A design of Automatic UAV Dock Platform System

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Abstract. At present, most unmanned aerial vehicles (UAVs) are powered by traditional aero modelling lithium batteries, which have poor endurance and cannot operate continuously for a long time. It greatly limits the application fields of UAVs. To tackle this problem, we design a fully-automatic UAV docking platform that can work under no human situation and assistance to charge the aircraft with insufficient power to help the drone extend its battery life. It also provides an implementation solution for a fully automatic drone docking platform with wireless charging, UAV takeoff and returns, auxiliary positioning, and relay communication. The system mainly includes apron part, docking platform protective shell, solar panel, power conversion equipment, wireless charging base, satellite positioning and communication module, radio positioning signal generator, and radio relay communication module, etc. The power system of the apron part uses electric pushrods.

1. Introduction
With the further development of miniaturization and functionalization, UAV is now widely used in various fields, such as aerial photography, pesticide spraying and express transportation [1]. For a large area of unattended, particularly harsh environment, UAV can instead of manual work, which is greatly reducing the risk and cost [2-3].

As we all know, UAV cannot operate continuously for a long time (usually the flight time is about 20-40 minutes) due to its traditional lithium-ion battery model [4]. It brings many problems to the use of UAVs and the expansion of its application field. Therefore, how to extend the battery life of UAV has become one of the hot issues in the research field. At the same time, satellite positioning systems (such as GPS in the United States and Beidou system in China) [5-6] are currently widely used global navigation positioning service systems that can provide all-round, all-weather, all-time, and low-cost. However, the accuracy of the global satellite positioning system open to the civilian field is about 10 meters. Using the satellite positioning system alone cannot make the UAV land to a designated location with a range of tens of centimeters [7]. In addition, the drone is battery-powered. Taking into account the lifetime of the UAV, the transmission power of its wireless transmitter is usually very limited.
Due to the load limitation of the drone, a small antenna is usually required, which limits the signal transmission performance of the antenna. This greatly limits the communication distance of UAV (usually only a few hundred meters to several kilometres).

Therefore, how to extend the communication distance of drones is also one of the problems urgently to be solved [8].

To tackle the above problems, this design uses a solar panel to provide the source of electrical energy for the entire device, and at the same time provides a platform for the drone to take off and land, and uses a wireless charging stand to charge the drone battery. Use STM32F407 as the main control chip, with the help of GPS, wireless communication module NRF24L01, temperature and humidity sensors, etc., to carry out information collection, interactive communication and task scheduling between the docking platform and the UAV.

2. System structure and working principle

2.1. System power supply and control
The main power supply method of this system is solar photovoltaic panels. To prevent the power shortage caused by a long cloudy day, the auxiliary power supply is 220V AC. The solar photovoltaic panel is stabilized by the solar controller, and the UPS power supply seamlessly switches between the solar power supply and lithium iron phosphate battery power supply to ensure that the system will not be powered off. The solar photovoltaic panel supplies power to the lithium iron phosphate battery, and other modules of the system, such as the control module and communication module, are directly powered by the lithium iron phosphate battery. Among them, the UAV lithium battery wireless charging device is directly powered by the solar controller, and the high current charging can ensure the charging time and efficiency. The voltage of the drone battery is detected, and the power supply is stopped after reaching the preset voltage. The lithium iron phosphate battery is only used for auxiliary charging and provides power protection for the drone lithium battery when there is no sunlight or the solar photovoltaic panel cannot work. Intelligent switching between 220V AC power and solar energy, when 220V AC power supply, solar energy is automatically cut off.

The overall control of the system is completed by the main control board equipped with the STM32F407 chip. Its main tasks are to collect and analyse the time, coordinates, temperature, and humidity information of GPS, temperature and humidity sensors, etc. And interactive communication and task scheduling of the UAV through the wireless communication module. Thereby, the functions of the fully automatic unmanned aerial vehicle [4] taking off and landing at a fixed time under the conditions are met. Fig. 1 shows System power supply and control.

2.2. System hardware structure
The hardware structure of this system adopts a detachable and assembled aluminum alloy structure to build a sealed cuboid structure table with a length * width * height of 2m * 1.8m * 1.5m (as shown in Fig. 2), which can be parked for a long time without drones. And the waterproof and moisture-proof material can protect the drone from external damage such as wind and rain. A solar battery patch is attached to the outer layer of the upper window to supply power to the system.
2.3. System mechanical structure

The mechanical structure of the UAV hangar mainly includes the lifting structure of the helipad and the solar skylight door, the centering device, the hangar frame and the related covering parts. The retractable structure of the solar sunroof panel door is only opened when the UAV is taking off and landing, and is closed at other times to protect the UAV and other parts of the circuit from rain or other factors. The helipad can be raised when the drone is ready to take off or return, and can descend after the drone has taken off or landed. Because there is a certain error from the predetermined landing point when the man-machine is landing, the pendulum is used to adjust the position of the drone so that it is at the center of the apron, which can make the center of the transmitter coil and the receiver coil of the wireless charging device coincide. The charging efficiency is the highest. The hangar frame is a splicable structure with aluminium alloy as the main material, and the related covering parts make the whole structure sealed to achieve a waterproof effect.

A base station box is installed at the back of the hangar, and a manual operation panel is installed on the right panel of the hangar. In necessary or emergencies, the hangar can be controlled through the manual operation panel. The lifting and lowering of the apron and the opening and closing of the solar
panel door are all completed by intelligent electric push rods. The electric push rod is an electric drive device that converts the rotary motion of the motor into a linear reciprocating motion of the push rod. Use the motor forward and reverse to complete the push rod action. There is a stroke limit switch at each end of the push rod. After the push rod runs to the end or top, it will automatically stop. A linear guide rail and a slider are installed below the solar cell panel, and the solar panel moves linearly on the linear guide rail through the slider. There are two rows of balls in the slider, which can greatly reduce the friction during the movement of the apron and the solar panel. The pendulum is installed on the horizontal surface of the final landing position of the apron, and is composed of four push rods and push rod slide rails. Through two pairs of horizontal and vertical push rods, the UAV is finally adjusted to the position directly above the wireless charging base according to the limit switch.

3. Software design

3.1. Software Requirements

The realization of the fully automatic UAV docking platform requires software to complete the following functions: under the working state, the drone is parked on the tarmac in the hangar. When the preset inspection time is reached, the main control chip reads the results of the temperature and humidity sensor, gyroscope, communication module, UAV lithium battery power detection module, etc., and comprehensively judges whether it is suitable for takeoff and whether the takeoff conditions are met. If
it is, it will send a takeoff signal to the drone, and at the same time control the solar skylight to open, and the drone will take off after the apron rises to the same height as the skylight; otherwise, a no-fly signal will be sent and the drone will stand by. After the drone took off, the apron descended, the solar skylight was closed, and the battery was charged with solar energy. When the drone return signal is received, the solar skylight door opens and the lifting apron rises. After the drone stops, the apron and skylight automatically retract and close. The wireless charging device under the apron directly gives recharge the lithium battery of the drone. Fig. 3 shows the operation of the fully automatic UAV docking platform.

3.2. Software Implementation
The realization of some software functions mainly includes circuit control, module and sensor data reading and communication. The circuit control of the sunroof, lifting apron and pendulum is realized by the relay, and the output level of the GPIO port determines the opening and closing of the relay. The data reading of the module and the sensor is realized by the serial port USART. Taking the reading of GPS data as an example, the serial port receives the information returned by GPS and processes it according to the NMEA-0183 protocol, and stores the obtained data in the corresponding array. The communication part uses the SPI protocol, by controlling the level of the CE pin and setting the PWR_UP and PRIM_RX bits of the CONFIG register to achieve receiving, sending, standby and other working modes.

4. Experimental results
This section is to check whether the system can work normally and meet the expected design requirements. Through the test of the system, you can judge the shortcomings of the system and improve the system in time. In this design, the system test mainly includes the hardware test of the system, the wireless communication test of the system and the function test of the system.

4.1. Hardware testing and analysis
The hardware test is to check whether the hardware part of the system meets the design requirements, whether it can work normally, whether there are poor circuit contact, and unreasonable design problems.

First, the hardness and tightness of the shell are tested. Assemble the whole structure and put it into the aircraft, close the skylight, and the test results show that the outer shell is hard enough to support and protect the internal structure, and meet the basic waterproof requirements.

After basic testing of the tightness of the designed hardware, power on the device to conduct power-on testing to determine whether each part of the system can meet the hard requirements and the required working state after power-on. After testing, the sunroof, lifting apron and pendulum can open / rise (close / down) at a moderate speed after being connected to positive (negative) power. After joining and using the main control board, the working sequence of each part is consistent with the design.

4.2. Wireless communication test and analysis
The communication part test is mainly to test whether the wireless module can be paired and send and receive data normally after power-on. After the initialization is successful, the platform and the UAV wireless communication module are paired successfully, and data can be sent and received normally. Communication distance test, this system uses NRF24L01 wireless communication module, the theoretical communication distance is within 1 km. According to actual measurement, when the straight line distance between the drone and the platform is within 200m, the communication effect is good, and no data loss occurs. From the test structure, we can know that the wireless module can send the collected data and instructions in real time and quickly, which can meet the needs of the system.

4.3. System function test and analysis
This system has three main functions: one is to provide the drone with a charging service to improve the endurance of the drone, and the other is to assist the drone to take off and dock at a fixed point for the
long or short stay of the drone. The third is to realize the communication between the drone and the service desk. The drone battery is a 2200mAh lithium battery with a rated voltage of 12.6V. This test compares the charging efficiency of the wireless charging solution designed this time with wired charging (Fig. 4). Carried out under the same starting voltage of 11.28V and charging environment. It can be seen from the test that the maximum full-charge voltage of wireless charging is about 12.53V, which is slightly less than the full-charge voltage of wired charging.

![Figure 4. Comparison between wireless charging and wired charging (the horizontal axis is the charging time and the vertical axis is the battery voltage; Curve one is under wireless charging, and curve two is under wired charging).](image)

5. Conclusion
This paper presents the design and implementation of a fully automatic drone docking platform system. The system uses solar energy as the main source of electrical energy, which can be used as a platform for takeoff and landing by drones, and to charge the batteries of drones to improve their endurance. In addition, the system can assign tasks to the UAV by analysing the collected data. In summary, this system can solve the problems of the current unmanned aerial vehicle's poor battery life, the small power of the communication transmitter, and the inability to use it in a relatively remote or harsh environment.

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