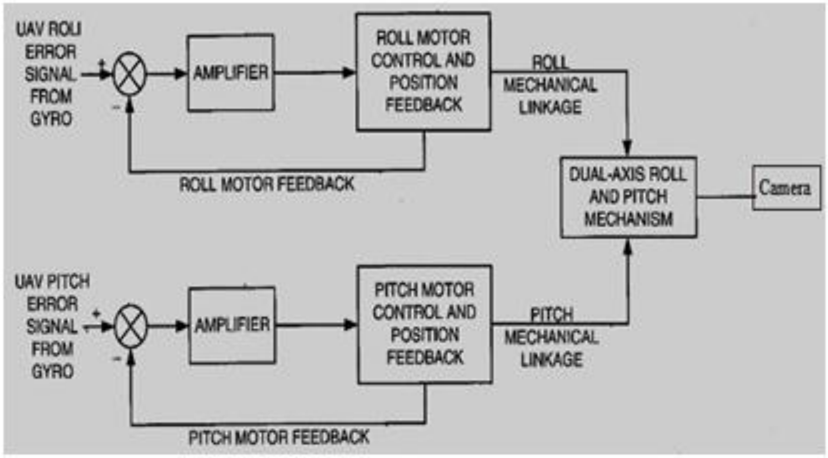

Figure1. Control system scheme for the camera in UAV

2.2. The Flight Controllers in UAV

The better method for controlling of a small UAV is to use the flight controller as consisting of two cascaded controllers as shown in Fig.2.The firstcontroller, is designed to control the attitude which takes desired attitude angles as inputs and generates the actuator commands that will result in the desired attitude. The secondcontroller, which controls the slower translational rate variables, takes desired velocity or position as input and generates desired angels to the inner loop.

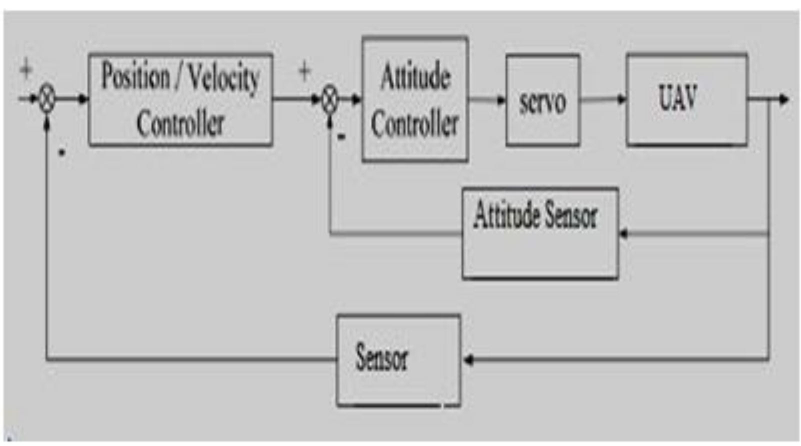

Figure 2.Overall control scheme

3. SYSTEM CONTROL REPRESENTATION

The transfer function of the servo motor used in our experiment as shown below:

firstwe will view the open-loop step response for the system, Then create a new m-file in Matlab and add in the following code:

num=1050; den=[1 30 0]; step(num,den)

The DC gain of the plant used the above transfer function is (∞) , so 10.5 x 10^5 is the final value of the output related to a unit step input. This corresponds to the steady-state error of 1.5x10^5, quite large indeed. Furthermore, the rise time is equal to the settling time.The goal of this problem is to obtain a controller to give the following parameters:

- Fast rise time
- Minimum overshoot
- No steady-state error

3.1. Modeling the optimal controller

The optimal controller equation in the Z-domain is given in the equation below:

$$W(z) = K_0 \frac{1 + b_1 Z^{-1} + b_2 Z^{-2}}{(1 - Z^{-1})(1 + a_1 Z^{-1})}$$

Where: K, b1, b2, a1 are coefficients defined as below:

$$K_0 = \frac{ab}{\alpha(1-A)(1-B)};$$

$$b_1 = -(A+B);$$

$$b_2 = AB;$$

$$a_1 = \frac{bB - aA + (a-b)AB}{(a-B)(1-A)(1-B)}$$

$$A = e^{-ah}; B = e^{-bh}; h = 0.001\sec$$

The modeling of the controller using MATLAB Simulink is as shown in the Fig.3

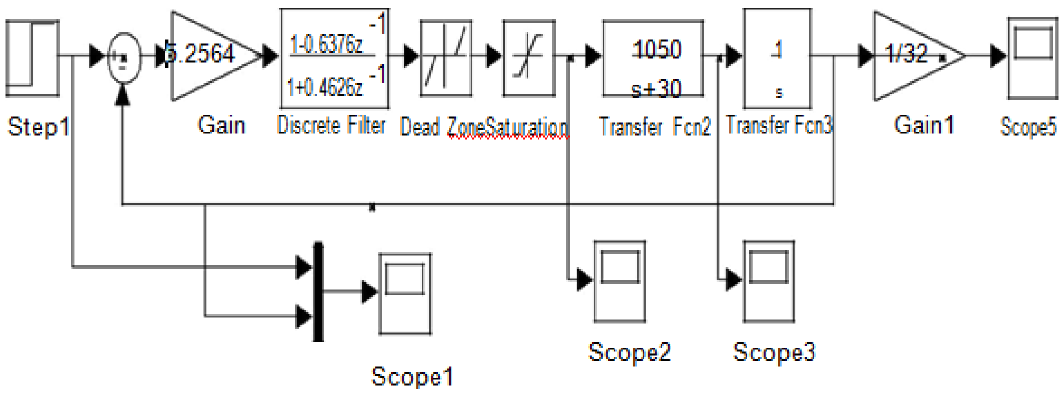

Figure 3.Optimal controller design simulink

After running this model we can see the output signal as shown in Fig.4:

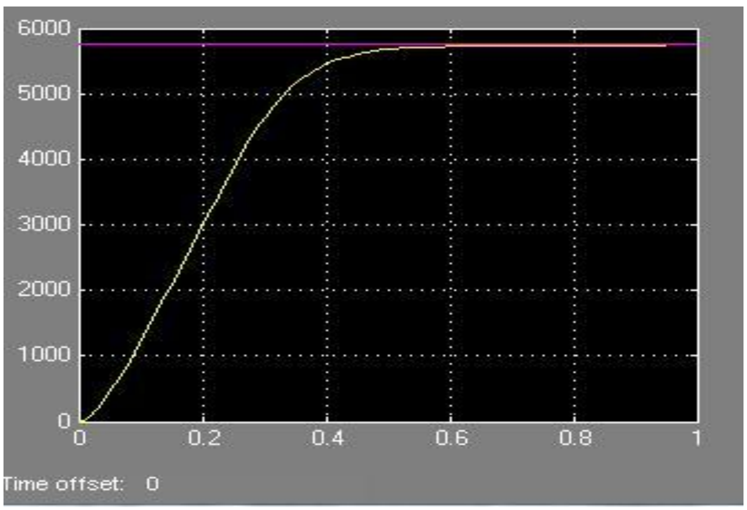

Figure 4.Output signal of the optimal controller

3.2. The PID Controller modeling

The transfer function of the PID controller is:

$$G(S) = K_p + \frac{K_i}{s} + K_d.s$$

Where:

Kp = Proportional gain ,Ki= Integral gain ,Kd = Derivative gain

The proportional gain (Kp) will reduce the rise time and will reduce (but never eliminate) the steady-state error. The integral gain (Ki) will eliminate the steady-state error, but it may make the transient response worse. The derivative gain (Kd) will increase the stability of the system, reduce the overshoot, and improve the transient response.Performance criteria were specified as:

Rise time $t_r \leq 0.1$
Settling time
$t_s \leq 0.5$

Maximum overshoot $M_r \leq 0.5\%$

Steady state error (e) $\leq 0.5\%$

Running the program and we will get the needed parameters. From the parameters tuning we can get:

Kd = 0.008672, Ki =0.008672, Kp = 0.114

Fig.5 shows the PID controller designed by using MATLAB Simulink where all of controller coefficients were adjusted.

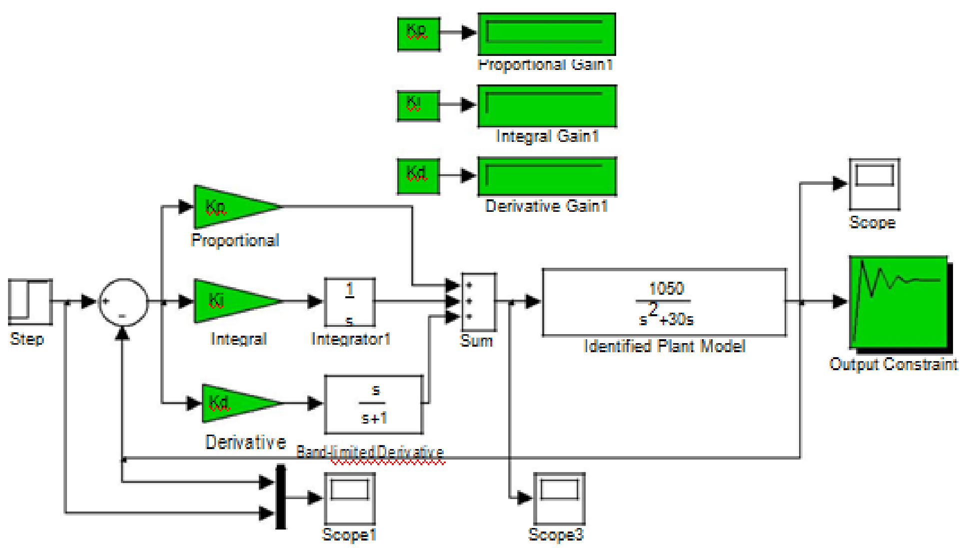

Figure 5.PID control system designed in MATLAB Simulink

After running this simulink, we can see the signal shown in Fig.6

Figure 6.Output signal in the case of PID

By comparing the signal output in case of optimal controller (Fig.4) and PID controller (Fig.6) we obtain the signals shown in Fig.7.

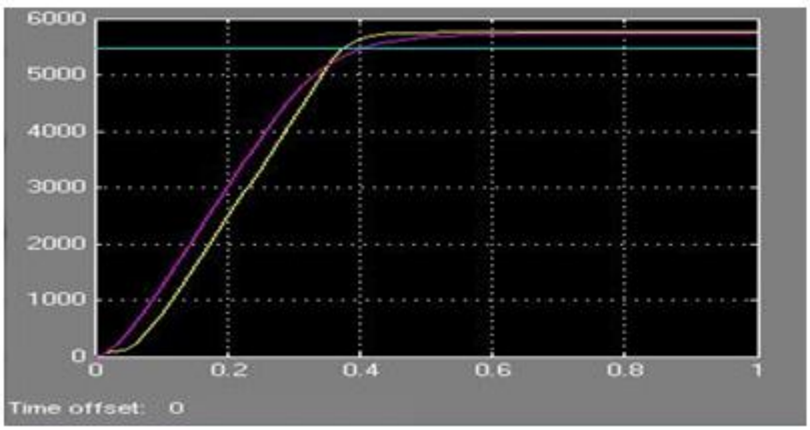

Figure 7.output signals compared between the 2-controllers

We can summarize the performance of the optimal and PID controllers obtained by our experiment as in the table.1 shown:

Table 1. OPTIMAL AND PID OUTPUT SIGNAL CHARACTERISTICS

controller	RISE TIME	OVERSHOOT	SETTLING TIME	S-S ERROR
optimal	0.2	none	0.4	0.4%
PID	0.2	none	0.57	0.53%

Let's now campaign the 2-controller as we explain above in cascade mode to get the desired output signal and the desired output voltage from the servo motor to give the right signal to the camera position (Fig.8).

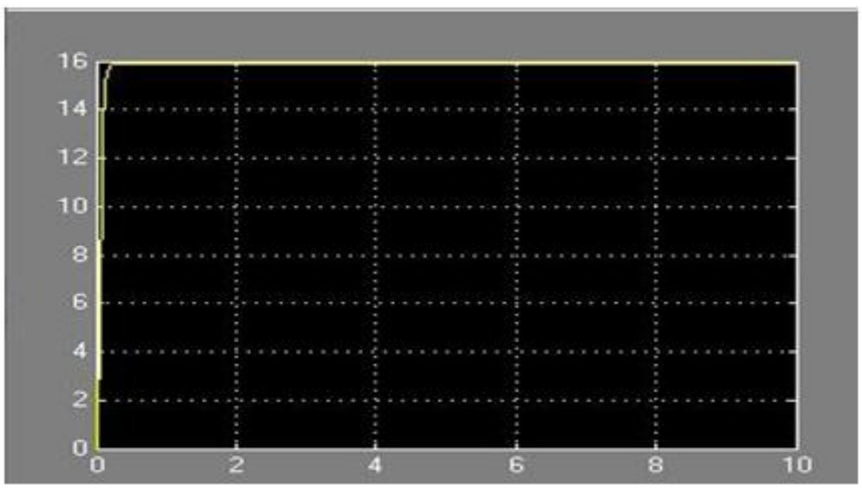

Figure 8.output signal for combining optimal and PID controllers

As we see in fig.8 the desired performance well obtained and this refer that the combined of the optimal and PID controllers in cascade mode give the performance better than if they worked separately.

4. Conclusions

• Flight control of UAV is done by using tow controllers instead of one and the tow controllers is designed by using MATLAB technic .

• Optimal controller satisfies the performance requirements. But, PID controller was unable to give fast rise time and it failed to satisfy the performance requirements.

• Combining the optimal and PID controllers as we suggested in this paper in cascade mode will give the desired performance and this will make no loss in information in the cameras movements in both roll and pitch.

ACKNOWLEDGMENTS

I would like to acknowledge my professor Alexander A.Lobaty and Mr.A.G.Streshnov for their big assistants.

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