Flight Attitude Control of Small UAV

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Abstract

Taking the engineering application as a starting point and summarized the research status of four rotor smicro UAV in the data acquisition and the attitude to put forward the design of UAV's data acquisition and attitude calculation system, with low cost, high precision and high reliabilityrequirements of the project. Then, paper designed the software and hardware system of UAV's dataacquisition and attitude calculation. It takes the STM32F40} MCU as the controlcore, and base on the electrical characteristics of the sensor to design the signal processing circuit, and also base on the size of UAV to design PCB board. Finally, paper is through the analysis of data acquisition of static, start-up but not flying and hovering flight and free flight to meet the system is satisfy of requirements of low cost, high accuracy and high reliability. This paper describes the flight control system in detail from three aspects: hardware design, software development, system debugging and flight test, and carries out relevant flight tests on the basis of system debugging. The embedded main control system designed in this paper meets the four rotor UAV with low cost, high precision and high reliability, and realizes the control of static, start-up, no flight and vertical rise, vertical descent, forward and backward movement, left turn and right turn.

Keywords

Four-rotor Unmanned Aerial Vehicle; Sensor; Quaternion; Filter;System Design.

1. Introduction

With the continuous development of automation technologies such as automatic control, communication technology, GPS and MEMS (micro mechanical sensing technology), many UAVs based on strapdown inertial navigation technology have emerged one after another. UAV has many advantages, such as flexible design, high space utilization, light weight, small volume, strong load capacity, strong survivability, low cost, long endurance time, strong autonomous control ability and so on. At present, micro UAV is mainly divided into micro fixed wing UAV, micro rotor UAV and flapping wing UAV Based on bionic design [1]. Multi rotor UAV has the advantages of small volume, light weight, vertical takeoff and landing, hovering and low requirements for working environment. As the core technology of four rotor UAV, flight control system is a complex nonlinear, time-varying and multivariable control system, which involves data acquisition, data processing, wireless communication, closed-loop feedback, modern control theory and other related contents. It has great market demand and research value, and its research results have a wide application market.

The small four rotor UAV is equipped with corresponding control system, which is composed of four independent motor-driven rotors (i.e. propellers) fixed on the cross structure.

The distance from the four motor shafts to the geometric center of the body is equal, and the four rotors installed on the motor shaft have the same structure and radius and are in the same height plane.

The main control system consists of a microcontroller, several sensors, electric regulator, power supply, receiver and remote controller.

The flight control system of four rotor UAV adopts modular design, which is mainly composed of main controller, sensor module, drive module, power supply module, wireless communication module and remote control module [2-3]. The main controller solves the attitude information and position information collected by the sensor module in real time, and outputs the PWM wave signal with appropriate duty cycle to control the speed of four motors according to the given flight mission command and the corresponding control algorithm, so as to control the flight attitude and position of the UAV.

2. Design and implementation of hardware

2.1 Hardware composition of four rotor UAV

The hardware experimental platform of X-type four rotor UAV Based on STM32 microprocessor can be divided into central control module, sensor module, drive module, receiver module, communication module and power module.The central module is the core processor, which is responsible for data calculation. The sensor module is composed of attitude sensor and height sensor, which are respectively responsible for different data acquisition. The drive module consists of four brushless motors [4]. The motor speed is controlled by electric regulation. The remote control receiver module includes a remote controller and a receiver. The power module is a lithium battery with a full working voltage of 16.8v.

2.2 Hardware design of control system

2.2.1 Sub-section Headings

The central control module, the core processor of the flight control system, is the core control part of the system. Collect sensor information and calculate the body attitude angle and height in real time; According to the remote control receiver information or navigation information, combined with the real-time calculated body attitude angle and height, control the motor speed; Two way data transmission with the ground station through the wireless communication module, including uploading control instructions or modifying parameters and downloading flight status data [5].

Stm32f405 single chip microcomputer is the CPU of 32-bit cortex-m4 core, and the working frequency is 168mhz,three 12 ADC with conversion time of 0.31uso, three I2C modules, six USARTs and 140 gpios, with single precision floating-point operation unit and enhanced DSP instruction set. Because STM32 Series MCU is cheap, has strong data processing ability, embeddedness, real-time performance and reliability. It is widely used in all walks of life.

2.2.2 Sensor module

The system adopts 6-axis accelerometer / gyroscope mpu6000.Leadless square package and programmable low-pass filter. Full digital interface, ultra small volume, pin pin pin lead out, more flexible configuration, module size 4 * 4 * 0.9mm.

2.3 Drive module

The motor rotates at high speed to drive the propeller to provide lift for the UAV. The six degree of freedom action transformation of the UAV is realized by changing the motor speed. It is the core component of the drive module.At present, there are mainly two kinds of motors used in aircraft models in the market: brushless DC motor and brushless DC motor.UAV requires high response speed and rotation speed of motor [6]. Therefore, brushless DC motor is selected in this paper.

2.4 Communication module

In order to display the flight data of UAV in real time on the upper computer, monitor the flight state of UAV and better control the flight of UAV, this paper chooses to build a communication module. The communication module consists of two parts: transmitting module and receiving module. The transmitting module communicates with the main controller through the corresponding interface, communicates various flight data of the UAV through the USB serial port, receives it through the receiving module, and finally transmits it to the upper computer for display.

3. Software Dsign Of Flight Control System

3.1 Program structure

The platform construction of UAV software includes embedded main control system, application of operating system functions, system programming, PID control algorithm and wireless communication. The system programming includes 12 tasks, such as attitude controller task, sensor processing task, remote controller PPM signal receiving task, remote controller processing task and so on [7]. According to the design requirements, this paper only expounds the main control system, the function of the operating system, some programming in the system program and PID control algorithm.The system software design flow chart is shown in Figure 1.

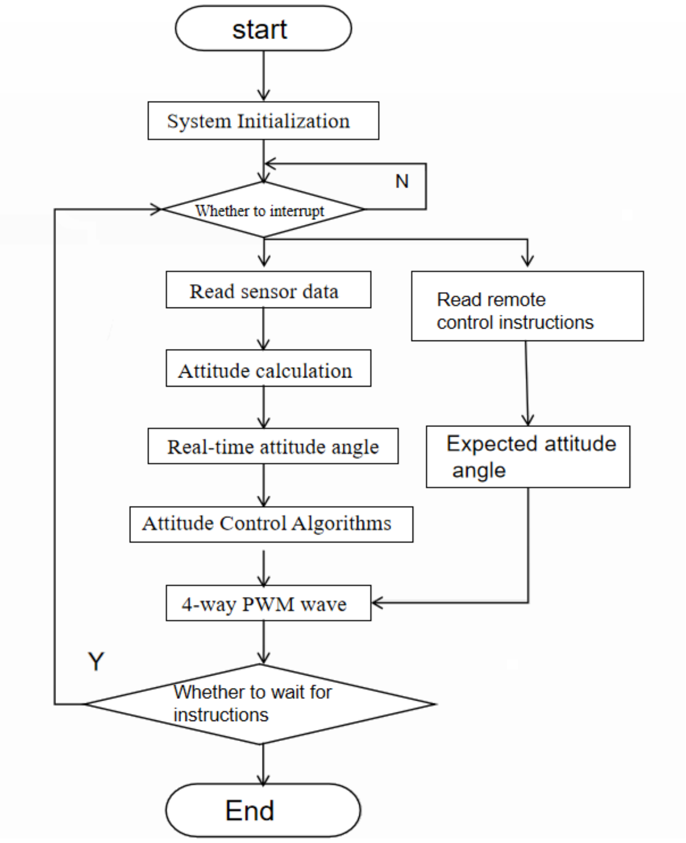

Figure 1. Software design flow chart

3.2 Function and application of embedded operating system

3.2.1 FreeRTOS operating system

FreeRTOS operating system is a completely free commercial RTOS, so it is very popular.It runs efficiently.

The functions provided by FreeRTOS include task manager, time management, semaphore, message queue, memory management, recording function and so on, which can basically meet the needs of small systems.Its main characteristics are: (1) scheduling algorithm; (2) Real time, (3) preemptive scheduling algorithm, (4) number of tasks (5) communication between tasks.

Create a task using FreeRTOS's API function xTaskCreate(), which can be used to change the priority of any task after the scheduler starts.Some of the functions that are often called are listed here for your reference. See Table 1.

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Table 1. List of functions frequently called by FreeRTOS

API Functions	Function name	brief introduction
xTaskCreate()	Create Task Function	Dynamic Creation
vTaskDelete()	Delete Task Function	Delete a task
vTaskPrioritySet()	Task Priority Change Function	Change the priority of the task
vTaskDelay()	Delay Functions	Task blocked
vTaskDelayUntil()	Absolute delay function	Delay an absolute time
xTaskResume()	Task Ready Call Function	Interrupt operation

3.2.2 PID control algorithm correlation

The PID controller consists of three unit modules: proportional (P), integral (I), and differential (D). The PID controller is a negative feedback mechanism. It calculates the difference between the information value returned by the real-time feedback of the control object and the target value, and recalculates the difference as the input signal. By repeatedly adjusting the relevant parameters of the controller, the gap between the actual output value and the target value is continuously narrowed, thus achieving accurate control of the control object. The desired angle is the angle value of the remote control to control the aircraft, and the feedback current angle is the angle of the aircraft measured by the sensor.

The expected angle comes from the remote control data, and the feedback angle comes from the sensor. The deviation between the two is the input of the outer ring angle ring and the expected value of the angle ring PID output angle speed. The angular velocity expected value minus the angular velocity feedback from the sensor obtains the angular velocity deviation value, which is used as the input of the inner ring angular velocity ring, the angular velocity ring PID outputs the attitude control amount, and the control amount is converted to PWM to control the motor, thus controlling the four axes.

3.3 Summary

Starting from the software design of the UAV system, this chapter designs the main architecture of the UAV system, the software design of the UAV system, the software design of the UAV system, the application of the embedded real-time operating system FreeRTOD, the writing of some programs and the relevant content of PID control. In addition, the system physical part has been debugged several times, and the problems encountered in the debugging process and the solutions are summarized in detail.

4. Problem solving

The calibration of the sensor mentioned in this paper mainly focuses on the calibration of the spiral instrument and accelerometer. The calibration method is hexahedral calibration.

Accelerometers are required for self-stabilizing mode. If the accelerometer is not calibrated properly or the flight control is not installed in the center position, it will cause serious drift of the self-stabilizing mode output line. Therefore, calibrating sensors and accelerometers is particularly important.

On the other hand, during the connection process, it is found that the PPM receiver and the remote control are not connected successfully. This problem may be caused by the mismatch between the parameters of the remote control and the parameters of the receiver when they are changed, the connection failure may also be caused by accidental encountering of the reset key of the remote control during the connection process. The solution is to reset the receiver and long press to make it in the connecting state, set up the remote control to connect, and reconnect successfully.

The problem of not displaying the motor value after PID bypass occurred during the calibration process, which was solved later by means of re-calibration and power-on of the motor.

5. Conclusion

This design takes the STM32F405 single-chip computer of ARM company as the core controller. Through the introduction of the previous chapters, each module is perfectly combined to achieve the basic functions: static, startup unflying and vertical rise, vertical descent, forward and backward motion, left-to-right turn control, etc.

This design mainly accomplishes the following main tasks:

The design of a four-rotator UAV system based on STM32 introduces the overall scheme and gives the schematic diagram. Design of four-rotator unmanned aerial vehicle system based on STM32.The design of a Four-rotor unmanned aerial vehicle system based on STM32 achieves the unmanned aerial vehicle's control of startup unflight, vertical rise, vertical descent, forward-backward motion, left-to-right turn, etc. Draw the corresponding software flowchart in Visio and write program code in Keil; debug the object.

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