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**Research Article**

# Design of Four Axis Aircraft Based on Arduino Used in City-wide Food Delivery

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**Abstract:** In the process of the short distance food transportation and distribution, the traditional transportation mode not only needs a lot of labor, but also the transportation efficiency is not very high. Therefore the four axis aircraft is used as a new type of UAV system, which can save a lot of labor time and improve the efficiency. According to the principle and design of the four axis aircraft, this study selects the Atmega 2560 processor platform based on Arduino system. The MPU-6050 of the integrated of accelerometer and gyroscope is used as the sensor of the flight attitude data acquisition, Neo6 GPS U-box and MS5611 are respectively used as GPS positioning system and fixed height barometer, the 2.4 Ghz global opening band is used for the wireless data transmission. The flight attitude of the algorithm is based on the smoothing filtering algorithm and fusion algorithm, then using PID control motor speed to adjust flight attitude. Finally, the paper makes the experiment and debug of the four axis aircraft prototype and the results were basically met the expected results of the design.

**Keywords:** Arduino, attitude calculation, food delivery, four axis aircraft

## INTRODUCTION

Four axis aircraft is a representative of the multi-rotor aircraft which has four symmetrical cross distribution of propeller, controlling the attitude of the aircraft through adjusting the speed of the propeller (Yang and Wang, 2008). It has the characteristics of small size, light weight, simple structure, reliable performance, flexible control, flight stability and so on Liu *et al*. (2010). Because four axis aircraft is more stable and reliable than conventional helicopters and has almost no mechanical structure problems, it can become a very good UAV platform and has a great advantage in the implementation of the task (Zhang, 1994).

With the in-deep study on the theory of automatic control, miniaturization and integration of motor and electronic device, progress and development of manufacturing materials, multi-rotor aircraft represented by the four axis aircraft has a rapid development (Zhou and Huang, 2009). Therefore, in this study, we study and design the four axis vehicle, so that it can be used in the city-wide transportation and distribution of food (Fan *et al*., 2014). Due to the advantage of not affected by traffic and save manpower, the four axis aircraft greatly improves the work efficiency. At the same time, the use of electric energy is clean energy, not only to protect the health of food and to protect the natural environment, so the design and production of four axis aircraft used in city-wide food distribution is of great significance (Li *et al*., 2015).

## MATERIALS AND METHODS

**System hardware components:** In order to achieve the stability of the four axis aircraft flight and of some kinds of attitude control, we should design a reasonable hardware system, including the sensor elements, signal control and receiving part, drive circuit etc. The complete structure of hardware system is shown in Fig. 1.

Microprocessor unit is the core of the structure of the hardware system, each sensors' real-time data transferred via I2C to processor, thus the processor performance determines the corresponding control system's speed. The main measurement unit is accelerometer and gyroscope, which measure three axis acceleration and angular velocity respectively; baro meter is used to measure the current altitude, the magnetometer and the GPS module are used to locate the motion direction and the space position of the aircraft. In the control and drive system, we send and receive signals through the remote controller and receiver. According to the current attitude and control command, the system drives the electronic speed controller in the way of PWM to control the rotation of the motor. This constitutes a basic four axis aircraft system.

For the basic structure of the four axis aircraft, we have the following options for each part of the device. The first is to use the Arduino development board to achieve the core control part of the four axis aircraft, this

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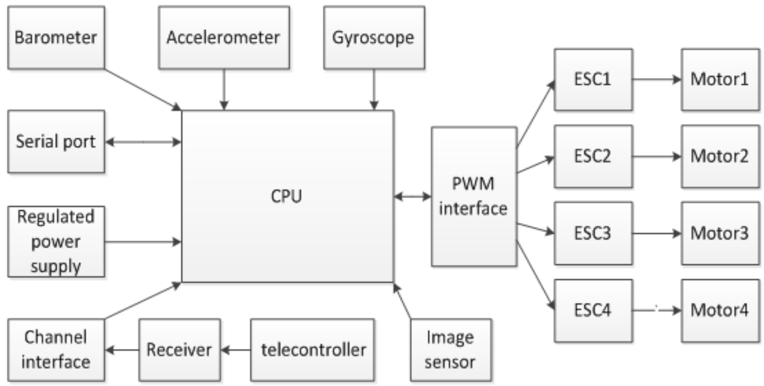


Fig. 1: Control system

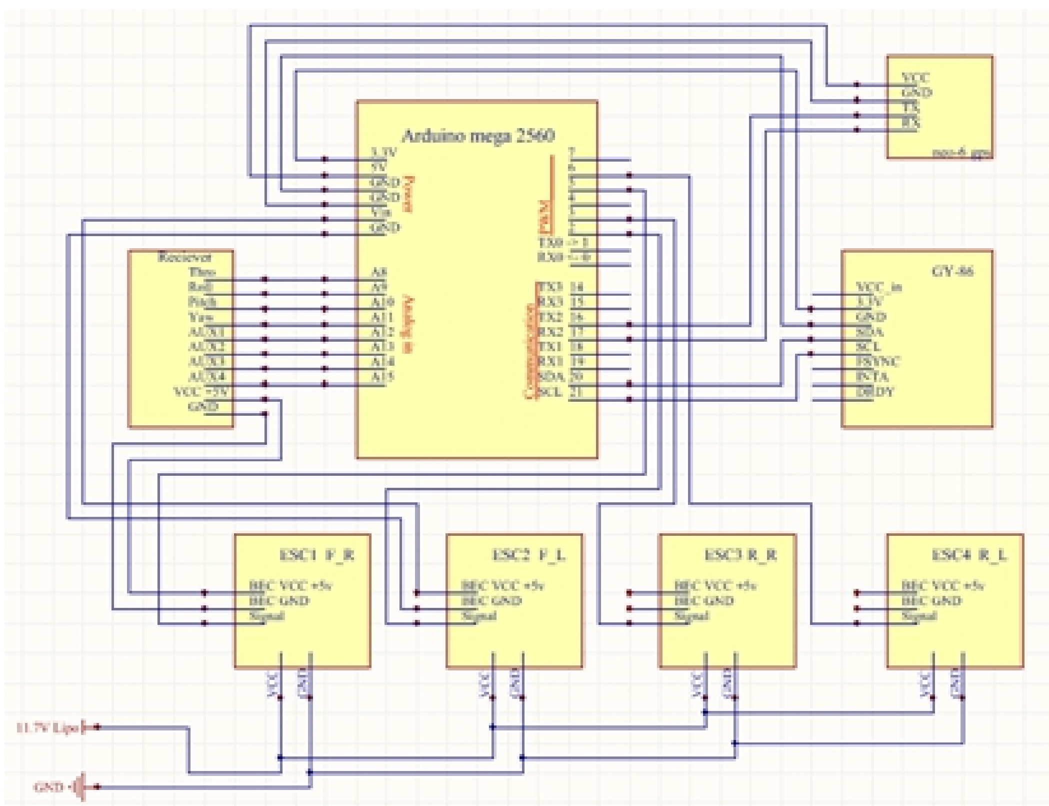


Fig. 2: Hardware system

is a piece of open source hardware and software development board, its rich basic functions save a lot of work for us, only through the wiring and a small amount of welding, we can achieve the construct of hardware (Cheng, 2013). At the same time, its programming software IDE Arduino uses the combination of C language and JAVA language, which saves a lot of time for users who have been exposed to programming language, we can write programs in a very short time and it can be very convenient for debugging (Song and Han, 2014).

We use the GY-86 module as sensors, which integrates MPU6050 accelerometer and gyroscope module, ms 5611 pressure meter module. The size of this module is very small and it can be fixed on the development board through adhesive. The NEO-6 Gps is used as the Gps module, it’s a high precision Gps made by U-blox which can set specific parameters through PC software U-center, meanwhile it can be connected directly through the Arduino development board serial communication port. The image sensor uses the RC832 receiver and the TS832 transmitter and uses the micro FPV camera to reduce the weight, the real-time monitoring can be carried out by liquid crystal display. The wiring of hardware as shown in Fig. 2.

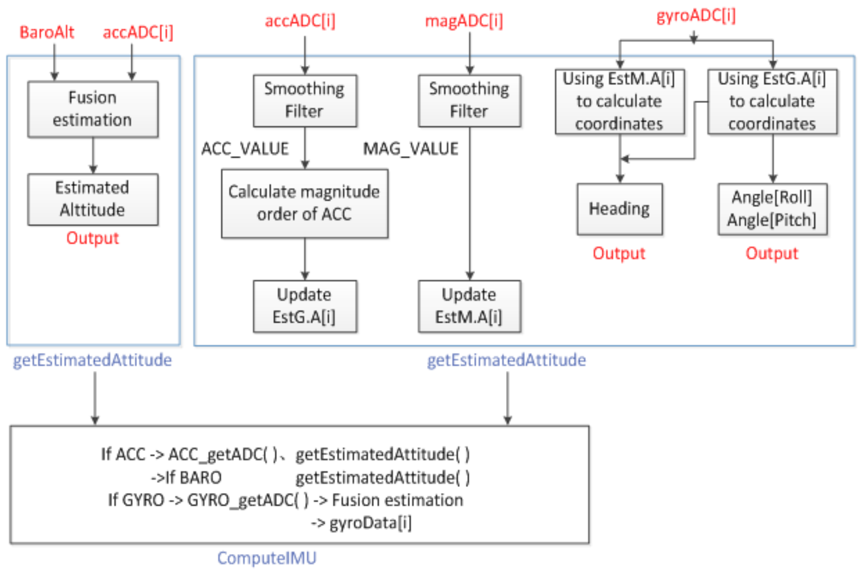


Fig. 3: Attitude solution process

**Software system design:** The control core of the four axis aircraft is the attitude calculation process, a stable detailed algorithm can accurately calculate the current flight attitude, the main process is to calibrate accelerometer, gyroscope, barometer's value to obtain an accurate results, so we adopt the attitude fusion algorithm. The main flow chart is shown in Fig. 3.

**Attitude solution process:** In the actual movement, the system will move along each direction, not a single axis movement, the movement of each axis will produce superimposed. So, so we have to carry out the operation of a attitude matrix, the original data is from the accelerometer, gyroscope, barometer, electronic compass. Because of the high frequency vibration of the system will influence the accelerometer, the gyro will drift after a long period of time working, so the original data value of the sensor must be filtered to obtain more accurate value (Pedro and Lozano, 2004).

When the system is running, the processor reads the value of each sensor and then carry out the corrected operation. First is the value of the gyroscope, record the initial value as the prerious value of the next state operation and carry on an average operation. Then carry on an smoothing filter, the average value of the gyro is used to smoothing filter calculation. However, the calculated values of the gyroscope are not angle value, we have to calculate the range through its sensitivity and then define a time point as the previous point of time, the command issue time point as the current time point, through this time period to calculate the changing angle of the gyroscope.

In the same, the magnetic force gauge and accelerometer value after smoothing filter can be used to rotate matrix operations and the two rotation matrix EstG and EstV are obtained. Since the motion of the four axis vehicle is a fusion process, so we decompose the process of motion and then superimposed, the process is the first Y axis, then the X axis, the final Z axis. We assume that the aircraft rotated γ degrees around Y axis, then rotated θ degrees around X axis, finally rotated φ degrees around Z axis. Superposition the obtained attitude matrix after each rotation, since the time period of our sample is very small, the angle of the change is very small, so we can use the small angle approximation method, cos θ≈1, sin θ≈0, than we can get:

$$\begin{pmatrix} X_b \\ Y_b \\ Z_b \end{pmatrix} \approx \begin{pmatrix} 1 & -\sin\varphi & \sin\gamma \\ \sin\varphi & 1 & \sin\theta \\ -\sin\gamma & -\sin\theta & 1 \end{pmatrix} * \begin{pmatrix} X_n \\ Y_n \\ Z_n \end{pmatrix} \tag{1}$$

This can calculate the three axis euler angle from the attitude matrix which has been corrected, the direction of the aircraft can be obtained by the fusion of the magnetic force meter matrix and the acceleration matrix. The current flight height can be obtained by the measurement of the air pressure gauge and the temperature compensation, now we have finished the calculation.

**Regulation of control signal:** This can calculate the three axis euler angle from the attitude matrix which has been corrected, the direction of the aircraft can be obtained by the fusion of the magnetic force meter matrix and the acceleration matrix. The current flight height can be obtained by the measurement of the air pressure gauge and the temperature compensation, now we have finished the calculation.

However, when the four axis aircraft normal flight, will be subject to external force or magnetic interference, there will be a distortion on accelerometer or magnetometer values. The system is difficult to run stably with the single closed loop, so the acceleration can be added as the inner loop, the angular velocity is collected by the gyroscope and the collection value is not affected by the external conditions, anti disturbance ability of the system is strong and the angular velocity of the system is sensitive to the change of the system. In the same way, the air pressure sensor in the high ring is also affected by the external interference. The introduction of the acceleration loop can effectively avoid the influence caused by outside interference and enhance the robustness of the system. Therefore, the calculation and the height of the euler angles are selected on the dual closed-loop PID control system, the PID output is the throttle value, through the electronic speed regulator to control the motor speed.

The throttle output is the fusion of multiple outputs and the output value of the PID regulation of the three axis euler angle is:

$$AngelPIDout(t) = k_p e(t) + k_i \sum_{j=0}^{t} e(j)T + k_d \frac{e(t) - e(t-1)}{T} \quad (2)$$

In the formula, $e(t)$ is the difference between desired angle and actual angle.

Similarly, the estimated height and acceleration of the PID regulator output values are:

$$AltPID(t) = k_p e(t) + k_i \sum_{j=0}^{t} e(j)T + k_d \frac{e(t) - e(t-1)}{T} \quad (3)$$

$$AccePID(t) = k_p e(t) + k_i \sum_{j=0}^{t} e(j)T + k_d \frac{e(t) - e(t-1)}{T} \quad (4)$$

In the formula, e(t) are respectively the difference between the expected height and the actual height, the Z axis acceleration and the acceleration of gravity.

Finally, the throttle output of the flight mode is:

$$\begin{cases} throttle\,[0]_{out} = RCcommand + altitude_{out} + pitch_{out} + yaw_{out} \\ throttle\,[1]_{out} = RCcommand + altitude_{out} + roll_{out} - yaw_{out} \\ throttle\,[2]_{out} = RCcommand + altitude_{out} - pitch_{out} + yaw_{out} \\ throttle\,[3]_{out} = RCcommand + altitude_{out} - roll_{out} - yaw_{out} \end{cases} \quad (5)$$

In the actual regulation, the p-value is correct aircraft back to the initial position of the force, increase the p-value will produce a efforts to prevent vehicle's shift, but too large p-value will shock the vehicle. I value indicates if there is a deviation of angle change when sampling and average calculation of the time period, return to the initial position has a modified process. In the process of revision efforts will be more and more until it reaches the maximum value, increasing the I value will decrease the drift and improve the stability effect. The D value indicates that the speed of the aircraft return to the Initial position, improve the D value will speed up the initial position of the aircraft.

Fig. 4: Final result

**Flight test:** After careful inspection and calibration of the aircraft, this study carried out several tests. The test results show that: In the case of using 2212 KV980 motor and APC1047 paddle, the maximum load can reach 3 kg, the maximum speed can reach 4 m/s and it can achieve smoothly fly in the 4 level wind. The transmission distance of the image sensor can reach 5 km, which is sufficient to meet the monitoring and control of the flight direction. Different capacity of lithium battery can reach different flight time, the use of high capacity of lithium battery can improve the flight time, but will increase load. So after many tests, the final choice is 4400 mA lithium battery, the flight time can reach about 17 min, enough to meet the short distance and light weight food distribution. Four axis aircraft product is shown in Fig. 4.

## CONCLUSION

On the basis of learning four axis vehicle principle and Arduino development board, this study using Arduino Mega 2560 development board, at the same time using the smoothing filtering and complementary fusion to reduce the error of sensor data and then through the rotation matrix get the accurate attitude, greatly improve the stability of the flight system, the results basically reached the design requirements. We designed the four axis aircraft used in Daqing City, Heilongjiang Province, after the customer phone to order some food or vegetables, we use four axis aircraft for delivery. Because it is not affected by traffic congestion, it can achieve sustained flight transport and it's flight speed is also very fast which completes a round-trip within 15 min. Meanwhile, this distribution methods can save a lot of manpower, greatly improve the efficiency, delivery staff only need through the remote control to send food or vegetable to the destination and control the aircraft return. Using the four axis aircraft to transport and distribution of food is a safe, environmentally friendly, efficient way. In the future, if we can carry on an order operation through APP and then through the route programming to achieve the real automatic distribution, the aircraft will be widely used in the developed cities with large traffic flow, this needs further study.

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