A Design and Implementation of Quad-rotor UAV

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Abstract

In the past 5 years, considerable attention has been paid to unmanned intelligent devices. The Quad-rotor UAV(Unmanned Aerial Vehicle) is an unmanned aircraft controlled by radio remote control equipment and self-contained program control device. Our UAV is based on TI MSP432, which can be connected to PC via USB port. This printed circuit board is used to transmit the program for the flight control of UAV. The OpenMV module serves as the data source of the line patrol controller, which is the top-level controller, the same level as the remote controller. The IMU unit calculates information to attitude controller, in order to keep the flight of UAV stable. After the IMU solution information is fused with the optical flow sensor, the information is sent to the horizontal controller to control the flight of the UAV in the horizontal direction. Similarly, After the IMU information is fused with the laser height information, the height controller is applied to control the flight height of UAV.

Keywords: UAV, OpenMV module, IMU unit

1. Introduction

With the rapid development of the times and the rise of the intelligence of unmanned devices, the unmanned intelligent devices have received extensive attention in the past 5 years. Four rotor UAV is a kind of UAV controlled by radio remote control equipment and independent program control device[1]. At present, the application of UAV in aerial photography, agricultural plant protection, mapping and other fields has greatly expanded the use of UAV itself [2][3].

Compared with general aircrafts, UAVs are widely used in both military and civil fields. The outstanding advantage of the UAV is that people can control the aircraft remotely, or even let the aircraft perform tasks according to the designed procedures to liberate human resources.

Based on the above discussion, this design focuses on the basic function realization of UAV and the realization of camera and line patrol function based on OpenMV. This design system uses MSP432 microcontroller of TI company for flight control, OpenMV3 camera for machine vision processing[4], optical flow sensor and other technologies, through program design and hardware production, the UAV can complete various tasks. In various fields of military and residential life, the design has a very high practical value.

2. Main control device

2.1. Selection of controller

With the development of electronic technology, we have more possibilities in the selection of main controller. Our team had planned to use STM32 single-chip computer and TI series single-chip computer respectively to carry out the flight control experiment of the line patrol robot.

Compared with 51 single-chip microcomputer, STM32 single-chip microcomputer has the advantages of faster processing speed and more peripheral serial ports. Besides, our team members are familiar with the application of STM32 single-chip microcomputer. Therefore, we choose this single-chip microcomputer in the beginning. We read the data collected by MPU6050 through the programming code, determined the state of the aircraft, and then carried out the corresponding data processing.

We find that in the flight control of Quad-rotor UAV, compared with TI series single-chip microcomputer, STM32 single-chip microcomputer has some disadvantages in program processing speed and power consumption. When the main controller of Quad-rotor UAV has a large amount of computation, STM32 cannot meet our requirements.

TI uses the Cortex-M kernel, which contains the access to the complete arm instruction set. In addition. It also includes the DSP extension instruction and a floating-point FPU module, which improves the performance compared with STM32. Therefore, after the discussion with team members, we chose TI series MSP432 single-chip microcomputer.

2.2. Control system scheme

We adopt the scheme of minimum system of single-chip microcomputer. The minimum system of single chip microcomputer has high-performance simulation technology and abundant on-chip peripherals, which can significantly reduce the design of peripheral circuits and reduce the difficulty of system design. It is very suitable for our system design, and this scheme has an efficient and flexible development environment.

3. Machine vision tools

Optical flow is the apparent movement of the image brightness mode. Under certain conditions, the motion information of an object can be obtained based on the optical flow[5]. We install the optical flow sensor at the bottom of the drone, use the optical flow method to analyze the ground feature information collected by the camera, calculate the speed of the aircraft relative to the ground, and combine the speed obtained by the optical flow method with the speed obtained by the inertial element to obtain more accurate Data, and then obtain the relative position information of the aircraft through integration to achieve positioning. Optical flow methods are divided into two categories, dense and sparse. Among them, dense optical flow calculation is complex and requires a large amount of resources. It requires the processor to have high computing power, so it cannot be applied to embedded platforms[6].

The maximum output of image information collected by Ov7725 camera is 300000-pixel image, which is smaller than the maximum output pixel of OpenMV. With active crystal oscillator and voltage regulator chip, and FIFO frame buffer chip - the chip contains 384K FLASH, which can cache two frames of QVGA image data, but the stability is relatively poor.

OpenMV is an embedded camera with STM32 as the processing core. It is equipped with micro Python interpreter and supports Python Programming on the embedded. This system uses OpenMV instead of computer to carry out a series of image acquisition and processing tasks, and can directly control the pan tilt system, simplifying the structure of the system, making the whole system less cost, smaller volume, and easier to apply to real life scenarios. When the whole moving target tracking system works offline, the system only takes up 10 cm *10 cm * 10 cm space, which is incomparable with another scheme. In addition, the anti-interference ability of OpenMV is stronger than that of Ov7725 camera.

To sum up, our team decided to choose the OpenMV3 camera and use Python language for machine vision processing. OpenMV is shown in the Fig.1.

Fig.1. OpenMV

4. Microcontroller

MSP430 is a 16-bit reduced instruction set microcontroller. Developers can write commonly used systems flexibly, including timer, input / output expander, system reset controller, electrically erasable programmable read-only memory (EEPROM), etc.

32 in MSP432 represents that the MCU is 32-bit. Compared with 16-bit RISC (reduced instruction set) MSP430, MSP432 adopts 32-bit RISC, which greatly improves the performance. While optimizing the performance, the power loss is reduced, and its effective power consumption and standby power consumption are only 95μA/MHz and 850nA/MHz respectively. After comprehensive consideration, we choose MSP432 controller. MSP432 board is designed as shown in the Fig.2.

Fig.2. MSP432 board

5. Mpu6050 sensor

Mpu-6050 is the first integrated 6-axis motion processing component in the world. Compared with the multi-component scheme, Mpu-6050 avoids the problem of the difference between the time axis of the combined gyroscope and the accelerator, and reduces a lot of packaging space. Mpu-6050 has a full sensing range of ± 250, ± 500, ±1000 and ±2000°/sec(DPS), which can accurately track fast and slow movements.

5.1. Calculation

The mpu6050 sensor has an internal digital LPF, which can be modified by setting the value of the config register.

This is the initialization program of mpu6050 sensor written by our team during the calculation.

```
I2C_Write_Byte(MPU6050_ADDRESS,
PWR_MGMT_1,     0x80);
I2C_Write_Byte(MPU6050_ADDRESS,
SMPLRT_DIV,     0x00);     0x00(1000Hz)
I2C_Write_Byte(MPU6050_ADDRESS,
PWR_MGMT_1,     0x03);
I2C_Write_Byte(MPU6050_ADDRESS,
CONFIGL,        0x04);     0x04(20Hz)
I2C_Write_Byte(MPU6050_ADDRESS,
GYRO_CONFIG,    0x18);
I2C_Write_Byte(MPU6050_ADDRESS,
ACCEL_CONFIG,   0x18);
```

5.2. Automatic correction (triaxial acceleration sensor)

$${}^{b}a_{m} = T_{a}K_{a}({}^{b}a'_{m} + b'_{a})$$

6. UAV attitude control

We use PID to control the position of the aircraft to obtain the desired speed, and obtain the actual speed based on the sensor fusion. The PID is used to control the speed of the aircraft, and then the closed-loop PID control algorithm is used to control the attitude of the aircraft [7]. In attitude control, we need to know three values: quaternion, rotation matrix and Euler angle.

If you need to transform vectors between coordinate systems, you can choose matrix form; another method is to use Euler angle as the “master copy” of azimuth, but maintain a rotation matrix at the same time. When the Euler angle changes, the matrix also needs to be updated at the same time. When large amounts of data are saved (such as animation), Euler angles or four yuan numbers are used, while Euler angles occupy less than 25% of the memory, but the conversion to matrix is slow. If the animation data needs to nest the connection between coordinate systems, quaternions may be the best choice. Smooth interpolation can only use quaternions. In other forms, we must turn to quaternion, then turn back after interpolation, and then get the attitude solution [8] [9].

7. Hardware circuit design

7.1. Overall system diagram

The overall diagram of the system is shown in the Fig.3.

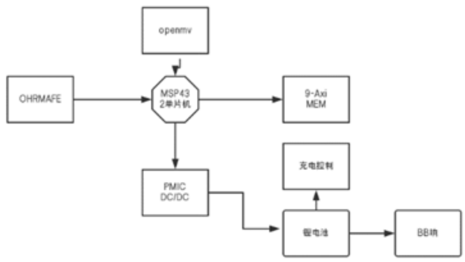
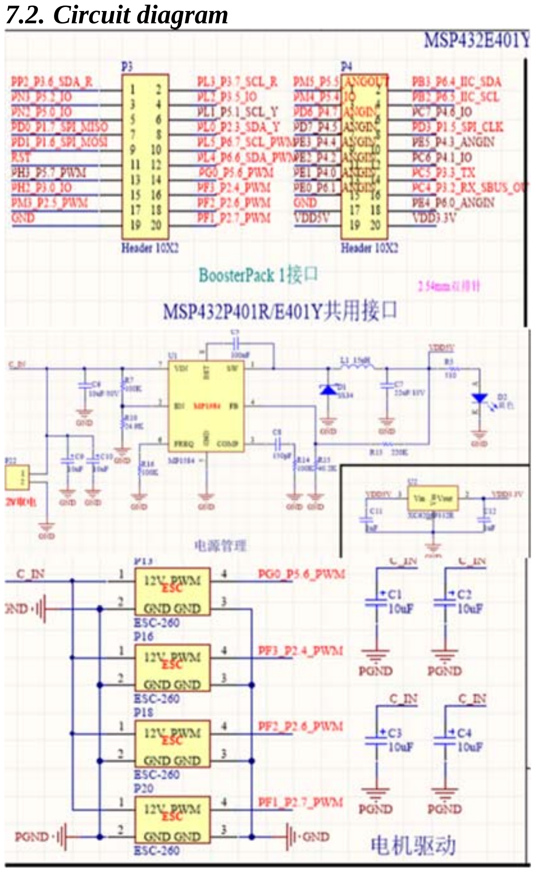


Fig.3. Overall system diagram

7.2. Circuit diagram



7.3. Power supply

The power supply consists of transformer, filter and regulator. Provide 5V or 12V voltage for the whole system to ensure the normal and stable operation of the circuit. This part of the circuit is realized by 3 terminal voltage-regulator tube.

8. Program design

The program design is divided into two parts, which are written by different members. The first part is the control of the aircraft, including take-off, hover height determination, rotation, horizontal flight and landing, etc. The second part is the OpenMV self-process, including color and line recognition, shooting, storage and so on.

The main idea of our programming is to first use the C language to write the one button take-off procedure, and then use the keil5 software and optical flow sensor to realize the four-rotor aircraft's height and stability.

After that, the joint debugging of OpenMV and flight control is carried out to realize the cable seeking flight of the aircraft. At the same time, the self-program of OpenMV realizes the function of taking photos and storing in the flight process.

9. Test plan and result analysis

According to the requirements of UAV safety performance, we set up the experimental site in our laboratory and carried out many tests. The main testing instruments and instruments we use are: MSP432 microcontroller, optical flow sensor, OpenMV3cam7 camera, HIGHDISCHARGELI-POBATTERY lithium battery and sw-lds50a laser module.

Through the above module and the corresponding program, we have been able to achieve the line finding and basic flight and can achieve the function of fixed height and camera shooting storage.

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