Design and Implementation of Hybrid Wing Unmanned Aerial Vehicle (UAV)

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Abstract: This paper designs a hybrid wing UAV based on the study of existing UAV modes and functions, and elaborates its functional implementation requirements and design possibilities in detail. It is hoped to be beneficial to the development of UAV to achieve the goal of energy saving and consumption reduction.

Introduction

UAV plays a prominent role in many fields in China. For the time being, there are mainly two kinds of existing UAV, fixed-wing and multi-rotor. Although the utilization rate is high, the problems brought by them cannot be ignored. This paper combines both advantages and disadvantages of the two types of UAV to design a new hybrid wing UAV on the basis of guaranteeing the advantages to reduce the problems in the UAV usage and provide help for the development of related fields.

Overview

UAV and their types. UAV is unmanned aerial vehicle, which is operated by wireless remote-control equipment and computer program. It has significant advantages in China's military, land resources survey and other areas. UAV has the characteristics of small size, cheap price, strong adaptability, high practicability, stable performance and so on. It can help the staff to complete the related tasks in the complex environment, which can not only improve the work efficiency, but also ensure the personal safety of the staff.

At present, the main types of UAV are fixed-wing UAV, multi-rotor UAV, unmanned airships, parafoil UAV, and flapping-wing UAV. Among them, fixed-wing UAV and Multi-rotor UAV are widely used due to their own advantages. However, with the limitation of battery capacity, the multi-rotor UAV has limited flight time and range to some extent. In addition, it will consume lots of energy in the flight process, which may easily increase the economic cost; Compared with rotary-wing UAV, fixed-wing UAV has much more flight time and range, but it is easily affected by the site due to the use of the sliding mode, which reduces their application range .

Hybrid Wing UAV. Hybrid wing UAV is a new type of UAV designed on the basis of fixed-wing UAV and multi-rotor UAV. It combines the advantages of fixed-wing structure and multi-rotor UAV to make a new type of UAV. That is, the rotor part is installed on the basis of the fixed-wing structure.

The design advantages of the hybrid wing UAV are: the rotor structure is installed on both sides of the fixed wing structure, and the vertical lifting of the UAV is completed through the action of the rotor wing, which avoids the problems existing during the takeoff and landing of the fixed wing UAV, and reduces the space limits.

During the flight, the hybrid wing UAV will fold up the rotors and just rely on the fixed wing for control to complete the relevant aerial survey. In this process, the requirements of UAV flight can be met just based on the motor in the fixed wing, which reduces the power loss, and on this basis, improves the flight time and flying distance of UAV.

Because of having the characteristics of both fixed wing and multi rotor UAVs, hybrid wing UAV can play the role of two UAVs in practical operation, complete aerial survey, patrol survey, rescue and relief work in complex areas, which helps to reduce the human, material and financial resource

losses. Especially in the military field, detailed data collection can be carried out in some islands or border conditions with harsh environment by the application of the hybrid wing UAV, providing sufficient data support for military research and development and other related work.

Design of the Hybrid Wing UAV

Hardware Design. Appearance and Structural Design. Through the in-depth study of fixed wing and multi-rotor UAVs and learning from their strong points to offset the weakness, we designed the hybrid wing UAV, which is mainly composed of fuselage, fixed wing, tail wing and four multi-rotors. Among them, 4 multi-rotors are evenly distributed on the left and right sides of the fuselage, but they are not fixed on the fuselage. Instead, they have a certain degree of flexibility, which can be expanded according to the instructions. During takeoff and landing, the four rotors will be expanded to ensure the stability of the fuselage and achieve the vertical lifting purpose; When the UAV is flying, the four rotors will be retracted back into the fuselage. The fixed-wing structure is used to ensure the normal operation of the UAV and reduce the energy loss during flight. In the process of designing the fixed wing structure, in order to give full play to its functions, we simplify the structure. Only two ailerons, two fixed tails and one lifting cabin are set in the fixed wing structure. Two ailerons are respectively installed on both sides of the aircraft, and the lifting cabin is arranged inside the fixed tail. Ailerons are directly controlled by the ground remote sensing device to reasonably plan the flight path of the UAV, while the pitch angle during the flight is scientifically controlled by the lifting cabin inside the tail wing.

Design of Quadrotor Arm Folding and Unfolding Unit. In the hybrid wing UAV, the four rotors will be extended to the outside of the fuselage during takeoff, and automatically be retracted back to the inside of the fuselage during landing to complete the vertical takeoff and landing. The control of the four-rotor extension and retraction is mainly controlled by the Arduino Nano single-chip microcomputer. The signal receiver adopts NRF24LO1 module. It has good independence, which can reduce the impact of other module operations, so as to enhance the timeliness and effectiveness of signal reception and transmission, and make UAV operation efficient. In addition, the MG995 steering gear is used as the main rotator in the hybrid wing UAV, and a 3S aeromodel lithium battery is installed. The operating voltage is controlled at about 4.6-6 volts, and the operating voltage of the single-chip microcomputer is 5 volts. Therefore, a step-down module is used to provide an integrated power supply solution for the single-chip microcontroller and the four steering gears. The instructions are sent to the single chip microcomputer through the remote-control equipment, and four steering gear action will be controlled after the single chip microcomputer processing, so as to achieve the retraction and expansion of four arms.

The detailed control procedures of the retraction and expansion of the arm is as follows: The control end sends instructions to the NRF24LO1 module, which transmits the instruction information to the ArduinoNano. After receiving the information, it ensures that the received instructions are sent back. ArduinoNano is used to control the steering gear to realize the expansion and retraction of the arm. Among them, the corresponding control of ArduinoNano and the retraction operation of the arm need to be completed using a voltage reduction module to ensure that the operation is done quickly and accurately. The startup of the voltage reduction module is controlled by a 11.1-volt power supply.

Software Design. The most important software system in a hybrid wing UAV is the flight control system. When debugging the flight control system, high-precision air pressure gauges, gyroscopes, accelerometers, and magnetometers are used to ensure the rationality of program debugging. Meanwhile, the quaternion arithmetic method is also used to analyze and master the UAV flight state in the system design, and the PWM output and PID speed control are used to ensure the stability during the flight. Besides, the single-chip microcomputer and wireless module are used to control the four rotors of the UAV to enable it to complete the expansion and retraction operations, avoiding aerodynamic layout, reducing air resistance, and maintaining the stability of the drone flight.

To be specific, the overall control procedures of hybrid wing UAV are: Firstly, combine the ground remote control device with the channel which the upper computer has debugged to define the

flight route of the UAV, and carry out the aircraft unlocking work after the combination. Then start the system power-on initialization, check the power supply voltage, and ensure that the parameter data displayed by the system equipment are within the specified standard value range. If the parameters are found to be inconsistent with the design parameters, stop operation and carry out the inspection to find the cause. After finding the cause, restart the operation again.

After passing the test, the controller is used for unlocking operation. At this time, the four rotors of the UAV will gradually extend and start to push the UAV to rise in the vertical direction. The controlling staff should control the UAV's rising speed to ensure the rising stability of UAV. After rising to the prescribed flight distance, the flight mode is switched. At this time, use the ground controller to control the four rotors to retract them into the fuselage, start the fixed-wing brushless electric machine, and start the cruise stable flight in fixed-wing mode. The flight mode conversion is over. When the UAV ends the cruise mode, control the speed to a landing value and continuously retarding the throttle. After the quadrotor arms are expanded, the mode is switched again and the UAV lands.

Design and Implementation of Hybrid Wing UAV

In this design, the hybrid wing UAV adopts the multi-rotor take-off and landing mode in the take-off and landing stage. The four rotors control the take-off and landing process to make the UAV lift in the vertical direction. During the flight, the advantages of the fixed-wing UAV are utilized to control the flight state of the fixed-wing structure through the steering gear, so as to control the flight stability and reduce the difficulty of operation. In addition to the advantages of fixed wing and multi rotor UAV, this design also has very reliable performance in the aerial delivery of disaster relief drugs, life-saving equipment and shooting. This kind of UAV is light in weight and large in size, so it can land anywhere without considering the environment.

Hardware Design. General Layout. The wingspan of hybrid wing UAV designed in this article is controlled within 2.2 meters and the bare weight is about 3 kilograms. The average speed of the four bypasses used in this UAV can reach about 42,000r per minute, and the flight distance is controlled to above 45 kilometers per hour. The minimum turning radius is 40 meters and maximum climbing angle is 40 degrees. This design enables the UAV to have a strong mobility and carrying capacity, so it can also carry out aerial photography and material transport work even in mountainous areas, cities and other terrain complex or high-density environment.

When we select the materials for the hybrid wing UAV, we pay lots of attention to their performance and quality, such as the application of aviation laminate, balsa green wood, heat-shrinkable film, carbon fiber composite material, aluminum alloy and other materials. The application of these materials not only reduces the weight of the fuselage, but also saves the production cost and reduces the difficulty of construction technology. In addition, a double tail beam structure is used in the tail end design, and the larger fuselage and wingspan make the flying distance of UAV longer. At the same time, the fuselage structure and operating system, onboard equipment occupy less space and their weight ratio is small, load space is larger, and the battery position designed is easier to balance. A larger wingspan makes the aspect ratio better, lift-to-drag ratio increased, and energy saved.

Graphic Design of Wings. The cruise speed of the hybrid wing UAV in this design is controlled at about 45 kilometers per hour, which means it is a slow-speed UAV. So, in the process of aerodynamic design, it is not necessary to consider the effects of air compression and shock resistance, and the 1/4 string sweepback angle can be set directly to zero. The larger aspect ratio of the wing can effectively reduce the induced drag and 3d effect, and in order to maintain the lift-drag characteristics, the tip root ratio can be controlled at around 0.45. According to the design experience in the past and the commonly used aircraft model materials, the chord length of the wing root is initially set as 0.3m, the chord length of the wing tip is 0.25 meters, and the span is 2.2 meters, which is added to the calculation as the reference value of the subsequent detailed aerodynamic design.

Power System Design. In order to realize the take-off and landing control and the stable control between flights, the bypass motor is taken as the core control device of the whole power system in the UAV power system setting, and it is arranged in an x-shaped arrangement on both sides of the aircraft. In this way, the bypass will directly control the rotor to complete the vertical takeoff and landing operation, ensuring the UAV to rise steadily to the specified flight distance; During takeoff, the steering gear is connected with the bypass to realize the retraction control of the rotor, and the UAV is switched to the fixed-wing flight mode for the stability control.

Design of Bypass Rotation Structure. Two types of aluminum alloy parts A and B are used in this design to carry out the equipment fixing treatment. During the connection process, one end of aluminum alloy A is fixed to the tail beam structure by screws at one end, and the other end is directly connected to the bypass to ensure the stability of the motor; The aluminum alloy B is directly fixed on the bypass motor for the connection with the steering gear. After the UAV takes off, the bypass motor will be at a 90-degree angle to the ground, providing the lift force needed for lifting the aircraft off the ground. When the aircraft reaches a predetermined altitude, the rotation of the steering gear will drive the bypass engine to rotate 90 degrees counterclockwise to make the aircraft fly at a flat level.

Software Design. We use Stm32f103c8t6 chip and ARMCortexM-3 core as the chip and core of the UAV, which are rich in resources and low in cost. They can optimize the performance of the UAV and save resources at the same time. The flight controller in this mode can complete the works, like the hardware platform initialization, the flight attitude solution, the remote-control signal decoding, the motor and steering gear control, and the flight mode switch.

In terms of attitude calculation, the official DMP library is used for joint operation with the platform, and the quaternion is used to do the conversion work in order to obtain the flight attitude of the UAV. In terms of remote-control signal decoding, we choose the stm32 timer for the ground controller for capturing signals timely, and the acquired signal data will not bring the problem of occupying a lot of space, which can ensure high-speed operation of each channel. In terms of motor control, the remote-control signal method is used for the control value acquisition. The accurate rotation angle is obtained through the comparative analysis with the calculated attitude and the application of the PID algorithm. Then the final result is sent back to the controller to realize the rotation operation and stability control of the UAV in flight mode

During controlling, we must ensure the quality of the fuselage so as to maintain the safety of the UAV in the process of lifting and flying, and optimize the overall maneuvering characteristics. In actual implementation of this design, the size and weight are all beyond the original design. Although the normal operation of each device is guaranteed, it will cause the power consumption of the airway during operation, which will have a certain influence on the cruising ability of the UAV. As a result, when the optimizing and adjusting this solution, we should strengthen research in this area and enhance the cruising ability of the UAV.

Summary

The emergence of hybrid wing UAV solves various existing problems of traditional fixed wing and multi rotor UAV, and optimizes the overall performance of UAV on the basis of giving full play to their functions. Although there are still some problems in power saving in the later implementation, it is believed that with the increase of research and the improvement of technology level, this problem will also be solved, so as to comprehensively improve the usage performance of UAV and contribute to its operation in various fields.

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