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DEVELOPING A LOW-COST RPA TO MEET THE DEMANDS OF TEACHING AND RESEARCH AT CCA - UFPB

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Abstract: This paper presents the development and improvement of a low-cost RPA for teaching and research in the Agronomic Engineering course at the Center for Agrarian Sciences at the Federal University of Paraíba. The use of these platforms for civilian use has become increasingly popular in the last decade, due to the growing demand for mapping, monitoring, imaging and inspection data, among others, driven by countries such as Brazil. The selection of the type of electric motor, propeller, battery, communication and telemetry channel, autonomous flight system, as well as other components, followed a technical study aimed at increasing the range of possible areas for obtaining data in the most varied areas of the agricultural sciences. The result obtained so far has been the development of a remotely piloted aircraft costing less than R$ 600.00, a much lower cost than that offered on the market.
Keywords: Unmanned Aerial Vehicles (UAV), Fixed-wing platform, UFPB, CCA, DSER.

INTRODUCTION

Remotely piloted aircraft (RPA) can be fixed-wing or rotary-wing, among other platform models. Fixed-wing drones have advantages such as greater speed, coverage, safety, autonomy and load capacity. They are used in various areas of the geosciences to obtain data.

The use of fixed-wing drones has several advantages over other platforms.

They have higher flight speeds, greater area coverage capacity, offer greater safety, consume less battery power, have greater load capacity for equipment, have longer flight times and lower manufacturing and maintenance costs. Over the last decade, these platforms have proved to be important tools for obtaining data in various areas of the geosciences.

Drones have many civilian applications, such as topographical and geological mapping, wildlife and fire monitoring, public safety, industrial and electrical inspection and evaluation, urban management, imaging, among others. Countries such as the United States, Israel and China are leading the way in developing drones for military use. Currently, European and American countries, including Brazil and Canada, are developing these platforms mainly for civilian use, since demand in this sector is constantly growing. In Brazil, in 2023, purchasing a commercial drone will cost around US$ 30,000.

These aircraft are mainly fixed-wing and required advanced technical knowledge to manufacture, as they used expensive and complex electronic equipment. Nowadays, however, cheaper electronics with greater processing capacity have been developed.

In this context, so-called "open hardware" and "open software" products appeared on the market, which reduced the prices of flight controllers (the brains of the platform) internationally. This has resulted in constant updates and improvements up to the present day. The application and validation of the data generated by these platforms in Brazil was initially demonstrated in works published by Medeiros (2007) and Longhitano (2010).

There are several models of fixed-wing platforms used in teaching and scientific research. The model we see in this work was developed at the Laboratory of Instrumentation and Applied Physics - LIFA (Fig. 1), using low-cost materials, the platform has been developed mostly in fiberglass and 3D printed parts.

When choosing a drone, it is important to consider the specific characteristics of each model, such as flight time, range, endurance, wingspan, weight, material, load capacity and development price.

However, in this paper, we will not be discussing technical comparisons between the models, but rather a methodology for assembling and technically improving a platform developed during a supervised internship. In addition to being used for teaching purposes at UFPB's Agricultural Sciences Center, it will also be used in the Project to Rescue Coffee Growing in Brejo Paraibano, which is supported by the Federal University of Paraíba's Center for Coffee Studies (NECAF UFPB).

Figure 1. Fixed wing platforms, model developed in fiberglass and 3D printed parts.

PLATFORM DEVELOPMENT

The project is currently in the development phase at the Instrumentation and Applied Physics Laboratory (LIFA) of the Department of Soils and Rural Engineering at CCA - UFPB. The RPA will be able to fly autonomously for various purposes, such as environmental monitoring, mapping areas, inspecting infrastructures, among others. As the project is still in progress, we don't have any concrete data on the flight range per hectare that the drone can achieve. However, intensive work has been done on building the autonomous flight system. The control system is based on the ARDUPILOT open source initiative, making it possible to add a wide range of instruments for environmental monitoring. This system will allow the RPA to follow a predefined route or mission without the need for human intervention.

The RPA is designed using fiberglass, a material widely recognized for its qualities. This material is a composition of glass filaments interwoven and impregnated with resin. This combination gives fiberglass several advantageous characteristics.

First of all, fiberglass is known for its high resistance and rigidity. It is able to withstand significant forces and impacts, making it ideal for applications where robustness is essential. In addition, it is a relatively light material, which contributes to the aerodynamic performance of the platform and facilitates transportation. commonly used in model airplanes, it is durable, strong and impact-resistant.

This platform can move in all three axes in relation to its center of gravity. The two ailerons/propellers are responsible for controlling the roll angle (ϕ), allowing it to tilt left and right, as well as the pitch angle (θ) up or down. This platform also has rudder control, so it is also able to perform lateral yaw movements (ψ) to the left and right.

COMPONENTS OF THE UAV

The operation of the fixed-wing platform requires the integration of various hardware and software components. The hardware components include the external physical structure, consisting of the body and wings of the aircraft, as well as the engine, propeller, control servos, battery, flight controller, telemetry, radio transmitter receiver and airspeed and pressure sensor. It is important to mention that this project is still in full development, so the autonomous flight system has not yet been completed and the RPA is undergoing constant improvements.

Software plays an essential role in flight operations, being responsible for telemetry and flight control settings that can be configured remotely. Any failure or error in one of these hardware and/or software components can compromise safety and the proper execution of the flight.

ELECTRIC MOTOR

The electric motor used was the D3536 model from NEEBREC, a brushless outrunner motor with a rotation rate of 1200kv (rpm/V). It has a maximum current of 70 A, a shaft diameter of 6 mm and a weight of 111 g (Fig. 2). This motor is compatible with 2- to 4-cell Li-po batteries (2S to 4S), and is capable of generating a maximum static traction of 1680 g. It is a low-cost motor, which in our tests has proved to be reliable (Fig. 2).

Figure 2 Electric motor model D3536 of the NEEBREC brand.

PROPELLER

The platform we developed has the propeller/engine assembly located at the rear, positioned behind the aircraft's center of gravity (CG). In this configuration, the propeller pushes the air backwards, propelling the aircraft forward during flight.

The characteristics of the propeller are related to its size, pitch, number of blades, shape and material. As for the size of the propeller, it is important to choose an appropriate proportion in relation to the platform used (Fig. 3).

Propeller pitch refers to the distance covered in a single revolution. In the case of our platform, which has no landing gear and makes belly landings, we use folding propellers to prevent damage during landing and reduce drag in flight when the engine is not in use. In terms of material, the propellers can be made from carbon fiber or plastic, offering different characteristics and performance.

Figure 3 - Type of propeller currently used on the platform.

BATTERIES

The batteries used are *lithium* polymer (LiPo) and have 11.1 V, equivalent to 3S (each S corresponds to a 3.7 V cell). The capacity of the battery used is between 2200 mAh (*milli--Ampere per hour*) and the *discharge rate* is estimated at between 20 C (continuous discharge) and 60 C (rapid discharge), as shown in figure 4.

Figure 4 - Li-Po 3S battery used.

At the time of writing, the UAV's flight range had not yet been evaluated, so we cannot provide a precise flight time for the platform with the battery mentioned above. Flight time can vary depending on factors such as the weight of the platform, wind conditions, type of take-off and cruising speed. However, the platform we have developed has space to carry up to two 2200 mAh batteries.

Battery settings, including quantity and amperage, are determined by the characteristics of the mission, such as flight time, distance and ambient temperature. In addition, increasing the amperage of the batteries results in an increase in weight, which does not necessarily translate into a longer flight time. In general, the addition of a similar battery increases flight time by around 40%, but also increases the weight of the platform.Traub (2016) proposed that, during cruise flight, maximum battery endurance is achieved when the weight of the battery(s) represents less than 2/3 of the total weight of the platform. This relationship between battery weight and platform performance directly influences flight duration.

BATTERY CHARGER

Li-Po batteries require chargers with special features. It is important that these chargers have a balanced charging option to ensure that all the battery cells have the same voltage. Batteries with balanced cells offer uniform performance, as their charges are equally reduced during use.

The chargers are equipped with microcontrollers that monitor the maximum charging time and automatically switch off when this time is reached. They offer various charging options, such as balancing, normal charging, unloading and storage.

When we charge and discharge a battery, we say that it has gone through a "cycle". LiPo batteries have a maximum cycle limit, which can vary depending on the charging current, the manufacturer's quality and storage conditions. On average, they can withstand around 400 cycles. For this purpose, we used the IMAX B6 model charger, which has charging, balancing and discharging functions, as shown in figure 5. This charger is compatible with Li-ion, LiPo, LiFe, Ni-Cd, NiMH, LiHV, NiZN and Pb batteries.

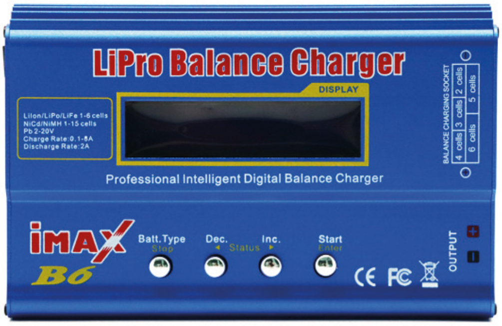

Figure 5: Charger/balancer model IMAX B6.

RADIO TRANSMITTER (TX)

The radio transmitter is the essential device for controlling the platform, allowing you to take command of it. It communicates with an on-board receiver, which receives and interprets the signal emitted by the transmitter, triggering the servos to move the control surfaces. In this way, the radio transmitter is responsible for transmitting the desired commands, giving you the ability to pilot and control the platform with precision.

BATTERY CHARGER

The radio controller system JR XG6 is designed specifically for model airplanes and offers several advantages in terms of performance and functionality. Developed in partnership with renowned airplane, helicopter and glider pilots, the advanced software provides a high-quality flying experience.

The highlight of the system is the DMSS (Dual Modulation Spectrum System) protocol, an innovative 2.4 GHz transmission exclusive to JR, which offers low latency and a robust RF link to ensure a reliable connection with the models. In addition, the XG6 transmitter has integrated telemetry, a significant feature for a 6-channel radio system. The receiver's voltage reading is monitored as standard, and we have the option of adding up to 6 additional telemetry functions, such as temperature, RPM, altitude, variometer and flight pack voltage.

The XG6 transmitter is ergonomically designed and lightweight, providing comfort during long periods of use. With a built-in memory for up to 20 models and a micro SD card slot, you can easily back up your aircraft settings and have virtually unlimited possibilities. The system also allows for future firmware and software updates to keep you up to date with the latest improvements.

The XG6 transmitter has an intuitive interface and comprehensive programming, meeting the needs of basic and advanced flying. The system is accompanied by the RG612BX DMSS 2.4 GHz 6-channel receiver from the XBus range, which has diversity features to ensure stable reception and maximize the features offered by the transmitter.

Figure 6 - JR XG6 radio controller.

ON-BOARD SENSORS AND CAMERAS

Due to its large load capacity, this platform is very versatile for transporting different types of sensors, with the possibility of transporting RGB and/or infrared cameras, thermal cameras, multispectral, hyperspectral, RADAR, LIDAR, among other sensors. Initially, a camera will be used so that we can work with the NDVI (*Normalized Difference Vegetation Index). It should be noted that the sensors and/or cameras to be carried depend solely on the task to be carried out on each flight.*

SERVOS

Four servos are used to move the platform's control surface, one servo for each wing and two servos for the rudder.

CONCLUSION

This internship report presents a methodology for developing a fixed-wing UAV with a low cost, below R$ 300.00, and of medium complexity in construction and maintenance. The main objective of this project is to significantly reduce costs compared to similar equipment available on the market.

The decrease in funds allocated to equipment purchases through funding projects in recent years has played an important role in the realization of this work. In addition, the development of the platform according to specific demand, whether for educational or research purposes, makes it possible to optimize the configuration to obtain the best cost-benefit ratio.

The platform developed at this stage has a wide range of applications and can be used by universities, research institutions, farms and government agencies with a public interest, among other sectors. One example of an application is geological mapping, using RGB and/or multispectral cameras to generate data on geological contacts in hard-to-reach areas, identify rock masses and perform volume and area calculations in mining areas.

The platform has a large load capacity and can carry various types of sensors, such as cameras with different spectra, RADAR, LIDAR and others. The aim is to use these sensors to obtain information about vegetation. One of the sensors that will be used is a camera that can calculate the NDVI index, the Normalized Difference Vegetation Index, which is a numerical indicator that measures the state and density of vegetation in a VARP and/or satellite image. It is calculated by the difference betwe-

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en the reflectance of light in the near infrared and visible red, divided by the sum of these reflectances. This index ranges from -1 to 1, with negative values indicating water, clouds or snow, and values close to zero indicating rocks or sunlight discovered, values between 0.2 and 0.3 indicate shrubs and grasslands, and values between 0.6 and 0.8 indicate temperate and tropical forests. NDVI can be used to estimate plant health, primary production, soil moisture and the risk of forest fires. In short, this index is obtained by the normalized difference between infrared and red radiation, which are reflected by plants. The aim of the project is to use NDVI to monitor the growth, productivity and stress of vegetation.

The RPA that has been developed at the ***Laboratory of Instrumentation and Applied Physics (LIFA) of the Center for Agricultural Sciences at the Federal University of Paraíba*** is a versatile platform that aims to bring technology, reliability, safety and precision to agriculture at an affordable price, as well as to any other activity that requires the use of a drone that has greater flight autonomy, greater speed, greater stability, and a greater load capacity compared to a quadcopter, so the use of a low-cost fixed-wing drone is an interesting option for the most diverse applications.

THANKS

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IMAGES

Below are some images showing some stages in the development of the RPA at the Laboratory of Instrumentation and Applied Physics (LIFA) at the Center for Agricultural Sciences at the Federal University of Paraíba.

Image 1: RPA in development:

Image 2: RPA's electric motor and propeller.

Image 3: Front of the RPA with FPV system camera and Pitot tube.

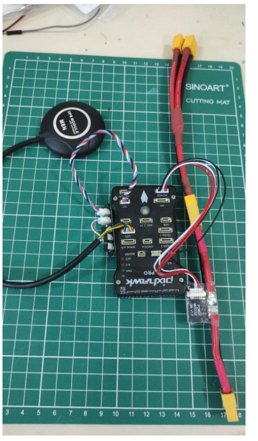

Image 4: Pixhawk Pro controller, GPS system.

Image 5: Side view of the RPA, currently still being assembled.

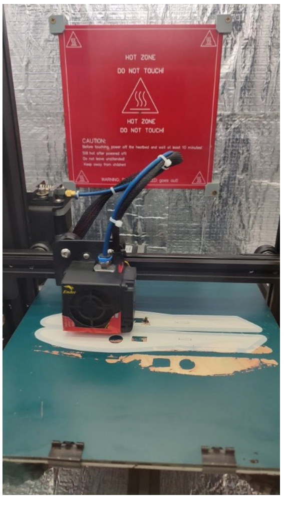

Image 6: Internal view of the 3D printer, printing RPA parts.

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