Dynamic Modeling and Simulation Analysis of Four Rotor UAV

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Abstract. With the development of unmanned aerial vehicle (UAV) technology, its application field is more and more extensive. At present, UAV inspection has become an indispensable part of the production and operation of distribution network. Most of the UAVs used in the field of distribution line inspection are four rotor UAVs. Because the control system of the four rotor UAV has the characteristics of underdrive, it is difficult to control it accurately. In view of the above problems, this paper has carried out the research on Dynamic Modeling and simulation analysis of four rotor UAV. The working mechanism of four rotor UAV is analyzed. The dynamic model of four rotor UAV is constructed. Taking the cascade proportion integration differentiation (PID) control method as an example, the control system framework of four rotor UAV is established. The relationship between the position and attitude of UAV in the process of motion is analyzed in depth. The attitude control sub module and position control sub module of UAV are designed. The simulation model of four rotor UAV control system is built. The simulation results show that the four rotor UAV has high requirements for the setting rate and accuracy of control parameters. The traditional PID control scheme is suitable for low-speed UAV. However, for the high-speed UAV, the control method needs to be further optimized. The research results of this paper have certain guiding significance for the research of four rotor UAV control system.

Keywords: Four Rotor Unmanned Aerial Vehicle · Dynamics · Modeling · Simulation

1 Introduction

UAV technology has been developed for more than 80 years. It involves many cutting-edge technology fields such as aviation, electronics, power, flight control, communication, image recognition and so on [1]. In recent years, the emergence of multi rotor UAV has further reduced the manufacturing cost of UAV and greatly improved the economy of related products. The most common multi rotor UAV is the four rotor UAV. Four rotors have outstanding advantages of light weight, small size and low cost. Therefore, the four rotor UAV has become a research hotspot in the field of UAV and has received more

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and more attention [2]. By carrying visible light, infrared detection and other equipment, the four rotor UAV can carry out efficient, non-contact and all-round inspection of power equipment. Therefore, UAV has been widely used in the field of distribution line inspection [3, 4].

The control system is the most important module in the four rotor UAV. The performance of the control system directly determines the flight state of the four rotor UAV [5]. However, the mechanical structure of the four rotor UAV is relatively complex. Its control system is a nonlinear system. When it controls the attitude angle, it will also affect the position state of the UAV. In addition, the control system of the four rotor UAV has four input signals, but controls six outputs. The six outputs of the control system include three position motion control signals and three attitude angle motion control signals [6]. Therefore, the four rotor UAV also has the characteristics of underdrive. The above problems make the research of UAV control system more difficult. Therefore, in-depth analysis and Research on the dynamic characteristics of UAV in the process of motion is the basis of optimizing the UAV control system and improving its control ability.

This paper focuses on the small four rotor UAV. The relationship between position subsystem and attitude subsystem is deeply analyzed. Then the dynamic model of four rotor UAV is constructed by Newton Euler method. Finally, the position sub module and attitude sub module of the UAV control system are designed respectively, and the simulation experiments are carried out on the matlab/simulink platform. Relevant research has laid a foundation for the research of the control system of four rotor UAV.

2 Control Principle of Four Rotor UAV

At present, there are mainly two kinds of attitude control schemes for small or micro four rotor UAV in the market, namely “X” control scheme and cross control scheme. The two control schemes are distinguished by the UAV itself. The “X” control scheme takes the forward direction of the UAV as the X axis. Determine the motion coordinate system according to the right-hand rule. Put the connecting lines of the two rotors of the UAV on the x-axis, and the connecting lines of the remaining two rotors will be plumb on the -x-axis at the same time. The cross control scheme takes the two connecting rods of the UAV used to connect the rotor as the coordinate axis. One of them is the x-axis and the other is the y-axis.

Although there are two flight postures of the four rotor UAV, both of them control the forward and overturn of the UAV by adjusting the speed of the four motors, which affects the direction of the UAV’s lift force.

This paper uses the “X” structure to explain the specific control mode.

(1) Vertical motion
The speed change of the four rotors of the four rotor aircraft will change the lift. As long as the lift of the four rotors is increased or reduced synchronously, the height of the UAV can be changed.

Pitching motion (fore-and-aft motion): increase the rotation speed of the two motors M1 and M2 at the same time, and decrease the rotation speed of the two motors M3 and M4 at the same time. In this way, the lifting force on the body becomes backward and upward, and the body will fly backward under the action of gravity, and the same is true for flying forward.

(2) Rolling motion (left and right rolling motion)
In order to make the lift force direction of the body incline to the upper right, it is only necessary to increase the rotation speed of two motors M1 and M3 at the same time, and reduce the motors of the other two motors at the same time, so that the attitude flight of the UAV can fly to the right. Fly to the left in the same way, just adjust the rotation speed adjustment sequence of the four motors.

(3) Yaw motion (left and right turn in place)
The need for the UAV to turn in place is that the two motors on the diagonal increase the speed at the same time, and the other two motors slow down. This operation can make our body turn in place.

The value ranges of pitch angle, roll angle and yaw angle of three angles are specified here.

(1) Pitch angle
Take the body motion coordinate system as the benchmark, take the forward direction of the body as the nose, and if the nose is raised, it is regarded as a positive angle. The rest are negative values.

(2) Roll angle
The UAV body rolls to the right as a positive value. The rest are negative values.

(3) Yaw angle
The UAV body yaw to the right is positive. The rest are negative values.

3 Dynamic Modeling of Four Rotor UAV

To model a small four rotor UAV, the position information of the body needs to be obtained through the transformation between coordinate systems. In order to accurately and completely describe the motion attitude of small four rotor UAV, it is necessary to establish a reasonable UAV dynamic model. This model can lay a good foundation for the later motion attitude control of UAV

(1) Ground coordinate system
The most important parameters in the ground coordinate system are the three coordinate axes of origin *O* and *XYZ*. You can choose any point in earth space as the origin *O*. With the origin *O* as the starting point, any direction can be specified as the *X* axis. The *Y* axis is perpendicular to the *X* axis. The direction of *Z* axis and its relationship with *X* axis and *Y* axis can be determined by the right-hand rule. The origin *O* coincides with the starting points of the three coordinate axes *XYZ* (Fig. 1).

(2) Body coordinate system
The body coordinate system (*oxzy* coordinate system) also conforms to the right-hand rule. The origin *o* of the coordinate system is at the centroid of the rigid body

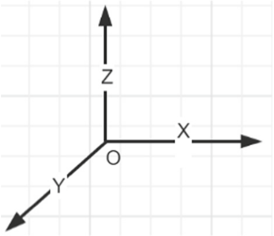

Fig. 1. Ground coordinate system

of the UAV. The *x*-axis is in the same horizontal plane as the rigid body of the UAV. The *x*-axis is located on the symmetry axis of the UAV and points to the forward direction of the body. The *y*-axis is perpendicular to the *x*-axis and is located in the same horizontal plane as the rigid body of the UAV. The *z*-axis is perpendicular to the *oxy* plane and in the upward direction. The origin o coincides with the starting points of the three coordinate axes *xyz* (Fig. 2).

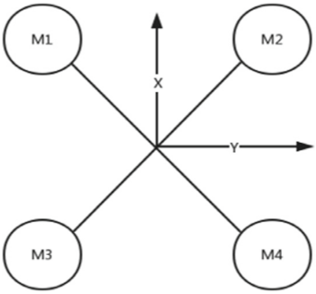

Fig. 2. Body coordinate system

(3) Coordinate conversion
After specifying the ground coordinate system and the body coordinate system, it is necessary to convert the body coordinate and the ground coordinate. If you want to convert, you can specify three Euler angles to represent the converted coordinates. The specified pitch angle is θ. Roll angle is Φ. Yaw angle is ψ.

It is assumed that the following relationship exists between the ground coordinate and the body coordinate system.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = R_B \begin{bmatrix} x \\ y \\ z \end{bmatrix} \tag{1}$$

The specific form of rotation matrix is as follows.

$$R_1 = \begin{bmatrix} \cos\theta\cos\psi & \sin\phi\sin\theta\cos\psi - \sin\phi\cos\psi & \cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi \\ \cos\theta\sin\psi & \sin\phi\sin\theta\sin\psi + \cos\phi\cos\psi & \cos\phi\sin\theta\sin\psi - \cos\phi\sin\psi \\ -\sin\theta & \sin\phi\cos\theta & \cos\phi\cos\theta \end{bmatrix} \tag{2}$$

The expression of UAV attitude control quantity is as follows.

$$\begin{bmatrix} U_1 = b(\Omega_1^2 + \Omega_2^2 + \Omega_3^2 + \Omega_4^2) \\ U_2 = lb(\Omega_4^2 - \Omega_2^2) \\ U_3 = lb(\Omega_3^2 - \Omega_1^2) \\ U_4 = d(\Omega_2^2 + \Omega_4^2 - \Omega_1^2 - \Omega_3^2) \end{bmatrix} \tag{3}$$

where, U_1 is the total lift of the four rotors. U_2 is the rolling torque of UAV. U_3 is the pitching moment of UAV. U_4 is the yaw moment of the UAV. When the micro four rotor UAV moves at low speed, it can be assumed that the structure of the four axis UAV is completely symmetrical, and the influence of air resistance is ignored.

After obtaining the expression of lift, the displacement equation can be obtained by Newton's second law.

$$\begin{aligned} \ddot{x} &= (\cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi)U_1/m \\ \ddot{y} &= (\cos\phi\sin\theta\sin\psi - \cos\phi\sin\psi)U_1/m \\ \ddot{z} &= (\cos\phi\cos\theta)U_1/m - g \end{aligned} \tag{4}$$

Because the four rotor UAV model is based on dynamic coordinates. According to Euler equation, the following expression can be obtained.

$$M = I\dot{A} + A \times (IA) \tag{5}$$

where, M is the moment. I is the moment of inertia. $\dot{A}$ AB is angular acceleration. A is the angular velocity.

The expression of moment of inertia is as follows.

$$I = \begin{bmatrix} I_X & & \\ & I_Y & \\ & & I_Z \end{bmatrix} \tag{6}$$

Using Newton Euler equation, the angular velocities of three coordinate axes can be derived.

$$\begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} \dot{\phi} - \dot{\psi}\sin\theta \\ \dot{\theta}\cos\phi + \dot{\psi}\sin\phi\cos\theta \\ -\dot{\theta}\sin\phi + \dot{\psi}\cos\phi\cos\theta \end{bmatrix} \tag{7}$$

When the four rotor UAV moves in a small range, the attitude angular displacement is very small.

$$\begin{cases} \sin\theta \approx \sin\phi \approx \sin\psi \approx 0 \\ \cos\phi \approx \cos\theta \approx \cos\psi \approx 1 \end{cases} \tag{8}$$

Further, the following expression can be obtained.

$$\begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix} \tag{9}$$

Therefore, the UAV dynamic model is defined as follows.

$$\begin{aligned} \ddot{x} &= (\cos\phi \sin\theta \cos\psi + \sin\phi \sin\psi)U_1/m \\ \ddot{y} &= (\cos\phi \sin\theta \sin\psi - \cos\phi \sin\psi)U_1/m \\ \ddot{z} &= (\cos\phi \cos\theta)U_1/m - g \\ \ddot{\phi} &= \frac{(I_Y - I_Z)}{I_X}\dot{\theta}\dot{\psi} + \frac{U_2}{I_X} \\ \ddot{\theta} &= \frac{(I_Z - I_X)}{I_Y}\dot{\phi}\dot{\psi} + \frac{U_3}{I_Y} \\ \ddot{\psi} &= \frac{(I_X - I_Y)}{I_Z}\dot{\theta}\dot{\phi} + \frac{U_4}{I_Z} \end{aligned} \tag{10}$$

4 PID Control Method of UAV

According to the four rotor UAV dynamic model constructed above, it can be determined that there are four inputs and six outputs of UAV. The four inputs are the speed of the four motors respectively. The six outputs are the three-dimensional actual coordinates and three attitude angles of the UAV. Therefore, the four rotor UAV is a complex nonlinear system. The traditional single loop proportion integration differentiation (PID) control scheme can not meet the dynamic response requirements of the UAV system. Using single loop PID will cause problems such as slow response and unstable operation of UAV. To solve this problem, this paper adopts cascade PID control method.

4.1 PID Controller

PID control scheme refers to subtracting the actual output from the expected input to obtain the error value. The error value is obtained by linear superposition of three links. So as to eliminate systematic errors. The traditional PID controller generally includes three main links: proportion, integral and differential. At present, PID control scheme or derivative control scheme of traditional PID controller is still mainly used in engineering. Because PID controller has the characteristics of easy realization, low cost and simple structure, PID control technology is widely used. In addition, PID controller has good compatibility, which can expand the application field of PID control method by integrating relevant cutting-edge technologies. Figure 3 is the schematic diagram of PID controller.

In the figure, K_p is the proportion link. K_i is the integral coefficient. $1/S$ is the integral link. K_d is the differential coefficient. S is the differential link.

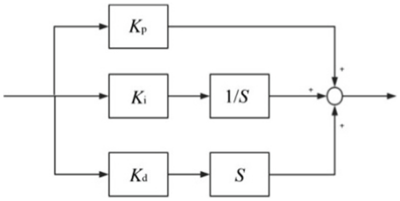

Fig. 3. Schematic diagram of PID controller

When the input is error $e\ (t)$, the expression of PID controller can be derived.

$$u(t) = k_p e(t) + k_i \int e(t)dt + k_d \frac{d}{dt} e(t) \tag{11}$$

PID can achieve different control effects according to the change of three coefficients. The proportional link can change the speed of system response. However, too large scale coefficient may lead to system imbalance. Too small proportion coefficient will lead to slow adjustment speed of the system and affect the response speed. Therefore, selecting the appropriate proportion link can make the system run stably and quickly.

The integration link is mainly used to adjust the system error. Proper integral effect can eliminate the static error of the system and improve the control effect of the system. The integration link is the accumulation of past state errors. Excessive integral adjustment may lead to integral saturation effect in the system. The integral saturation effect will cause serious overshoot of a system, which will greatly affect the stability of the system.

The differential link has certain prediction function. The differential link can reflect the change rate of the current error signal and predict the future change trend. The differential link can make the controller produce advanced control effect, so that the system can quickly reduce overshoot. In addition, the differential link can also indirectly improve the lag caused by the integral link. However, excessive differential action will make the system adjustment time longer and the system response slower. The most important thing is that it will seriously affect the anti-interference ability of the system.

There are many ways to adjust the three parameters. Generally, the parameter value of PID controller is set through the test data in engineering. In addition, the control parameters can also be adjusted according to the trial and error method and the critical proportional band method. As long as the appropriate control parameters can be set, a good control effect can be achieved through the PID controller.

4.2 Cascade PID Controller Principle

Cascade PID control method is an effective means to improve control quality. Unlike single loop PID, cascade PID adopts two controllers to form the control system. The output of the outer loop control loop is the input of the inner loop control loop. The output of the inner loop control loop controls the actuator. This method can make the control effect of the system better. Figure 4 is the schematic diagram of cascade PID control.

According to the cascade PID control principle, the cascade PID control method of four rotor UAV can be obtained. Take the position signal as the control object of the main

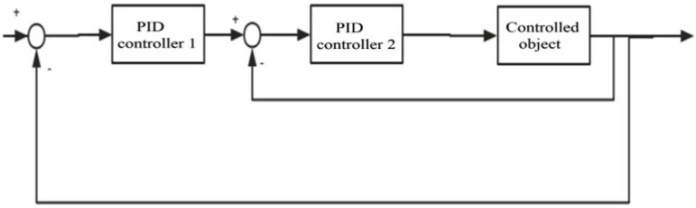

Fig. 4. Cascade PID control schematic diagram

circuit of the control system. The angle signal is the control object of the secondary loop of the control system. The output value of the position signal between the two is the input value of the attitude signal.

The four rotor UAV is a front drive system. It cannot track the six degrees of freedom of the system at the same time. Therefore, three attitude angles and an altitude value of the system can be used as control quantities. These four control quantities can be converted into the rotational speed of four rotor motors through calculation. The rotational speed of the four rotor motors is the input of the controlled object of the system. Therefore, the coordinates [x, y, z] and yaw angle of the UAV trajectory can be controlled ψ To control the attitude of UAV. Figure 5 is the flight control schematic diagram of a small four rotor UAV.

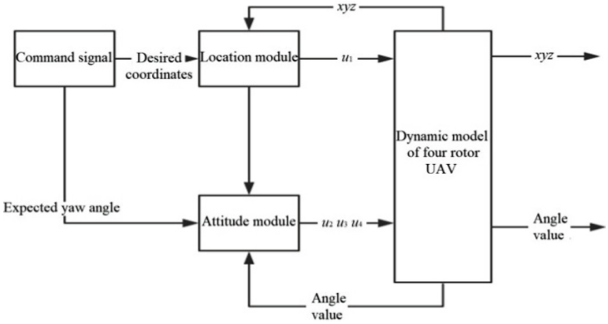

Fig. 5. Flight control schematic diagram of small four rotor UAV

As shown in the figure, the flight control system of the small four rotor UAV consists of two parts. One part is the outer loop control loop used to control the position parameters. The input of the outer loop control loop is the desired position signals x_{d}, y_{d} and z_{d}. Calculate the difference between these three signals and the actual position signal *xyz* fed back by the system. The difference generates intermediate variables through the position subsystem φ_{d}. Another part of the system is the inner loop control loop for attitude control. The control parameters of the attitude controller are θ_{d} and U_1. The input of the inner loop control loop is the intermediate variable generated by the position subsystem φ_{d}, θ_{d} and yaw angle ψ. Calculate the difference between these three angles and the actual angle signal fed back by the system. Then the calculation results are transmitted to U_2, U_3 and U_4 of the attitude subsystem. By taking U_1, U_2, U_3, U_4

and other relevant parameters into the UAV dynamic model, the actual coordinate value and attitude angle of the UAV can be calculated.

4.3 UAV Attitude Control Sub Module

To make the attitude angle at $t \to \infty$, the angle error is 0. It is suitable to use PID control law to design attitude angle control.

set up φ_{e}, θ_{e} and ψ_{e} are the errors of three attitude angles respectively. φ, θ and ψ are the current angles of the UAV.

$$\begin{cases} \phi_e = \phi_d - \phi \\ \theta_e = \theta_d - \theta \\ \psi_e = \psi_d - \psi \end{cases} \tag{12}$$

The attitude control law of roll angle is as follows.

$$\ddot{\phi} = k_p\phi_e + k_i \int \phi_e dt + k_d \frac{d}{dt}\phi_e \tag{13}$$

The pitch angle control law is as follows.

$$\ddot{\theta} = k_p\theta_e + k_i \int \theta_e dt + k_d \frac{d}{dt}\theta_e \tag{14}$$

The yaw angle control law is as follows.

$$\ddot{\psi} = k_p\psi_{\mathrm{e}} + k_i \int \psi_e dt + k_d \frac{d}{dt}\psi_{\mathrm{e}} \tag{15}$$

It can be derived from the dynamic model.

$$\begin{cases} \ddot{\phi} = \dfrac{(I_Y - I_Z)}{I_X}\dot{\theta}\dot{\psi} + \dfrac{U_2}{I_X} \\ \ddot{\theta} = \dfrac{(I_Z - I_X)}{I_Y}\dot{\phi}\dot{\psi} + \dfrac{U_3}{I_Y} \\ \ddot{\psi} = \dfrac{(I_X - I_Y)}{I_Z}\dot{\theta}\dot{\phi} + \dfrac{U_4}{I_Z} \end{cases} \tag{16}$$

The calculation expression of the moment is as follows.

$$M = I \times \ddot{A} \tag{17}$$

where, M is the moment. I is the moment of inertia. $\ddot{A}$ is angular acceleration.

$$\ddot{\phi} = U_2/I_X$$
$$\ddot{\theta} = U_3/I_Y$$

$$\ddot{\psi} = U_4/I_Z \tag{18}$$

The control law of the attitude control sub module is as follows.

$$\begin{aligned}
\ddot{\phi} &= k_p\phi_e + k_i\int \phi_e dt + k_d\frac{d}{dt}\phi_e \\
\ddot{\theta} &= k_p\theta_e + k_i\int \theta_e dt + k_d\frac{d}{dt}\theta_e \\
\ddot{\psi} &= k_p\psi_{\mathrm{e}} + k_i\int \psi_e dt + k_d\frac{d}{dt}\psi_{\mathrm{e}} \\
U_2 &= \ddot{\phi} \times I_X \\
U_3 &= \ddot{\theta} \times I_Y \\
U_4 &= \ddot{\psi} \times I_Z
\end{aligned} \tag{19}$$

4.4 UAV Position Control Sub Module

In order to make the position error tend to 0 at $t \to \infty$, it is necessary to use PID control law for the position module. *Xyz* are the current coordinate values. x_{d}, y_{d} and z_{d} are the expected coordinate values entered. x_{e}, y_{e} and z_{e} are three error values.

$$\begin{aligned}
x_e &= x_d - x \\
y_e &= y_d - y \\
z_e &= z_d - z
\end{aligned} \tag{20}$$

It is assumed that the three virtual control quantities u_{x}, u_{y} and u_{z} represent the following meanings respectively.

$$\begin{aligned}
u_x &= k_{p1}x_e + k_{i1}\int x_e dt + k_{d1}\frac{d}{dt}x_e \\
u_y &= k_{p1}y_e + k_{i1}\int y_e dt + k_{d1}\frac{d}{dt}y_e \\
u_z &= k_{p1}z_e + k_{i1}\int z_e dt + k_{d1}\frac{d}{dt}z_e
\end{aligned} \tag{21}$$

Then the position control law can be obtained according to the dynamic model.

$$\begin{cases}
T = m\sqrt{(u_x^2 + u_y^2 + (u_z + g)^2)} \\
\phi_d = ac\sin((\sin\psi_d u_x - \cos\psi_d u_y)m/T) \\
\theta_d = ac\sin((u_x m - T\sin\psi_d\sin\phi_d)/(T\cos\psi_d\cos\phi_d))
\end{cases} \tag{22}$$

There is an anti sinusoidal trigonometric function in this expression. Define it again. $AC = (\sin\psi_{\mathrm{d}}u_{\mathrm{x}} - \cos\psi_{\mathrm{d}}u_{\mathrm{y}})m/T$. $AB = (u_{\mathrm{x}}\, m - T\sin\psi_{\mathrm{d}}\sin\varphi_{\mathrm{d}})/(T\cos\psi_{\mathrm{d}}\cos\varphi_{\mathrm{d}})$.

When the value of *AC* and *AB* are greater than 1, the expression (22) will not have a solution. Therefore, when *AC* and *AB* are greater than 1, $\varphi_{\mathrm{d}} = \pi/3$, $\theta_{\mathrm{d}} = \pi/3$. When the absolute value of *AC* and *AB* are not greater than 1, set $\varphi_{\mathrm{d}} = \mathrm{acsin}(AC)$, $\theta_{\mathrm{d}} = \mathrm{acsin}(\boldsymbol{AB})$. When the value of *AC* and *AB* are less than 1, set $\varphi_{\mathrm{d}} = \theta_{\mathrm{d}} = -\pi/3$.

5 Design of UAV Flight Control System

After obtaining the control laws of the position sub module and the attitude sub module, the UAV control system can be simulated according to these equations. The simulation of flight control system of four rotor UAV is mainly realized by matlab simulink. The design idea of four rotor unmanned flight control system mainly includes six processes. The first step is to enter the desired coordinate value. The second step is to compare the coordinate value calculated by the system with the current actual coordinate value of the UAV, and generate an error value through operation. The third step is to transmit the generated error value to the position controller. A virtual control quantity will be generated, together with the pitch angle and roll angle calculated by the system. The fourth step is to compare the pitch angle and roll angle calculated by the system with the current actual angle of the UAV, and generate an error signal through calculation. The fifth step is to transmit the error signal to the attitude control module and generate three virtual control quantities U2, U3 and U4. The sixth step is to transmit the above virtual control quantity to the UAV dynamic model module, and generate six outputs through operation. The six outputs are three coordinate values and three angle values respectively. Then the six outputs are fed back to the control system. Repeat the above operation steps until the output value of the control system is consistent with the set expected value.

The MATLAB Simulink simulation diagram of UAV flight control system built in this paper is shown in Fig. 6.

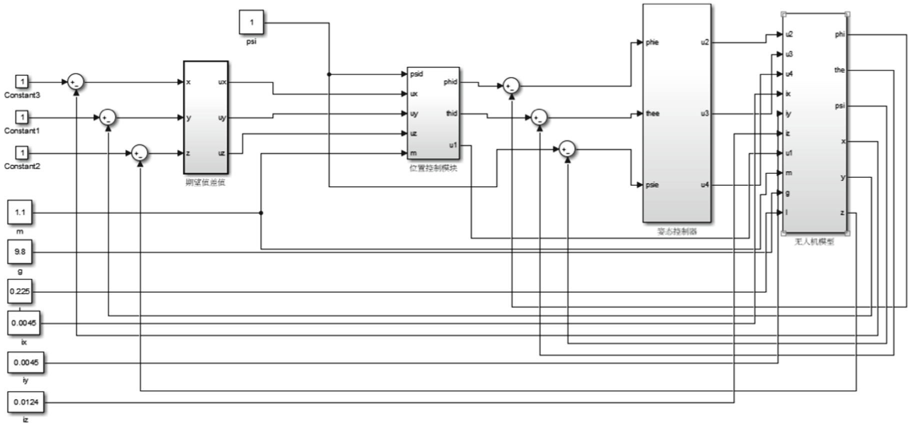

Fig. 6. Simulation diagram of UAV flight control system

6 Simulation Analysis

According to the simulation system shown in Fig. 6, the flight control system of UAV built with cascade PID controller is simulated. Before the simulation test, the parameters in the UAV flight control system are assigned (Table 1).

Table 1. Parameters of four rotor UAV

Parameters	value
K	0.75
L/m	0.225
m/kg	1.1
$I_x/(\mathrm{kg{\bullet}m^2})$	0.0045
$I_y/(\mathrm{kg{\bullet}m^2})$	0.0045
$I_z/(\mathrm{kg{\bullet}m^2})$	0.0045
$g/(\mathrm{m{\bullet}s^{-2}})$	

Assume that the expected coordinate value of the system is (4, 4, 4). Set the yaw angle to 1. The simulation results are shown in the figure below.

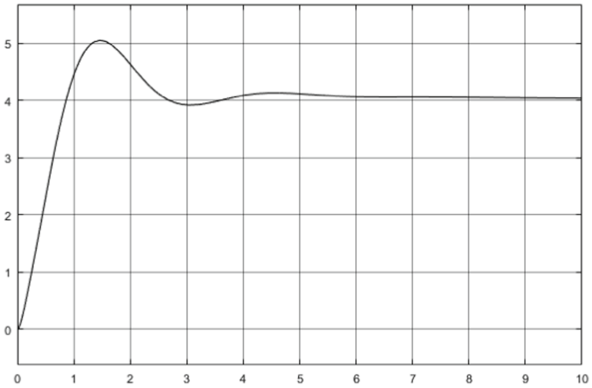

Fig. 7. Response curve of X channel

The position sub module uses PID controller to control the main loop. Analyze the response curves in Fig. 7, Fig. 8 and Fig. 9. In general, the control parameters of the three channels of *XYZ* respond well under the control of PID controller. However, there is still some overshoot in the initial stage of the control process, which makes the system unable to reach a stable state quickly.

Analyze the response curves in Figs. 10 and 11. In the initial stage, the roll angle and pitch angle will change rapidly. The final roll angle and pitch angle approach 0. When unmanned flight reaches the desired position, there will be no error value. The input of the final position controller is 0. The following roll angle and pitch angle will also make the error equal to 0 under the control of the controller. Thereafter, the control quantity transmitted to the control system model is also 0. The production angle calculated by the model also becomes 0. In this way, all the operation processes of the control system are basically completed (Fig. 12).

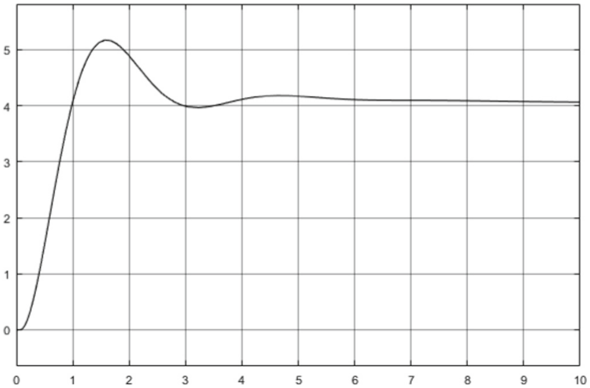

Fig. 8. Response curve of *Y* channel

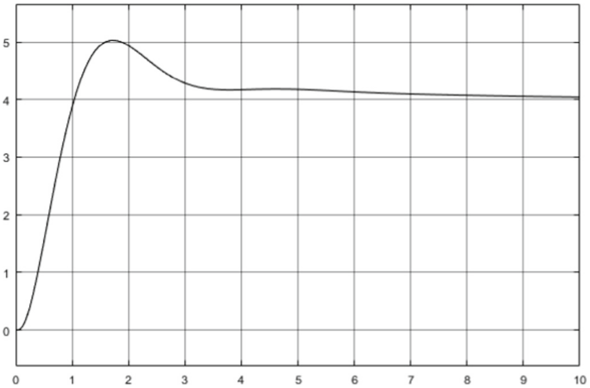

Fig. 9. Response curve of *Z* channel

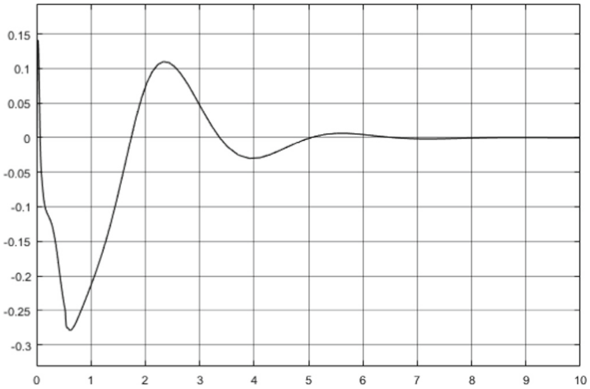

Fig. 10. Response curve of rolling angle

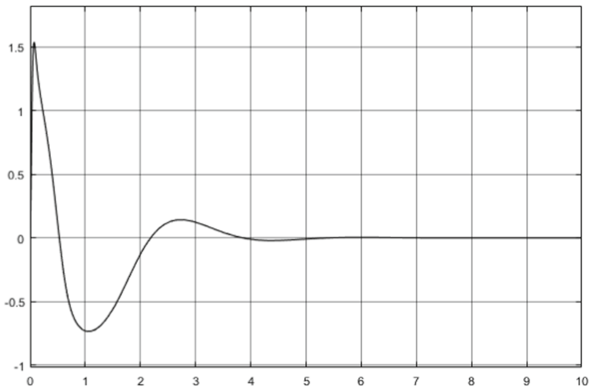

Fig. 11. Response curve of rolling angle

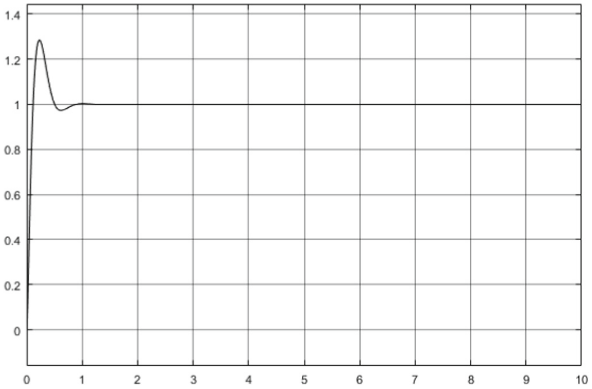

Fig. 12. Response curve of yaw angle

The yaw angle is different from the pitch angle and roll angle. Yaw angle is a desired angle set artificially. The desired angle is the UAV operating attitude when the control system finally reaches a stable state. Assuming that the value of the initially set expected yaw angle is 1, the parameter value of the yaw angle will be maintained at 1 after the system is controlled by the controller.

7 Conclusion

This paper focuses on the motion characteristics of four rotor UAV. Based on the mechanical structure of the four rotor UAV, the force analysis of its flight state is carried out. The relationship between position control and attitude control of four rotor UAV is analyzed. The dynamic model of four rotor UAV is constructed. Finally, taking the classical cascade PID control method as an example, the simulation experiment is carried out by using matlab/simulink platform. The simulation results show that the traditional PID control method can well control the four rotor UAV in low-speed operation. However, it is still difficult to control the underactuated system of the four rotor UAV in high-speed flight. We need to find a more advanced control method to achieve precise control of the four rotor UAV flying at high speed.

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