Design of reconnaissance system based on STM32 small multi-rotor real-time image transmission

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Abstract. This project analyses the main technical points of aircraft design, makes a preliminary discussion on rotor dynamics and mechanical analysis of four-axis aircraft, analyses the particularity of aircraft structure, control flexibility and control principle, establishes three-dimensional rigid body coordinate axis for aircraft. Describes the relationship between flight attitude and coordinate axis. Chooses a multi-channel attitude fusion algorithm, anti-jamming data transmission mode, adjusts the relationship between frequency and rate of wireless data transmission in detail. At the same time, the principle and arithmetic of the PID controller are analyzed in detail, and it is applied to the speed control of DC motor of aircraft. Through experimental verification and test, a good stable control effect is obtained. The design and implementation of the flight control system and remote control software and hardware are completed, and the test and flight test of the whole aircraft are completed. The flight control stability is good. It has the characteristics of small size, fast response and long communication distance. It can fully meet the reconnaissance requirements of obtaining real-time high-definition images in various complex situations. The upper computer software can quickly decode image data, convert it to video output to ground personnel, and realize FPV reconnaissance.

1. Introduction

In response to various needs of social development, the work scene is becoming more and more diverse. In this application context, UAV has received widespread attention, and the Rotor UAV carrier has been developed more mature. In practical application, UAV is suitable for aerial photography, near-ground reconnaissance, surveillance, Agricultural Broadcasting and other tasks. It can accomplish tasks independently under the established program control, save costs, liberate human labor force, and has a very broad application prospect. For example, in the military field, many products at the forefront of science and technology are always the first to be tried in the military field, so are multi-rotor aircraft, which first appeared in the military field. The military designed multi-rotor aircraft to solve some difficult tasks in the military field, such as real-time surveillance of targets, precise survey of narrow terrain, interception of mission targets, and so on. The evaluation of attack effect and so on can even directly attack the target with ammunition. Small multi-rotor aircraft is especially suitable for short-range detection. It can carry out real-time detection tasks in the air which is tens or hundreds of meters close to the target. Logistics: Some foreign companies, such as Amazon [2], are studying the application of multi-rotor aircraft in logistics. Because the four-axis aircraft has the characteristics of low take-off environment, fixed-point suspension, convenient collection and delivery of express
delivery, stable flight for a long time, ensuring that express delivery will not be damaged in the transport process, and so on, it meets the requirements of the logistics industry. And in the game field: because the cost of UAV is getting lower and lower, and the price is more close to the people, it can be applied to the game industry. Previous aircraft simulation games used to operate virtual aircraft, but when four-axis aircraft was used in the game industry, real small aircraft could be operated for game confrontation.

In summary, four-axis multi-rotor aircraft has broad application prospects in both military and civil fields. The long-distance FPV (First Person View) [3] reconnaissance system based on STM32 four-axis aircraft developed in this project can acquire real-time image information of the target area with ground station, which is very suitable for military reconnaissance and natural detection.

2. Systematic overview

2.1. Research method
The idea of top-down and step-by-step refinement is adopted in the overall implementation process. Firstly, it lists all the functions needed by the system, and then decomposes all functions into a small independent function. Then it tests the independent functions of UAV flight control, high-definition image acquisition and long-distance wireless communication separately. After each independent module passes the test, the whole system is integrated, which makes the whole system decomposed and modularized, and facilitates the subsequent supplement and replacement of some design functions.

The four-axis aircraft designed in this project is based on the actual cases of four-axis aircraft at home and abroad [4-5], learning its advantages, and combining with its own research conditions, through continuous theoretical improvement, a more perfect design scheme of four-axis aircraft is finally obtained.

2.2. Main Technical Indicators
The UAV system developed in this project is a small multi-rotor UAV and its ground station system which can be used for reconnaissance of complex geological areas and image collection. The main technical indicators are as follows:
1) Load: 2-3 kg
2) Flight time: 20-30 minutes
3) Wind Resistance: Level 3-4
4) Communication Distance: 1-2 km
5) Image quality: 480P-1080P

3. Implementation plan
The overall scheme of long-distance FPV reconnaissance system based on STM32 four-axis vehicle is shown in Fig. 1. It consists of four hardware components: small multi-rotor UAV, UAV remote controller, image acquisition and wireless communication, including multi-rotor UAV control system, image acquisition system, wireless communication system and ground station.
4. Design Scheme

The main research contents of this scheme are as follows: the design of multi-rotor UAV system, including UAV attitude resolver and attitude controller, is mainly used to control UAV to maintain balance. The design of remote controller of UAV mainly lies in the design of multi-degree-of-freedom joystick. Man controls the small multi-rotor UAV mainly through remote controller and completes specific image acquisition tasks. To design a wireless communication transceiver system, it is necessary to ensure long-distance control and high-speed transmission of image data on the premise of low cost. An image acquisition system is designed to collect real-time high-definition images of the observation area and surrounding environment. The main technical route of the system is shown in Figure 2.

Figure 2. Technical Roadmap
4.1. Four-Axis Vehicle Control System

The control system of small multi-rotor UAV includes attitude estimator, attitude controller and UAV power system. The control system block diagram of multi-rotor UAV is shown in Fig. 3. In this study, the attitude of UAV is fused with three-axis accelerometer, three-axis gyroscope data and three-axis magnetometer using complementary filter to get the accurate attitude of UAV. This design uses MPU6050 six-axis digital sensor, which integrates three-axis accelerometer and three-axis gyroscope. It can provide the required acceleration and gyroscope data at 200 Hz frequency for attitude estimation. At the same time, the HMC5883L three-axis digital magnetometer can provide the required direction data at 50 Hz frequency and assist in attitude control.

The controller of UAV mainly uses the widely used PID controller [6-7] to control the attitude of UAV and keep the balance of UAV. In this design, STM32 based on ARM cortex-m4 core is selected as the controller of UAV. Complementary filters are used to estimate attitude and PID control for multi-rotor UAV balancing control and other required calculations. The control period is 0.02s.

As the actuator of the control system, the performance of the power system of the Rotor UAV has a great influence on the control effect. Brushless motor, commercial brushless motor governor, propeller and aviation lithium battery are selected as the power system of this design. Brushless motor has the advantages of high efficiency, no electromagnetic interference, long life and reliable operation because it cancels the mechanical contact structure composed of brush and commutator, and has no commutation spark and mechanical friction. Therefore, brushless motor is chosen as power system, and commercial electronic governor and propeller matched with brushless motor are used to ensure the good performance of power system.

The battery requirements of small multi-rotor UAV have the following characteristics: high current discharge capacity, small size, light weight and so on. Aviation lithium battery pack can well meet the above requirements, is a better choice, choose lithium polymer battery as our power supply system.

4.2. Wireless Communication System

The remote controller of the Rotor UAV is designed by imitating the commercial model remote controller. The remote control joystick uses the same joystick as the commercial model remote control. The wireless module of the remote controller chooses to use the wireless transceiver chip NRF24L01. NRF24L01 is a new type of monolithic RF transceiver. Its working frequency range is 2.4 GHz–2.5 GHz ISM, and its effective working distance is long. Functional modules include frequency synthesizer, power amplifier, crystal oscillator, modulator, etc. Output power and communication channel can be

![Figure 3. Control System of Four Axis Vehicle](image-url)
configured by program, and enhanced Shock Burst technology. NRF24L01 has low power consumption, such as 9 mA working current when transmitting at -6 dB power and 12.3 mA working current when receiving, which has strong endurance ability. Figure 4 shows the NRF24L01 hardware module designed by this project.

Figure 4. NRF24L01 hardware module

4.3. Image Acquisition System
In order to record the information of Geology and geomorphology, this design uses OV7620 high-definition camera to collect the image information of reconnaissance area, and transmits the information to the upper computer of ground station through wireless communication system, so that the reconnaissance personnel can understand the situation of reconnaissance scene and the surrounding environment in real time. Because of the large amount of image data and the high resource of data transmission, the design separates the image acquisition system from the four-axis aircraft control system. The image acquisition system will not occupy the resources of the MCU of the UAV control system, so as to avoid affecting the control of the UAV.

4.4. Ground Station System
The ground station system is mainly composed of wireless communication receiving and processing system and upper computer software. The host computer is a multi-rotor dedicated host computer developed by the anonymous Kechuang team, which is mainly responsible for the display of image data. However, the image data sent by the aircraft will generally produce a lot of noise and distortion. Before decoding to the image, it needs to be filtered and de-distortion processing, so that the ground reconnaissance personnel can have a more intuitive view.

5. Concluding remarks
The design of the Four-rotor UAV flight system in this paper includes a safe, stable and self-stabilizing UAV flight system, which can fly flexibly under the control of ground personnel to reach the appropriate location in the reconnaissance area. Four-rotor UAV uses complementary filter to solve attitude, uses PID algorithm to control, uses STM32 (32-bit) controller based on arm cortex-m4 to estimate attitude and calculate attitude PID control. The running frequency of STM32f4 series is up to 180 MHz, and can complete all calculation within 0.02s of UAV control cycle. It has been realized in the project research foundation. In this project, the unmanned aerial vehicle remote controller uses NRF24L01 wireless transmission module, the transmission distance is more than 2 km, and realizes the remote control of the unmanned aerial vehicle in a larger radius. This project adopts PFV reconnaissance system, and the rapid transmission of UAV aerial photographs, including a high-definition image transmission equipment with high reliability and long-distance rapid transmission of data, to ensure that UAV can...
still carry out reliable and fast transmission of image data in the process of long-distance flight. The Four-rotor aerial survey UAV designed in this paper is easy to carry and operate. It has the advantages of low site requirement, no airport takeoff and landing, flexible and fast operation mode, fast response to shooting tasks, low altitude operation and under-cloud photography. It has great advantages in local information acquisition. It can also take multiple photographs of a geological disaster point, obtain high overlap image and enhance it. The reliability of subsequent processing can be used to acquire high resolution images in small and difficult areas.

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