Research on the Intelligent Aircraft Design based on STM32

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Abstract

With STM32f767 igt6 (M7 series) as the core, the intelligent aircraft designed this time will finally realize the intelligence of the aircraft by using the optimized attitude algorithm (cascade PID and single-stage PID share the optimized control), omni-directional ultrasonic radar detection barrier collision prevention technology, long-distance wireless transmission technology (to realize the timely transmission of images recognition), navigation technology (Beidou and GPS double positioning to realize more accurate positioning), voice recognition technology, man-machine interaction technology, and wireless local area network technology.

Key words: Aircraft, man-machine interaction, wireless transmission, PID

1. Introduction

1.1. Research background

In the inspection of the expressway, the UAV is used to conduct the inspection of the high-speed section. It is possible to carry out the first-time processing of various emergencies, and truly grasp the road conditions of the expressway in real time. In the field of forest fire prevention, various line electronic devices are not easy to install, so the application of the drone can immediately monitor the situation of the forest[1].

Another advantage of the four-rotor unmanned aerial vehicle is its small size. Unmanned aircraft can achieve autonomous flight in the air and perform certain tasks. Compared with ordinary aircraft, it has a simple structure, low cost, and it is easy to maintain and manufacture. It can be used for real-time battlefield investigation, target positioning, and unit tracking in military rain. It can be used for civilian disasters and technology to detect major disasters. It can find lost personnel rescue work and can also carry a variety of scientific equipment for scientific experiments.

1.2. This design innovation content

The designed aircraft, voice interaction, image recognition, and stereo radar design are the highlights. The main control core adopts STM32F767 as the first aircraft designed for M7 in China. M7 processing speed, excellent running effect and stable performance. It can carry a variety of smart sensors, and have multiple peripheral interfaces to support IIC, USART communication external device mounting and large-size screen display.

1.3. The main work of the paper

The control algorithms, software programs, and hardware circuits of large quadcopters are developed and designed.

In this paper, the communication protocols used by various quad-rotor aircrafts are analyzed in depth and optimized for program design.
According to the current mainstream algorithm of quadrotor, the attitude control is optimized.

This design analyzes the fusion algorithm that uses multiple types of sensors to achieve flight movement control.

2. Principle and Modeling of Four-rotor Aircraft

2.1. Four-rotor dynamics analysis

First, the four-rotor aircraft has a cross shape with four arms. In flight, there are generally two states, X-shaped or cross-shaped. The aircraft is equipped with an imaging device. The principle is to realize the action of the aircraft through the angle between the aircraft and the horizontal plane. First of all, the quadrotor has a cross shape and has four arms.

Generally, there are two states when flying, X-type or cross-type X. The angle between the arm and the forward direction is 45 degrees, and the adjacent arms are perpendicular for each other. The arms coincide with the forward direction, and two adjacent vertical arms are crossing[2].

2.2. Four-HelicalMathematical Modeling

The four-helical aircraft is a nonlinear, multiva-riable, highly coupled, underactuated system. The motion state of the aircraft has 6 degrees of freedom, and there are only 4 inputs. The idealized model is assumed as follows[3].

2.2.1. DC motor modeling

The phase voltage of each winding of the three-phase brushless DC motor is composed of the winding induced potential and the copper wire's own resistance[4]. Therefore, the following voltage balance equation can be used for each voltage.

$$U = IR + L\frac{\mathrm{di}}{\mathrm{dt}} + E \tag{1}$$

Then the three-phase DC state equation is

$$\begin{bmatrix} U_a \\ U_b \\ U_c \end{bmatrix} = \begin{bmatrix} R_a & 0 & 0 \\ 0 & R_b & 0 \\ 0 & 0 & R_c \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} L_{aa} & L_{ab} & L_{ac} \\ L_{ba} & L_{bb} & L_{bc} \\ L_{ca} & L_{cb} & L_{cc} \end{bmatrix} \begin{bmatrix} \dot{i}_a \\ \dot{i}_b \\ \dot{i}_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \tag{2}$$

The equivalent circuit diagram of the three phase brushless motor can be obtained from the voltage equation, as shown in the Fig.1 below.

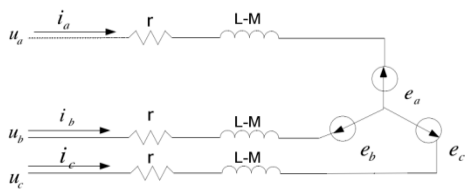

Fig.1 Equivalent circuit diagram of three-phase brushless motor

2.2.2. Establishment of the torque equation

The current magnitude and electromagnetic tor -que of a phase brushless motor are proportional to the flux.

$$P = T_e \omega = \sum_x i_x e_x \tag{3}$$

The equation of motion of the motor is as follows:

$$T_e = T_L + J\frac{d\omega}{dt} \tag{4}$$

2.2.3. Establishment of the aircraft model

The four-rotor has six flight states: rising, descending, forward, backward, leftward, and rightward. In order to stabilize the hover, it is necessary to detect the angle between the four motors and the horizontal plane. The aircraft uses the quaternion and Euler angles in 3D stereology to represent the angle of rotation. The calculation formula uses a 3D Cartesian coordinate system, as shown in the Fig.2 below.

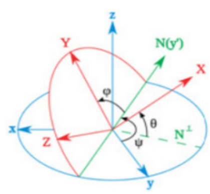

Fig.2 3D Cartesian coordinate system Definition of quaternion

$$\mathrm{q} = [\mathrm{w}\ \ \mathrm{x}\ \ \mathrm{y}\ \ \mathrm{z}]^T \tag{5}$$

$$|q|^2 = w^2 + x^2 + y^2 + z^2 = 1 \quad (6)$$

Conversion of Euler angles to quaternions:

$$q = \begin{bmatrix} w \\ x \\ y \\ z \end{bmatrix} = \begin{bmatrix} \cos(\phi/2)\cos(\theta/2)\cos(\psi/2) + \sin(\phi/2)\sin(\theta/2)\sin(\psi/2) \\ \sin(\phi/2)\cos(\theta/2)\cos(\psi/2) - \cos(\phi/2)\sin(\theta/2)\sin(\psi/2) \\ \cos(\phi/2)\sin(\theta/2)\cos(\psi/2) + \sin(\phi/2)\cos(\theta/2)\sin(\psi/2) \\ \cos(\phi/2)\cos(\theta/2)\sin(\psi/2) + \sin(\phi/2)\sin(\theta/2)\cos(\psi/2) \end{bmatrix} \quad (7)$$

Quaternion is converted to Euler angle:

$$\begin{bmatrix} \varphi \\ \theta \\ \psi \end{bmatrix} = \begin{bmatrix} \arctan\left(\dfrac{2(wx + yz)}{1 - 2(x^2 + y^2)}\right) \\ \arcsin(2(wy - zy)) \\ \arctan\left(\dfrac{2(wz + xy)}{1 - 2(y^2 + z^2)}\right) \end{bmatrix} \quad (8)$$

3. Aircraft scheme design

3.1. Overall scheme design

The aircraft modules used in this design include M7 series control cores, attitude sensors, intelligent interactive equipment, wireless remote control equipment, obstacle avoidance equipment, positioning equipment, and upper computer display equipment[4].

3.2. Equipment selection

This article frame (F450), motor (B2212 brushless motor), ESC (SimonK ESC), NRF24L01 wireless module, ESP8266 WIFI module, voice recognition module LD3320A, ultrasonic module HC-SR04, OV5640 camera module, GPS Beidou dual positioning Module S1216, attitude sensor MPU6050 AK8975.

4. Hardware scheme design

4.1. Overall design

After the selection is completed, the overall circuit design scheme is born accordingly. Each module we use has its own communication method. Each module occupies different internal resources of the core main control board according to different design schemes.

4.2. STM32F767 minimum system design

This system includes a reset circuit. The hardware reset button for testing the system; the Jlink download interface is used to download programs and online testing. The SDRAM external expansion circuit uses the W9825G6KH chip to expand the 256K memory capacity to 32M, which enhances the demand for memory of each program. The FLASH chip used in the FLASH external circuit is MT29F4G08, which adds 512M of storage space to the main control.

It can be used to store pictures and key information.

4.3. Power supply design

This power supply contains 5V to 3.3V regulated power supply, which mainly supplies power to 3.3V modules and core STM32F767 chips. Expand the power supply 5V-3V, in order to prevent the voltage from being too high, the voltage regulator is used to stabilize the voltage.

4.4. Module Interface Circuit Design

As each module transmits information through digital signals, the common interfaces are IIC, UART, and motor interface, voice interface, camera interface, etc.

5. Software scheme design

5.1. Single-level PID control algorithm

The PID algorithm of input and output response is controlled, and the parameters are adjusted to make the input and output response reach an ideal state[5]. The PID is divided into positional and incremental, and the positional PID is related to the error of the whole past, and the integral link is used. The incremental PID is only related to the error of the first two beats, and the output is the control increment.

5.2 . Cascade PID control algorithm

Cascade PID is divided into inner ring and outer ring. The input and feedback are angle data, but the inner ring input feedback is the angular velocity data, which is quickly corrected according to the expected speed. The outer ring is input to the inner ring according to the angular deviation, and the inner ring determines how much the speed should be operated according to the angular deviation.

Generally, we only use PI control in the outer ring. Proportion corrects the aircraft from the deviation angle to the desired angle; Integration eliminates the angular static difference. In the inner ring, we adopt PID control. Proportion corrects the yaw angular velocity of the aircraft to the desired angular velocity. Integration eliminates the static acceleration difference[6]. Different coefficient suppresses the system motion.

6. Testing and conclusion

The design satisfactorily completed the design requirements, realized the stable flight of the aircraft. It detected the environmental parameters and realized the function of human-computer interaction. It provided more convenient control through the remote control of the mobile phone, and supported real-time one-megapixel image transmission. It can record or take pictures and support GPS/Beidou global positioning and synchronize positioning in real time in Google Earth.

Google Earth is a simulated earth that contains information about various roads and buildings on the entire earth. A 3D version of the earth model, we will use the NMEA protocol format positioning information to configure the corresponding serial port with Google Earth . Then it can show Google Earth the location of its aircraft. The aircraft positioning information is shown in Fig.3 and The Google Earth interface is shown in Fig.4.

Fig.3 Aircraft position

Fig.4 Google earth

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