Partial study of quadrotor based on Quaternions

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Abstract

In this paper, the attitude calculation of quadrotor is studied, and the attitude angle of quaternions and the method of using IIR low pass filter to filter the high frequency noise are proposed.First of all, this paper puts forward the characteristics of quadrotor more flexible than other aircraft.The flexible steering mode of quadrotor is classified into three categories.Starting from reality, this paper proposes an algorithm to transform the value of acceleration sensor to pose angle, which can greatly reduce the amount of computation and is the theoretical basis for real-time attitude calculation of aircraft.When introducing the number of quaternion, this article starts from the theoretical model and first introduces the conceptual meaning of the number of quaternion.In this model, the aircraft's own coordinate axis and the geographical axis are regarded as two rigid bodies, and they have three coordinate axes that are orthogonal to each other.When the steering operation is involved, the corresponding acceleration is generated. By using the quaternion multiplicative formula mentioned in this paper, the change of attitude angle can be obtained.n reality, in order to ensure the accuracy of the output attitude angle. More accurate input variables are often needed, and the IIR low pass filter is introduced in this way.In this paper, a nine order IIR filter is designed according to the actual situation, and its spectrum characteristics are obtained by simulation software.After mixing the original signal generated by propeller's high frequency noise, it outputs clean signals through filter, all of which are intuitively reflected by three spectrum images.After giving some practical solutions, this paper looks forward to the prospect of the aircraft.

Keywords

Quadrotor quaternions Attitude calculation IIR low pass filter.

1. Introduction

The pilotless aircraft is called "UAV", which is abbreviated as "UAV", which is operated by radio remote control equipment and its own program control device, or operated autonomously by vehicle mounted computer completely or intermittently.[1] According to the different principles, unmanned aerial vehicles can be divided into fixed wing aircraft and rotor aircraft. Among them, the fixed wing aircraft refers to the wing relative to the body. The technology that does not produce relative motion is already very mature and shows superiority in the field of aircraft. On the other hand, the rotorcraft is relatively complex, and develops relatively slowly. It has the characteristics of vertical take-off and landing and floating in the air. Now it has a broader development prospect.

Early rotorcraft is mainly single rotor helicopter with traditional, sensor technology and computer technology, from 1950s to the present, has emerged a number of ruav concepts, such as the three axis, four axis, six axis aircraft etc.. Among them, the quadrotor attracts the attention of many researchers

because of its novel and simple structure and unique and flexible way of flight, and has increasingly become the focus of the field of UAV.[2]

Figure 1. Four axis rotor unmanned aerial vehicle [3]

As a vertical take-off and landing unmanned aerial vehicle (UAV), quadrotor has a very broad application prospect. In military affairs. In the field, it can be used for ground battlefield surveillance, reconnaissance, close air patrol, access to enemy intelligence, ground communication。

In the civil field, it can be used in agricultural testing, emergency rescue and disaster relief, film and television shooting, etc.[4]

The quadrotor also has very considerable potential economic value. Four - axis aircraft is simple in structure, convenient in maintenance, low in cost, and for its wide use. Its application prospect and market are very huge. In a word, it is of great significance to carry out academic theoretical research, promote related industries and technology development, strengthen national defense construction and create economic benefits and so on, which is of great significance for theoretical and technological research of quadrotor. At the same time, the four - axis vehicle is of great value for sustainable development. For example, in visual development, you can using the airborne image equipment of quadrotor as the experimental platform, the research of visual positioning and visual navigation system is carried out.[5]In the field of automatic control, as an input system with four control inputs and six degrees of freedom output, the underactuated system has the characteristics of multivariable, nonlinear and strong coupling.

2. Model foundation

2.1 The basic structure and principle of quadrotor

A quadrotor is usually driven by a control module located at its center. The basic structure is mainly composed of a cross frame and a hollow cup propeller at the arm.The whole aircraft can be regarded as a rigid body. The center of the aircraft includes the power module, the control module, the attitude sensor, the barometer and so on. The control module generates power through controlling the propeller rotation, and the information collected by sensors helps the control module to determine the state of the aircraft and control the rotation direction and speed of the four propellers, so that the aircraft can run steadily.

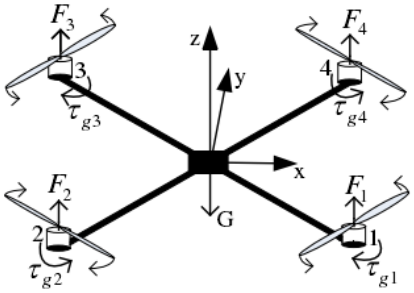

Figure 2 A schematic diagram of the force of a quadrotor[6]

As shown above, in order to ensure the smoothness of the flight, the rotation direction of the propeller is not the same, and it is necessary to ensure that the reverse torque of the body is counterbalanced to each other.

2.2 The principle of three main postures for quadrotor

The motion state of the quadrotor is mainly described by the translations in the direction of X, y, Z in the coordinate system o-xyz and the rotation of the three axes around x, y, and Z. Among them, the rotation of the X, y and Z axes around the body coordinate system is also known as pitching, rolling and yaw motion. The translational motion in the direction of X, y and Z is also called the front and rear movements, the left and right movements and the ascending and descending motion [6].

Pitching movement

Which refers to the rotation of the body around the axis of the coordinate axis on the Y axis

$$\begin{cases} F_1 = F_2 \\ F_3 = F_4 \\ F_1 + F_2 < F_3 + F_4 \end{cases}$$

Rolling movement

Similar to the pitching movement, rolling movement refers to the rotation of the X axis of the aircraft around the coordinate system.

Yaw movement

In previous studies, it was mentioned that the rotation of the propeller of the quadrotor would have the effect of reverse torque on the body. And the yaw movement formally uses the anti torque action of four propellers to turn the body in the center of the Z axis of the axis. The flexibility of this movement is one of the features of the quadrotor.

$$\begin{cases} T_1 = T_3 \\ T_2 = T_4 \\ T_2 + T_4 < T_1 + T_3 \end{cases}$$

3. Attitude angle model establishment

3.1 The relation of quaternions with attitude matrix

The three simple movements mentioned above can achieve a steady steering of the aircraft relative to itself. In reality, if we want to make the aircraft fly according to the set program, we must use the attitude calculation. This is a transformation between the coordinates of the aircraft itself and the actual coordinates acquired by the velocity and acceleration information obtained by the sensor In reality, if we want to make the aircraft fly according to the set program, we must use the attitude calculation. This is a transformation between the coordinates of the aircraft itself and the actual coordinates acquired by the velocity and acceleration information obtained by the sensor.

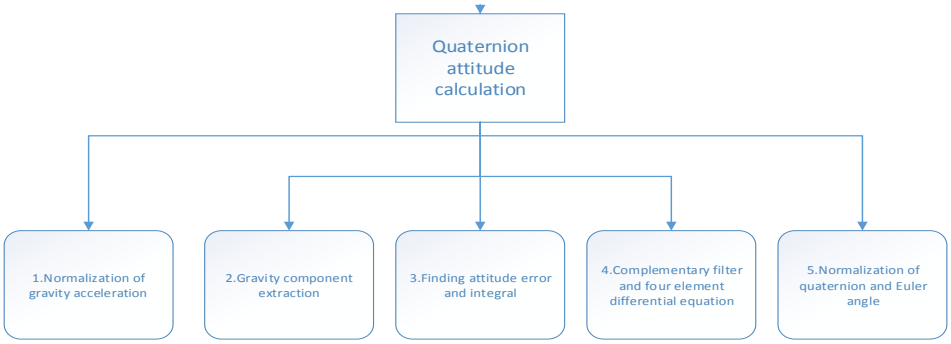

Figure 3 quaternion solution for attitude thinking guided map

After learning the attitude of quaternions, I divided the process into five main steps and summed up as a mind map. In this paper, I will briefly introduce the quaternion, and introduce the algorithm in the order of the diagram.

3.2 The definition of the number of quaternion

As the name suggests, the number of quaternion is quaternions.

$$Q(q_0, q_1, q_2, q_3) = q_0 + q_1 i + q_2 j + q_3 k$$

Among them, q0, q1, q2, q3, is a real number, i, j, k unit vector is orthogonal to each other, and the imaginary unit. The relationship can be described as the same as quaternion, the unit vector number is virtual unit properties, a unit vector product characteristics of different unit vectors for quaternion by the number of. So the number of quaternions can be considered as a super complex number.

3.3 The relationship between the quaternion and the attitude array

There is a reference coordinate system R,The axis of the coordinate is x_0, y_0, z_0,Fixed point rotation of rigid body relative to R coordinate system. The rotation unit axis vector is $\vec{r} = (x, y, z)$.The angle of rotation is θ. Then the representation of the quaternion is:

$$q = \begin{bmatrix} q_0 \\ q_1 \\ q_2 \end{bmatrix} = \begin{bmatrix} q_0 \\ \vec{q} \end{bmatrix} = \begin{bmatrix} \cos(\theta/2) \\ \vec{r}\sin(\theta/2) \end{bmatrix}$$

According to the multiplication rule of quaternion, the attitude matrix of quaternion can be obtained.

$$R = \begin{bmatrix} q_0^2 + q_1^2 - q_2^2 - q_3^2 & 2(q_1 q_2 + q_0 q_3) & 2(q_1 q_3 - q_0 q_2) \\ 2(q_1 q_2 - q_0 q_3) & q_0^2 - q_1^2 + q_2^2 - q_3^2 & 2(q_2 q_3 - q_0 q_1) \\ 2(q_1 q_3 + q_0 q_2) & 2(q_2 q_3 - q_0 q_1) & q_0^2 - q_1^2 - q_2^2 + q_3^2 \end{bmatrix}$$

In the conversion of the two coordinate system, the transformed matrix is also the orthogonal matrix because it keeps the right angle coordinate system. Usually, in order to conform to people's habit of spatial thinking, they will turn the result into the form of Euler angle matrix

3.4 Attitude signal filtering

A quadrotor, the processor must filter the sensor online in real time. In reality, there will be many high-frequency noises generated by power components, which is technically unavoidable. Too much noise can increase the processor's computing burden and reduce the accuracy of the processed data. So I use the digital low pass filter to filter the signal, which can improve the signal to noise ratio of the signal. From the unit impact response of the filter, the digital filters can be divided into two categories: the limited impact response (FIR) and the infinite impulse response (IIR).IIR filter can obtain high selectivity through the lower order, with less storageunit, high efficiency, but contains a nonlinear phase; FIR filter with linear phase filter, but to achieve the same performance, the order number is 5~10 times higher than the IIR filter, the signal delay. For quadrotor, the processor must make real-time online filtering. So the algorithm can't be too complicated, and the delay must be within the control range.

By analyzing the frequency of the sensor signals and noise signals, I found that the high frequency signal is the main component of the noise. After preliminarily setting the parameters of the filter, I designed a nine order low pass IIR filter.

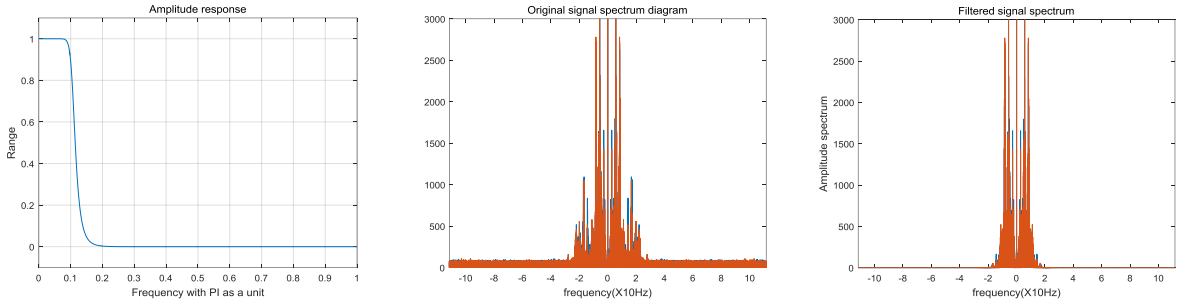

Figure 4 Filtering results

On the original signal waveform collected, I superimposed the Gauss white noise and the noise produced by the motor in the way of software simulation. The original signal was synthesized and its spectrum was obtained by fast Fourier transform. After the filter, such as the amplitude characteristic, as shown in the first picture, I succeeded in restoring the spectrum of the original signal. It can be seen that the IIR low pass filter is helpful to the removal of noise signals.

4. Conclusion

The development of shaft aircraft has been developing for a century, but its early development is very slow. Until the popularity of electronic technology, the quadrotor has been developing rapidly in recent years. Although the technology in this field has matured, this paper studies the quadrotor from one point of view, and has some reference results. To sum up the work done in the previous article, the main points are as follows. The background, development history and domestic and foreign research status of quadrotor are investigated and analyzed. Then the steering mode and its principle of the quadrotor are studied, which play a role in the establishment of the following two coordinate systems. In order to solve the problems mentioned above, the theory of four variables is introduced. In the paper, the theory of quaternion is introduced in detail, and the formula of obtaining the attitude matrix from the gravity component is given. As the core content and purpose of this paper, after the algorithm is put forward, a feasible solution is also given for the noise interference in practice.

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