Design of the Reconnaissance UAV based on TGAM

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Abstract. The application of UAV in military reconnaissance field is mostly fixed-wing aircraft, such as global hawk and predator. But they have no fixed wing aircraft bulky, need a runway to land, the reconnaissance mission is confined to the reconnaissance range larger operations, is now considering the individual special operations to the demand of the UAV reconnaissance, is adopted to helicopter down small four rotor design, convenient carrying, used to fill a vacancy low-altitude reconnaissance a small scale. In addition, considering the clarity and planning of the purpose of the reconnaissance mission, the UAV can carry out the reconnaissance mission of aerial photography and return according to the predetermined route completely, and no excessive human intervention is needed in this process. Therefore, the small quadrotor is mainly designed for autonomous flight system. But fully autonomous flight can not be very good to adapt to the complex environment, for the sake of it, and the principle of liberation operators hands as far as possible, decided to adopt a simple electrical control of auxiliary control flight, to complete after being spotted by enemy UAV height of rise and fall, immediately return to action, such as to ensure the practicability of the reconnaissance drones.

Keywords. UAV; Individual special operations; Drone reconnaissance; Autonomous flight; Electrical control

1. Introduction
From the perspective of scientific and technological progress and the evolution of IT-based warfare, informationized special operations will be one of the key battlefield in the future. From the perspective of the core development of war, the command means of future special operations will be highly automated and intelligent, and will be a combination of unmanned, modular and biological. At present, brain control technology[1] is still in the primary stage of development, but brain control technology has attracted more and more attention, and is gradually applied in the consumer electronics market and the field of medicine. This design applies brain control technology to the system control of unmanned aerial vehicle[2]. Without handheld remote control or other devices, the UAV can be controlled to complete the basic flight movements and meet the basic control requirements. Under the human-computer interaction platform, users can communicate with the computer system through natural interaction methods such as voice, eyes, expressions and gestures[3], which expands the research field of brain control technology.

2. Scheme Design
In the reconnaissance readiness phase, it is programmed through the Keil 5 development environment to enter airline data. The UAV starts up to perform sensor calibration, acquires accurate sensor data and then takes off with one key, shooting reconnaissance mission according to the scheduled route. In the whole process, various sensors attached to the UAV conduct real-time detection of its own attitude[4] and realize self-stabilization attitude, so as to ensure smooth flight and obtain clear and stable video effects. In addition, equipped with RPLIDAR-A lidar, two-dimensional maps can be constructed for environmental perception, so as to ensure real-time flight route planning. When encountering obstacles, the flight path can be slightly adjusted according to the algorithm. In the whole process of autonomous reconnaissance flight,
the control information is received in real time, and the highest priority is given to respond immediately to change the flight altitude or turn back. When the scheduled route patrol is completed, the UAV returns immediately, ending its reconnaissance mission. The specific task flow is shown in Figure 1.

Figure 1. Design of task flow

3. Hardware Design

Based on the MSP432P401R Launch Pad as the core, the UAV control system adopts a variety of correction methods to correct the data of each sensor according to different characteristics of each sensor. After that a low-pass digital filter is used for filtering, and then attitude information is estimated through complementary filtering optimization calculation, so as to achieve accurate attitude measurement. Finally, through attitude control overlay and PID algorithm, the four motors of the quad-rotor UAV are controlled, so as to complete various flight actions and achieve the purpose of flight. The specific process is as follows: first, the sensor information is obtained, and the data is input into the controller, and the self-check program is executed. Then the controller obtains its own control rudder quantity for calibration. In the course of flight, the attitude information of the accelerometer, barometer, gyroscope and so on is input into the IMU in real time to solve the problem, so as to obtain the relative position of the UAV in space. Meanwhile, the controller will control the motor in real time according to the calculation results returned by the controller, so as to achieve the attitude self-stabilization of the UAV. In the autonomous flight stage, the 2d map and positioning information can be acquired by SLAM lidar in real time for airline route planning, so as to realize the requirements such as patrol inspection.

3.1. The frame of Controller

The attitude controller is the most basic controller to ensure the UAV has a relatively stable flight. The dual-ring PID controller is adopted. The height controller controls the UAV to keep at the stable height when it is fixed; The horizontal controller controls the UAV to remain stable in the horizontal direction; The time controller and action controller constitute the time line and action line of program control together, so that the program control has strict timing and continuity. The framework is shown in Figure 2.

Figure 2. Frame of Controller

3.2. FPV wireless graph transmission

As a reconnaissance UAV, FPV image transmission function is indispensable. The MOBIUS camera with infrared night vision function was selected. In order to reduce its weight and volume, it was slightly modified to remove the shell and lithium battery and share the lithium battery power with the aircraft. As the imaging definition of MOBIUS is demanding on the voltage, it adopts the booster voltage regulator circuit to maintain the voltage at 5V, avoiding the influence of the battery voltage ripple and achieving a relatively clear image
transmission quality. The image transmission and receiving end adopts wearable watch to implement the design concept of freeing hands. FPV image transmission watch commonly seen in the market is selected. It has the advantages of stable image transmission, clear display and long battery life, which can better meet the requirements of reconnaissance UAV image transmission and receiving.

3.3. EEG intervention

Considering the performance and command requirements of MSP432, the TGAM[5,6] (Think Gear Asic Module) PCB Module provided by Neuro Sky was selected as the EEG acquisition and processing chip in this design, as shown in Figure 3. This module reads human brain signals through dry electrodes, and has strong anti-interference ability. It can automatically filter out the noise around the signals and interference from electrical appliances, and then convert the detected brain wave signals into digital signals. The core of TGAM module is TGAT chip, which is a highly integrated single EEG sensor that can perform analog-digital conversion, output three eSense parameters, detect abnormal state with bad contact, and filter out electrical noise and 50/60Hz AC interference.

![Figure 3. TGAM module](image)

TGAM has a built-in digital signal algorithm for EEG signal conversion, which combines with Arduino Nano for signal processing and corresponding control instruction output. The working process is shown in Figure 4.

![Figure 4. Flow of EEG intervention](image)

4. Software Design

The design task of the software system of the aircraft is to read the data of MPU6050, filter the data, perform attitude calculation, and maintain self-stability through cascade PID controller[7]. At the same time, read the action instructions in the program control line and fly according to the established mission route, and call the camera to carry out reconnaissance mission. In addition, the brain control channel and remote control channel are monitored in real time, and instructions are received to complete such actions as immediate return and low-altitude concealment, and return the attitude data, voltage data and PID data of the aircraft.

4.1. Attitude calculation and cascade PID control

Attitude solution is the foundation and key part of the smooth flight of aircraft. The flight controller reads its own sensor data to estimate the attitude of the aircraft in real time, such as Roll, Pitch, Yaw and other information, and then further calculates the output of four motors based on these information, so as to control the aircraft to keep steady or keep a certain inclination Angle to fly in a certain direction. Therefore, the algorithm used in attitude calculation determines whether the aircraft can maintain stable flight. The specific method is as follows: Firstly, the working state of the attitude sensor is analyzed. Gyroscope is a non-direct angular measurement device with high dynamic characteristics. What it measures is angular velocity, namely the derivative of Angle. Therefore, it is necessary to integrate angular velocity with time when calculating Angle. Secondly, under the action of integration, low frequency interference and drift will eventually occur to the gyroscope due to the continuous accumulation of errors such as noise. The accelerometer is mainly used to measure acceleration, and its measurement principle makes it immune to low-frequency interference and more sensitive to high-frequency signals. Therefore, in the vibration environment, the accelerometer is greatly affected by high-frequency interference.

Thus, the following conclusions can be drawn: the gyroscope is sensitive to low frequency disturbances,
and the accelerometer is sensitive to high frequency disturbances. The gyroscope can be trusted in a short time, and the accelerometer needs to be trusted in a long time, so the solution idea is to use the attitude calculated by the accelerometer to correct the gyroscope. Based on the above consideration, this paper uses the complementary filter fusion method based on quaternion as a gesture decoding algorithm, using the acceleration vector and gyroscope angular velocity vector for cross products, if there is no change between two attitude, then the cross-product results should be zero, but if have change, the result can be used as a correction of gyroscope angular velocity correction. Adding variables Kp and Ki can be used for PI correction and fast correction of angular velocity value. When the compensated angular velocity is used to update the quaternion, a more accurate attitude value can be obtained. During the calculation, the attitude is actually updated, and then the result of Euler Angle is put into the controller to calculate the control result of the motor, the process is shown in Figure 5.

![Figure 5. Attitude solution process](image)

As UAV is a nonlinear unstable system, in the control of aircraft, if the traditional PID controller cannot adapt to the nonlinear four-axis, then cascade PID controller is introduced to control the aircraft. In the cascade PID controller, the outer ring is used as the Angle ring and the inner ring as the angular velocity ring to control the aircraft. The outer ring adopts pure P control as fast response lead control. As a stabilizing link, the inner ring mainly controls the stable flight of the aircraft. The flow chart is shown in Figure 6.

![Figure 6. Cascade PID controller](image)

4.2. SLAM diagram navigation
Simultaneous Localization and Mapping (SLAM) provides autonomous location and navigation of the UAV. SLAM can be described as enabling the UAV to locate its position and attitude according to the repeatedly observed map features (such as pillars, corners, and so on) in the process of moving from an unknown location in an unknown environment, and build incremental maps based on the location information, so as to achieve the purpose of accurate positioning and map construction. [8] The implementation of SLAM is generally divided into two steps, the first stage is to map, the second stage is to locate. In the map construction stage, gmapping algorithm is used for map construction[9], as shown in Figure 7. In the Localization stage, AMCL algorithm (Monte Carlo Adaptive Localization) was used. This is a very common positioning algorithm, which compares detected obstacles with known maps to locate and correct odometer errors.
4.3. EEG intervention

EEG control is to achieve mind control[10]. Brain waves are signals generated by the activity of nerve cells in the brain. When the brain is engaged in thinking activities, the bioelectricity formed by the sum of the postsynaptic potentials synchronously generated by a large number of neurons is the EEG signal. With a device that can accurately capture and decode brain waves and translate them into specific control commands, we could be able to achieve the long-awaited “control of the mind.”

Electrical activity in the brain is actually neuronal oscillations, and brain waves are electrical impulses generated when neurons are active. When neurons work synchronously, a micro rhythmic electrical potential occurs in the specialized synapses between them. Voltage (V) and frequency (F) are two important parameters to measure the main characteristics of brainwaves. The more synchronized the neurons are, the greater the amplitude (amplitude) of the electrical oscillations measured. The faster the neurons work together, the higher the measured oscillation frequency.

When people are under anesthesia or in deep sleep, the lowest frequency (0.5 to 3Hz) of Delta waves are in the brain. Theta waves (4-7Hz) are slightly faster than this and tend to occur when dreaming or dealing with simple everyday problems. Alpha waves (8-13Hz), which are produced during meditation and calm relaxation, are the first neuronal oscillations to be discovered. The electrical waves in the brain are Beta waves that fluctuate more rapidly (14-30Hz) when people are in a heated debate; The fastest Gamma waves occur in the perceptive thinking process. Neuronal oscillations can subtly transport information in a way that allows the brain to choose which signals to pay attention to or ignore.

4.3.1. Signal acquisition. Two electrodes, one positive and one negative, are placed over the head and electrical signals from the brain are emitted to measure the potential difference. Common mode input voltage affects the bias point of input differential pair. Due to the inherent mismatches of the input circuit, the input voltage will change with the change of the offset point, thus changing the size of the output voltage. In the process of EEG signal acquisition, it will be interfered by ambient noise and power frequency noise, so it is necessary to filter out the noise of the original signal first. The signal between 0.5Hz and 50Hz can be taken out through the bandpass filter, among which the signal with a frequency higher than 32Hz is regarded as high-frequency noise, as shown in Figure 8(a). Then, butter worth bandpass filter is used to filter the signal, as shown in Figure 8(b).

4.3.2. Signal processing. Because the EEG signal is very weak, it is necessary to further process the collected EEG signal. Firstly, preprocessing is carried out to reduce noise and artifacts. EEG signals are easy to be interfered by various signals from the environment and the human body, and the external environment should be controlled to be quiet and stable as far as possible, while the human eye electrical signals, ECG signals, EMG signals and so on will be adulterated in the collected EEG signals, so it is very important to effectively remove these artifact signals. Then feature extraction and feature selection are carried out. Feature extraction is to extract useful signals from EEG to construct feature vectors for classification. However, since the constructed features are generally high, which is not conducive to subsequent calculation and analysis, further feature selection is needed. Features with more representational ability should be retained as far as possible to remove...
interference in high-dimensional feature space.

The communication protocol of TGAM module brain signal[11] is UART, and the packet is sent as asynchronous serial byte stream. Each packet begins with its header, is followed by its data payload, and ends with a checksum byte of the payload. Typically, the output of the data value is once per second.

4.3.3 Electromyographic signal auxiliary detection In view of the effective range and control intensity and precision of EEG signal control, it is necessary to design more stable and accurate auxiliary control strategies on the basis of the original brain control. According to the principle of existing conditions and maximization of resource utilization, myoelectric signal detection is increased. When the brain-controlled UAV fails, the UAV can be controlled by blinking and other specified actions to prevent the UAV from losing control, so as to design a complete brain-controlled UAV system with protective measures. The principle of EMG signal detection is analyzed according to the original wave data collected by EEG acquisition equipment. The raw wave data value consists of two bytes and represents a single raw wave sample. Its value is a signed 16-bit integer, with the first byte from -32768 to 32767 representing the high order of the binary complement value and the second byte representing the low order. To reconstruct the full original waveform value, simply shift the first byte 8 bits to the left, then shift it by bit or by the second byte. That is:

\[
\text{raw} = \text{val}[0] \times 256 + \text{val}[1]
\]

Val [0] is the highest byte and Val [1] is the lowest byte.

Figure 9. Vibration detection of EMG signals

In Figure 9, 1-4 can easily control the flight of UAV for the four control commands of backward, forward, left and right flight respectively, so as to realize safe control when the UAV is not controlled by brain wave.

5. Conclusion

In military applications, small reconnaissance UAV is more suitable for special operations than the mainstream fixed-wing UAV, which is convenient for individual soldiers to carry and operate. The reconnaissance UAV system designed in this paper belongs to the category of individual equipment, aiming at expanding the information perception ability and space scope of individual soldiers or tactical teams to the combat environment, and providing new equipment for small-scale operations.

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