ECE 445

SENIOR DESIGN LABORATORY

PROPOSAL

FIXED-WING DRONE WITH AUTO-NAVIGATION

Team #7

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1 Introduction

1.1 Problem and Solution

In recent years, the increase in natural disasters such as chemical leaks, wildfires, and volcanic eruptions has led to the need for prompt notification of affected areas and the collection of accurate environmental data to reduce casualties and prevent environmental damage. Traditional methods of communication and data collection may not be effective in hazardous or hard-to-reach areas, creating a need for a novel solution.

This project aims to build a fixed-wing drone using 3D printing technology, which offers several advantages over traditional manufacturing methods. 3D printing allows for greater design flexibility and faster production times, which is essential for rapidly responding to natural disasters. Additionally, the use of lightweight materials in 3D printing can enhance the drone's flight performance, making it more efficient and capable of flying longer distances.

The drone will be equipped with a loudspeaker, enabling it to broadcast information during flight to notify individuals in affected areas of imminent danger or provide evacuation instructions. The designed drone can automatically fly along a specified route based on computer instructions when it receives an alarm signal. This will improve the response speed to disasters and reduce the risks of flight operation. Additionally, the drone will carry an air quality sensor to collect air condition data including temperature, humidity, air pressure and so on, during flight and transmit it in real-time or store it in SD card for later analysis. This solution offers a more efficient and effective way to communicate and collect environmental data during natural disasters, reducing the risk of harm to individuals and the environment.

1.2 Visual Aid

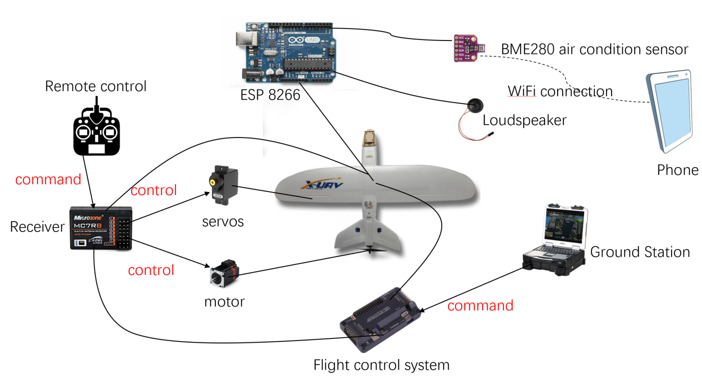

Figure 1: Visual Aid

1.3 High-level requirements list

- The drone can be controlled manually so that we can control the drone to some places to collect data including the air quality.
- The drone can realize self-stabilization in the air, allowing the drone to work in extreme weather, especially the windy days.
- The drone' can navigate autonomously so that the drone can collect data from different places autonomously when out of the remote controller's receiving range.
- The drone can be placed on the landing gear to take off instead of jettisoning, avoiding the risk of injury from the tail propeller.

2 Design

2.1 Block Diagram

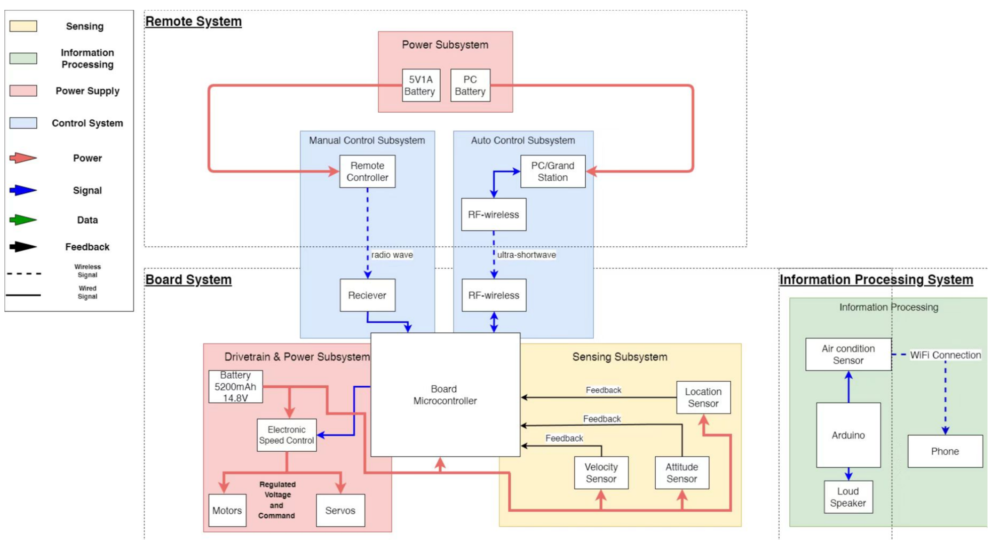

Figure 2: Block diagram

2.2 Subsystem Overview

Manual Control Subsystem

This subsystem consists of the remote control and its receiver, which receives signals from the remote control and signals from the flight control system and sends signals to the drivetrain system. This subsystem is connected with the auto control subsystem through the receiver and with the power subsystem through the remote control.

Auto Control Subsystem
This subsystem consists of two main components: a ground station software installed on a laptop and a microcontroller installed on the aircraft. These two components are connected wirelessly through a pair of RF-wireless modules. One module is connected to the laptop, while the other is connected to the microcontroller on board the aircraft, establishing a bidirectional wireless communication link between them. The microcontroller receives commands from the ground station software and sensor data from the Sensing Subsystem, which it uses to control the aircraft through the Drivetrain & Power Subsystem. Additionally, the microcontroller will transmit data from various sensors described in the Sensing Subsystem back to the laptop via RF-wireless communication. The primary function of this subsystem is to enable the aircraft to achieve self-stabilization and perform automatic cruising.

Sensing Subsystem
This subsystem is composed of five components: an MS5611 barometer, an L3GD20 gyroscope, an LSM303D accelerometer/magnetometer, an MPU6000 accelerometer/gyroscope, and an M8N GPS module. These components are powered by the 5200mAh battery in the Drivetrain & Power Subsystem of the aircraft. The sensors are responsible for collecting various types of data during flight, which are transmitted to the microcontroller on board the aircraft.

Drivetrain & Power Subsystem
This subsystem consists of a 5200 mah battery with an XT60 socket that powers the remote's receiver by connecting to the electronic speed controller, one electronic speed controller, four steering engines and one motor. This subsystem provides power to various electronic components on the aircraft, and adjusts the power to control the flight of the aircraft based on commands from the manual or automatic control subsystems. This subsystem is connected with the control subsystem through the ESC and the receiver of the remote control.

Power subsystem
This subsystem consists of four AA batteries that power the remote control and the power supply that powers the computer.

Information Processing Subsystem
This is an independent subsystem. We plan to design the system to use Arduino to control the sensors and the speakers and put the system on the drone. While in the air, the drone can detect air quality through the sensor and transmit data to the ground. It can also emit a warning sound in the air.

2.3 Subsystem Requirements

Manual Control Subsystem
This subsystem includes the Microzone6 remote control and the MC7RB receiver.By adjusting the frequency of the remote control and the receiver, the remote control can be used to control the channel corresponding to the receiver. When the four

steering engines are connected to the channel corresponding to the receiver, You can use a remote control to turn the steering gear and turn the wing end of the drone up. At the same time, the receiver is connected to the microcontroller and can receive signals from the microcontroller to achieve self-stabilization and automatic cruise of the drone.

Auto Control Subsystem
This subsystem is achieved through the integrated control and communication between the ground station software and the microcontroller on board the aircraft. The ground station software allows for remote control and monitoring of the aircraft's flight status, while the microcontroller processes the sensor data and controls the flight dynamics accordingly. microcontroller is capable of timely transmitting aircraft data such as linear acceleration and heading, atmospheric pressure and altitude, orientation and movement, etc. to the ground station via RF-wireless module, and adjusting servos and motors based on the output signals to the Drivetrain & Power Subsystem in order to achieve functions such as aircraft self-stabilization and automatic cruise. The communication frequency of RF-wireless module V5 is 915MHz, with a maximum communication distance of 2000m. It needs to operate under a DC power supply of 3.7V-6V. microcontroller uses a current meter with an output voltage of 5.3V and a maximum output current of 3A to supply power after being connected to the 5200mAh battery.

Sensing Subsystem
This subsytem consists of five components: MS5611 barometer, L3GD20 gyroscope, LSM303D accelerometer/magnetometer, MPU6000 accelerometer/gyroscope, and M8N GPS module. Each of these components must function properly and communicate with the microcontroller on board the aircraft in order to collect various types of data during flight, which is necessary for altitude control, navigation, orientation, and movement of the aircraft.

The MS5611 barometer measures atmospheric pressure and altitude, providing crucial information for altitude control and navigation. The L3GD20 gyroscope measures the angular rate of the aircraft, providing information on the aircraft's orientation and movement. The LSM303D accelerometer/magnetometer measures acceleration and magnetic field strength, providing information on the aircraft's linear acceleration and heading. The MPU6000 accelerometer/gyroscope also measures acceleration and angular rate, providing additional information on the aircraft's orientation and movement. Finally, the M8N GPS module provides location data, allowing for precise navigation and control of the aircraft.

This subsystem contributes to the overall design by providing crucial data that is necessary for the proper function of the aircraft. Without this data, the aircraft would not be able to maintain altitude, navigate accurately, or stabilize itself in the air. Additionally, without accurate orientation and movement data, the aircraft would not be able to navigate autonomously, which is a key requirement for this design.

Drivetrain & Power Subsystem
The subsystem includes a 5200mAh power supply, a SKYWALKER 50A electronic speed controller, four ES08MAII 8.5g steering engines, and an X2216 KV1250 motor. The power supply is connected to the ESC and to the receiver of the remote control, while the motor is connected to the ESC and the steering gear is connected to the receiver of the remote control. When the receiver receives the signal, it is passed to the steering gear, which acts on the signal, and the signal is passed through the ESC to the motor, which operates to power the aircraft.

Information Processing Subsystem
The subsystem includes Arduino, loudspeaker, and the air condition sensor. The sensor can detect the air quality including temperature, humidity and pressure and the Arduino can create a network and transmit the air quality data back and we can get the data through our phone or computer connected with the network.

2.4 Tolerance Analysis

The circuit of the Arduino
When we install it on the drone, we should have the power supply for the Arduino. For ESP8266, the input can be 3.3V and 5V. However, we just have a cell box that can contain 3 AA batteries which can supply 1.5V voltage. According to the pin rule, we cannot supply Arduino. Then after learning ESP8266, we find that the tolerance of voltage range of digital part is 1.8V - 3.3V and the operating voltage of the analog part is 3.0V - 3.6V, with the lowest 2.7V. We can use two AA batteries to supply Arduino.

Manufacturing of aircraft fuselage and control surfaces
For the manufacturing of aircraft fuselage and control surfaces, we use numerically controlled (NC) machining equipment to ensure their precision and dimensional accuracy. We measure the thickness of the fuselage and control surfaces with precise measurement tools to ensure thickness errors are within ±0.5 millimeters. We also pay attention to the symmetry of the fuselage, using precision measurement tools to detect any asymmetry and ensure it does not affect the stability of the aircraft.

To ensure the precision and dimensional accuracy of the fuselage and control surfaces, we need to pay attention to the following details during the manufacturing process:

1.The material selection needs to meet the design requirements.

2.Regular inspection of machining tools for wear and tear and timely replacement to avoid affecting machining precision.

3.Accurate calibration of the machine tools, including calibration of the coordinate axis and machine rigidity, to ensure machining precision.

4.For complex-shaped fuselage and control surfaces, multiple machining processes are required, such as milling, cutting, and stamping, to ensure their accuracy and dimensional accuracy.

5.In the manufacturing process, measures need to be taken to prevent deformation of the fuselage and control surfaces, such as fixing them with fixtures and making compensations during the machining process.

6.Regular inspection of the dimensions and thickness of the fuselage and control surfaces, as well as their symmetry, to ensure they meet the design requirements.

Numerical control equipment uses computer-aided manufacturing (CAM) technology to convert design drawings into machine language and control NC machine tools for processing. Common NC machine tools include CNC milling machines, CNC lathes, and CNC cutting machines, which can achieve the processing of complex curves and polyhedrons, as well as cutting and forming of different materials. Precision measurement tools such as micrometers, vernier calipers, and height gauges are needed in the manufacturing process of the fuselage and control surfaces. In the manufacturing process, it is necessary to measure the dimensions and thickness of each component to ensure they meet the design requirements. The thickness of the fuselage and control surfaces is an important parameter because their strength and weight are related to their thickness. We need to ensure that their thickness errors are within ±0.5 millimeters to ensure their performance and safety. In addition, symmetry is also crucial for the fuselage. Asymmetry can cause unstable flight and affect the performance and safety of the aircraft. Therefore, we need to use precision measurement tools to detect any asymmetry of the fuselage and ensure it does not affect the stability of the aircraft.

Possible equations that may be used are:

Thickness formula for the fuselage and control surfaces:

$$t = \frac{m}{V}$$

where t represents thickness, m represents mass, and V represents volume.

Symmetry error formula:

$$e = \frac{L1 - L2}{L}$$

where e represents symmetry error, L1 represents the length of the left side of the fuselage, L2 represents the length of the right side of the fuselage, and L represents the total length of the fuselage.

Electric motors and electronic speed controllers (ESC)
For electric motors and electronic speed controllers (ESC), we use high-precision testing equipment to measure their rotational speed and current stability tolerance. We have established strict tolerance standards, where the speed error of the motor should be within ±5%, and the current stability tolerance of the ESC should

be within ±10%. During the manufacturing process, we use precision machining equipment and processes to control the tolerance of the motor and ESC, ensuring their performance meets design requirements.

To ensure the precision and performance of electric motors and ESCs, we need to pay attention to the following details during the manufacturing and testing processes:

1.Material selection: The motor and ESC should be made of high-quality materials that meet the design requirements, with high strength, good thermal conductivity, and low resistance.

2.Precision machining: The motor and ESC should be processed with high-precision equipment, such as CNC machines, to control their dimensions and tolerance.

3.Testing equipment: High-precision testing equipment, such as tachometers and ammeters, should be used to measure the rotational speed and current stability tolerance of the motor and ESC.

4.Tolerance control: Strict tolerance standards should be established for the motor and ESC, and the manufacturing and testing processes should be controlled accordingly.

5.Thermal management: Proper thermal management should be implemented to prevent overheating of the motor and ESC, which could lead to performance degradation or failure.

Possible equations that may be used are:

Motor speed formula:

$$\omega = 2 \cdot \pi \cdot f$$

where ω represents the rotational speed of the motor, and f represents the frequency of the motor.

ESC current formula:

$$I = \frac{V}{R}$$

where I represents the current flowing through the ESC, V represents the voltage supplied to the ESC, and R represents the resistance of the ESC.

In summary, the use of high-precision testing equipment and strict tolerance standards, along with precision machining and thermal management, are crucial for ensuring the performance and reliability of electric motors and ESCs in aircraft systems.

3 Ethics and Safety

3.1 Ethics

Privacy: The use of drones for surveillance or other purposes can raise privacy concerns, as drones can capture images and video of individuals without their consent. This issue is addressed in the IEEE Code of Ethics [1], which emphasizes the importance of respecting privacy and avoiding harm to others.

Autonomy and Responsibility: The use of autonomous drones raises questions about responsibility and accountability in the event of accidents or other incidents. The ACM Code of Ethics[2, 3] emphasizes the importance of ensuring that autonomous systems are designed and used in ways that are consistent with ethical principles and that prioritize human welfare.

Bias: Machine learning algorithms used in the navigation system of the drone may have biases that could impact decision-making, which could have implications for fairness and equity. The IEEE Code of Ethics[1] emphasizes the importance of avoiding bias in decision-making and ensuring that systems are designed to be fair and equitable.

To avoid ethical breaches, it is important to follow best practices in the design and deployment of the drone, including conducting rigorous testing and ensuring that the system is transparent and accountable. It is also important to involve stakeholders, such as members of the public and regulatory agencies, in the design and deployment process to ensure that concerns are addressed proactively.

3.2 Safety

FAA Regulations: The Federal Aviation Administration (FAA)[4] has strict regulations governing the operation of drones, including requirements for registration, certification, and flight restrictions. It is important to ensure that the drone is in compliance with all relevant FAA regulations.

Safety Standards: There are various safety standards that apply to the development and operation of drones, such as those issued by the International Organization for Standardization (ISO)[5]. It is important to ensure that the drone meets all relevant safety standards.

Operational Risks: There are various operational risks associated with the use of drones, such as the risk of collisions with other objects or aircraft. It is important to conduct thorough risk assessments and implement appropriate safety measures, such as collision avoidance systems and emergency landing procedures.

To mitigate potential safety concerns, it is important to conduct thorough testing and risk assessments, and to implement appropriate safety features and procedures in the design and operation of the drone. It is also important to adhere to all relevant regulatory requirements and to seek guidance from regulatory agencies as needed.

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