IOP Conf. Series: Earth and Environmental Science **170** (2018) 042112 doi:10.1088/1755-1315/170/4/042112

Simple Four - Rotor Obstacle Avoidance Design based on Ultrasonic Wave

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Abstract. The design and implementation of a simple four-axis obstacle avoidance system based on STM32F4 equipped with a steering gear and ultrasonic wave is introduced. It is mainly used to solve the problem of possible impact due to wrong manual operation. With the increasing popularity of the unmanned aerial vehicle (UAV) consumer market and the low threshold of UAV use, many people can purchase and use UAV without professional training. The safety issues of using the UAV should not be underestimated. UAV avoidance has become an urgent problem for the UAV to go to mass market.

1. Working Principle

The ultrasonic module starts timing when signal transmitted, and stops timing when received the reflection signal from obstacles, and record the time as‘t’. Ultrasonic propagation velocity in the air is 340 m/s. Meanwhile I0 outputs a 10us pulse trigger signal, the module emits eight cycles of 40 kHz cycle and detects the echo. ‘D’ is the distance between obstacle and UAV, and so the computational formula is:

$$d = \text{high time } (t) * \text{Sound velocity } (340 \text{ m / s}) / 2 \quad (1)$$

Ultrasonic sensor has low cost and is easy to install. It has strong directivity, real-time, and simple calculation. However, the detection distance still has some limits due to the degree of the surface roughness of the reflector [1]. The electrical parameters are shown in table 1.

The servo angle is adjusted by the duty cycle of the PWM. Generally, the pulse width can be 0.5 ms to 2.5 ms. It can realize rotation of servo from 0° to 180° with a period of 20 ms as one cycle and a reference cycle of the timer as 0.1ms. Due to the servo detection is not accurate near 0° and 180°, the steering angle is selected from 30° to 180° in our work. Servo equipped with ultrasound, and scanned continuously with a period of 20 ms. Through the steering angle and ultrasonic detection range, it accurate access to the front of a short distance and a wide range of visual field information and also extend the detection Angle of ultrasonic sensor.

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The basic parameters are shown in Table 1.

Table 1. Ultrasonic sensor electrical parameters

Operating voltage	DC2.4~5.5 V	Quiescent current	2mA
Operating temperature	-20~70 ℃	Detection angle	15°
Detection range	2cm~450cm	Detecting precision	0.3cm±1%
Operating frequency	40kHZ	Operating current	15mA

2. System structure

System structure diagrams are shown in Figure 1.

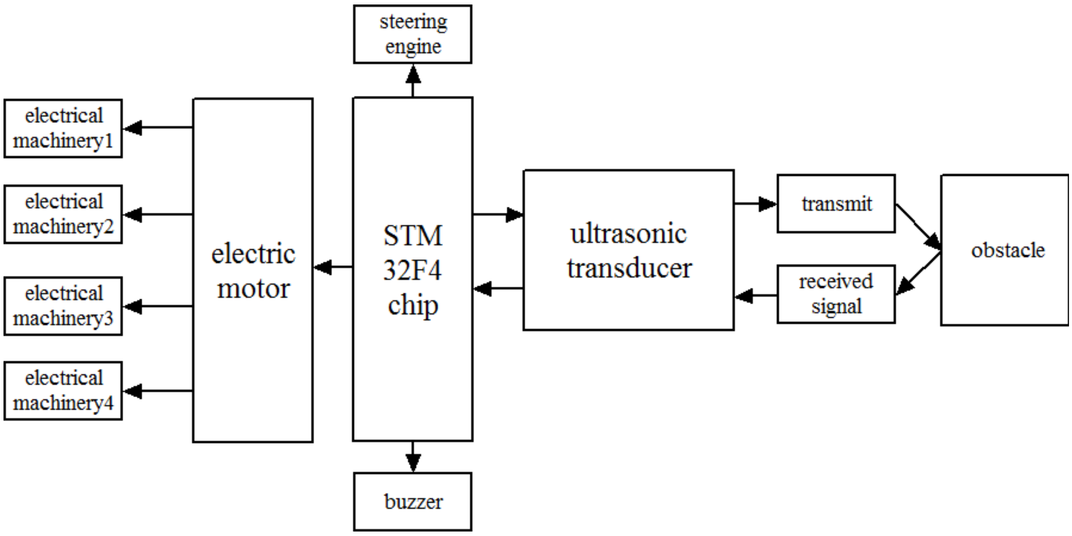

Figure 1. System block diagram

The system consists of the master chip STM32F4, ultrasonic obstacle avoidance PTZ, motor modules and other components. The gyroscope, magnetometer and accelerometer are used to solve the attitude algorithm. In the quad rotor installed two servo PTZ equipped with ultrasonic sensor module, as shown in Figure 2. The direction of ultrasonic 1 towards motor 1and ultrasonic 3 toward motor 3, the relative installation is to avoid the echo of the ultrasonic interference, but also to prevent the back when hit the rear obstacle, reducing the use of ultrasonic module [2]. The ultrasonic 2 is located in the middle of the platform, facing down, and is used to set height and avoid obstacles below. Ultrasonic sensor module continues to transmit and receive signals, and expands the detection range using servo rotation. When detecting the distance between the obstacle and the UAV is less than the safety range, the ESC is used to control the motor speed, and an alarm is always prompted in the process.

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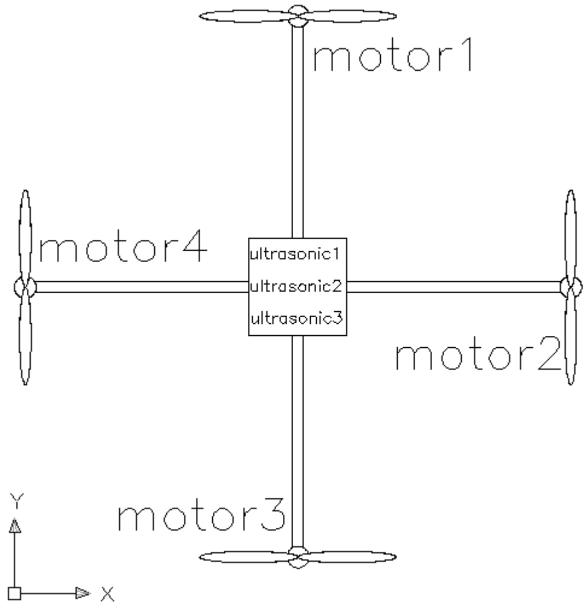

Figure 2 Ultrasonic placement location diagram

3. Software Design

According to the back and forth motion principle of quadruple, when the sensor detects a collision risk, the program enter the interrupt function. Firstly the remote control lever control signal is cut off, and the four-axis drone can be suspended by controlling the motor speed. At the same time, the route has been modified by combined with ultrasonic distance information and steering angle information to avoid obstacle. The buzzer has been alarm throughout the obstacle avoidance process. The throttle and direction control of the remote control are turned off, until it reaches a safe distance and the buzzer is no longer alarm. At this point, manual operation mode can be run again. Set up a switch on the remote control to select whether to open the obstacle avoidance mode, for the highest priority, that can interrupt the obstacle avoidance at any time, and restore human control.

Figure 4 is Main block diagram, and Figure 5 is Obstacle avoidance subroutine block diagram.

A, b and c represent ultrasonic 1, ultrasonic 2 and ultrasonic 3 detected minimum, respectively, corresponding to ultrasonic front, bottom and rear. The angle θ1 is defined. It indicates that the first angle on the left was detected and the angle's distance is greater than far.θ2 is the angle at which the minimum is detected. Θ3 indicates that the first angle on the right was detected and the angle's distance is greater than far. The rotation angle $\theta \in [30°, 150°]$. Taking the center of gravity of a drone as the center of a sphere, the environment is divided into three areas: safety zone, early warning zone, and alarm zone. The three areas correspond interval [0, 80], (80, 120] and (120, ∞), respectively. We set three values. One of the three values is the alarm value, and it is "near = 80cm". The interrupt will be opened when the distance information is less than this value. The second one is the warning value, and it is "far = 120cm". When the obstacle distance is greater than this value, it is indicate that UAV fully reached safe area. The system can exit interrupt, and remote control can be resumed. If the value is "mid = 100cm", it indicates that the UAV is in a sub-safe state and can fly forward to avoid obstacles [3]. Range of obstacle avoidance is shown in Figure 3.

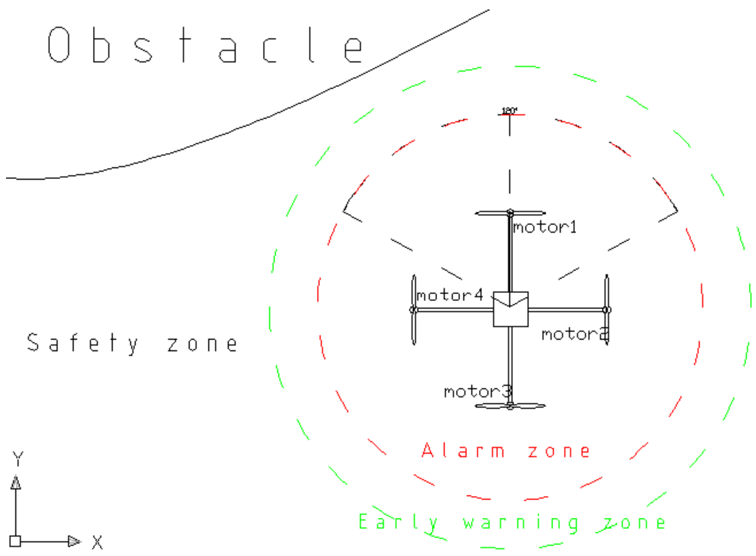

Figure 3. Obstacle avoidance diagram

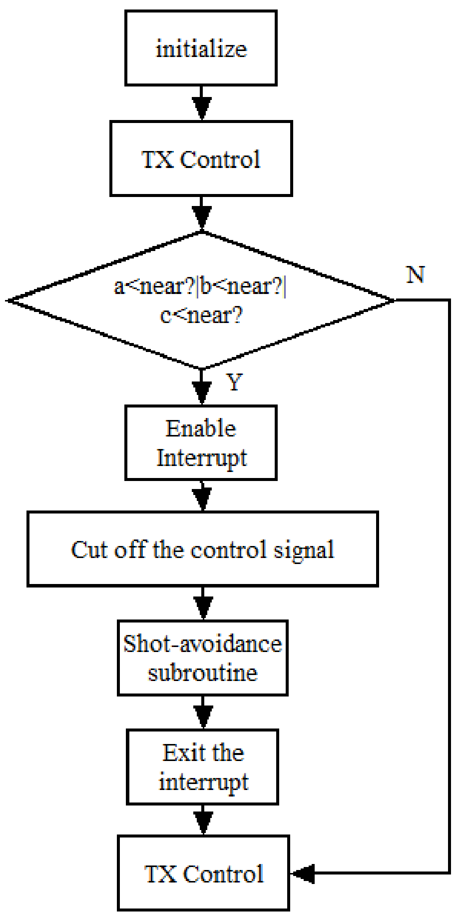

Figure 4. Main block diagram

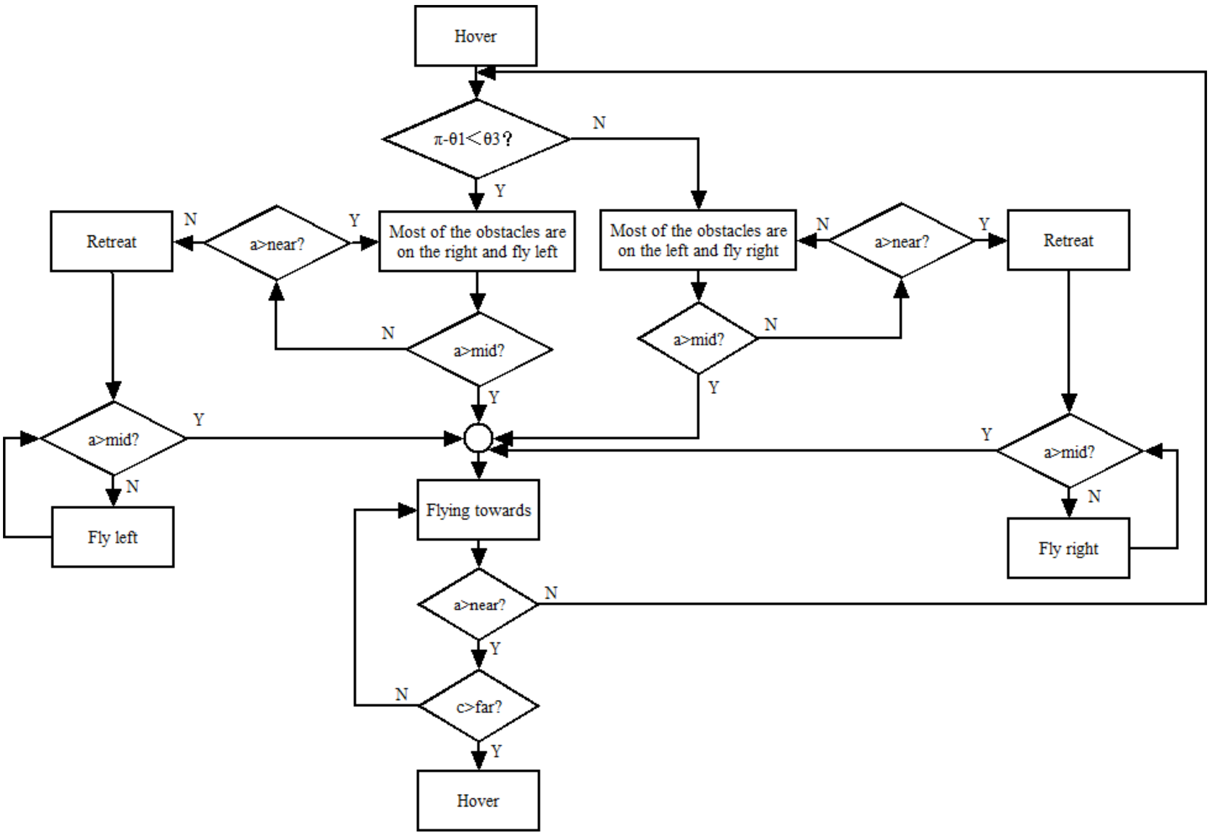

Figure 5 Obstacle avoidance subroutine block diagram

Obstacle avoidance can be divided into the following four situations:

1. When the obstacle information has not been detected, remote control can be used.

2. If the obstacle is bounded, the sensor can sense the start and end of the obstacle and detect θ1 and θ3. If π - θ1 <θ3, most of the obstacles are located on the right side. Increasing the rotation speed of the motor 4 to increase the pulling force, and reducing the rotation speed of the motor 2 to reduce the pulling force, and keeping the rotation speed of the motors 1 and 3 unchanged, the UAV will move to the left [4]. When the value of "a = near" is detected again, that is the distance from the obstacle is close. Increasing the rotation speed of the motor 1 to increase the pulling force, and reducing the rotation speed of the motor 3 to reduce the pulling force, and keeping the rotation speed of the motors 2 and 4 unchanged, and deceasing speed of Y axis, the UAV will slant and move backward, until it exits the alarm area. The UAV continues to the left movement, and that cycle repeats. When a> mid, the UAV forward movements, until bypasses obstacle. When it measured with the rear distance c < far, indicating that it reach the safe area and can continue to human operation. Designed the "if" statement in the process is used to prevent another obstacle threatening drones safely. If π - θ1 > θ3, the obstacles are mostly on the left side, and the flight direction is opposite to π - θ1 < θ3.

3. When the obstacle is too large, the ultrasonic wave does not detect θ1 and θ3 within one revolution of the steering gear. The obstacle avoidance path is determined by θ2 on the left or right. If θ2 > 90°, the minimum obstacle is on the left side, and the path is most likely to be located on the left side of the obstacle. If θ2 < 90°, the minimum obstacle is on the left, and the path is the one with the majority of the obstacles on the left.

4. When the downward sensor is in obstacle avoidance working status, and distance information of obstacle b < near, the output power of the four motors is increased at the same time to increase the motor speed, so that the total pull force is enhanced. The UAV moves vertically upwards. When distance information of obstacle b > mid, alarm is cleared and the remote control signal is restored.

4. Conclusion

The design takes STM32 as the main control chip. By the way of ultrasonic ranging and servo rotation angle adjustment, a number of obstacle avoidance routes have been planned based on a lot of obstacle distribution models. When the UAV detects the obstacle in front of it, the system can choose the most excellent path. It can judge whether the obstacle was completely avoided by rear ultrasound. When the complex obstacle information is difficult to judge, the system automatically turns off obstacle avoidance subroutine to avoid abnormal and dangerous situations, and resumes manual operation. Interval measurement will greatly reduce the impact of interference and parameter changes on data judgment.

Acknowledgments

This work was financially supported by the provincial Training Program of Innovation and Entrepreneurship for Undergraduates (S201710656008).

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