Design, implementation and control of a UAV blimp for photography

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Abstract— *Aerial vehicles as VTOL 's (VERTICAL TAKE OFF LANDING), who meet tasks such as exploration are costly in terms of maintenance and resource consumption, as commonly these work self -powered propellers, which generates high energy consumption. One solution is the use of dirigible, which are economical and effective for the task of exploration, these it possible to obtain aerial images accurately and less consumption of energy resources due to flying at a constant height and should not counteract weight, which facilitates the execution of tasks such as scanning and monitoring.*

Keywords— Dirigible, IMU, consumption of energy resources, slenderness, complementary filter.

I. INTRODUCTION

When there is a need to carry out exploration, are required aerial vehicles type VTOL's [1], this set of vehicles are linked to problems such as high consumption of energy resources, because they are commonly supported by propellers, and these must remain moving, representing, low autonomy. In contrast an airship can travel at low speeds and can sweep an area similar to that of a VTOL, however, the advantage of going at lower speeds and no load is the low power consumption, so that autonomy could be higher and even eventually energy is taken from sunlight (photovoltaics) [2].

An airship can be static developing tasks as collection environmental data or vigilance for long periods of time, tasks in which highlight due to its low consumption of energy resources.

An alternative that reduces operating costs and increases autonomy; is the use of airships UAV (Unmanned Aerial Vehicle) [3]. The project focuses on designing, implementing and controlling a blimp UAV type.

II. METHODS AND MATERIALS

2.1 Physical Design Airship

The dirigibles are part of the family of the aerostatics, classified as lighter than air, operating under the Archimedes principle that states that a total body or partially submerged in a fluid, will be pushed with a force equal to the weight of the fluid volume displaced by the object [4]. Thus, when a body is immersed in the fluid an aerostatic thrust resulting from the pressure on the body surface is generated, based on the equation 1. The volume of helium required for the system is at no load is obtained.

$$V = \frac{P}{\rho_{air} - \rho_{gas}} \tag{1}$$

Where,

P= Payload (kg.)
V= Volume Airship (m^3)
ρ_{air} = Air density (kg. /m^3)
ρ_{gas} = Gas density (kg. /m^3)

Weight of airship or payload is 0.6 kg based on this value was calculated the volume of helium required for the system is at no load, this is 0577 m3 according to equation 1.

The blimp dirigible with which the project was realized is characterized by a smaller size and lighter weight of rigid airships type [5].

2.2 Principle slenderness

Slenderness means the ratio between length and diameter of the ellipsoidal membrane. For airships it is understood that if the slenderness value is decreased, it would increase the area of the body, increasing proportionally resistance and thrust force [6]. Equation 2 shows the corresponding slenderness at first mathematical expression, it should be noted that it is necessary to first The length is set for the dirigible is 1.5 m so that this does not have mobile limitations, since this was designed to move in places with a height of two meters and a width of two meters, based on these criteria a value of slenderness of 1.75 was selected, considering Fig. 1, this value ensures that the airship not destabilize the receiving airflows by any of its sides, which has a sufficient pushing force to the system find with no load and no moving limitations, the figure that describes the principle of slenderness is taught below.

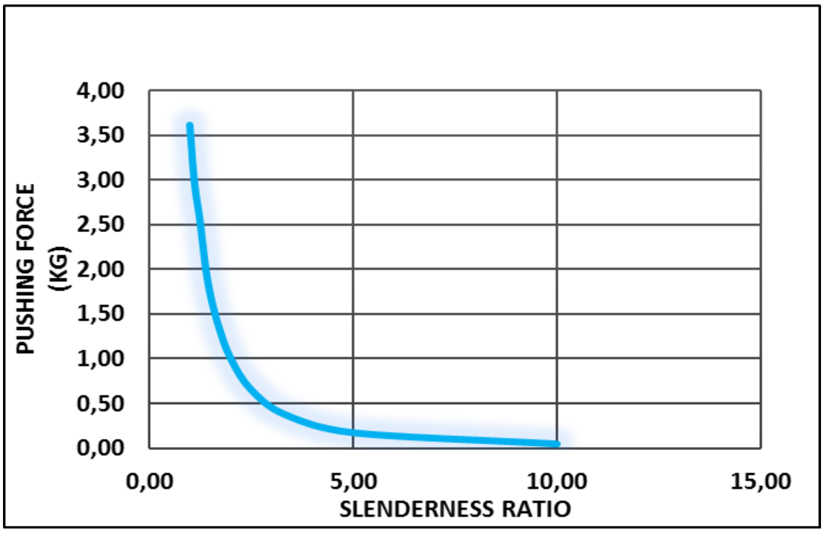

FIGURE 1. SLENDERNESS RATIO VS. PUSHING FORCE

Based on slenderness, the volume of helium and the length of the airship diameter which is 0.86 m were determined.

2.3 Stability

The shape of the vehicle is strongly linked to stability, since vehicles must remain in one orientation and specific position even though they are acting on them, forces as drafts or maneuver forces [7-8].

In the geometric definition of the airship; we want to prevent the tip or tail of this have any inclination a1 and a2 must be located at a different center distance, as the gondola is located next to the front region of the airship and the tail flaps [9] these elements have different weights and thereby cause imbalance in the airship for which a value of a1 and a2 experimentally where "a1" should be close to 40% of the total length of the airship was found, so this is in a position horizontally as it taught in Fig. 2.

Airship dimensions are: length equal to 1.5 m, diameter 0.86 m, the length a1 is 0.6 m length a2 is 0.9 m.

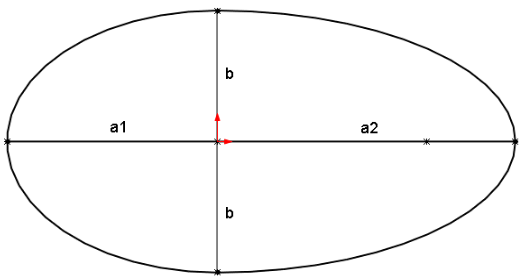

FIGURE 2. GEOMETRY OF DIRIGIBLE.

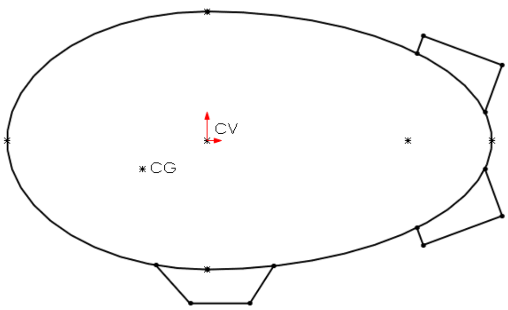

FIGURE 3. CENTER OF GRAVITY AND CENTER OF VOLUME OF A DIRIGIBLE.

In order to generate a stable model was considered the center of volume (CV), the center of gravity (CG) and weight of the nacelle (W) generate a stabilizing torque. To return the vehicle to a specific position [10] .as taught in Figure 4.

For the previously mentioned conditions are met, an airship classically, a semi-ellipsoid, in Figure 3 the geometry to which this criterion was employed observed.

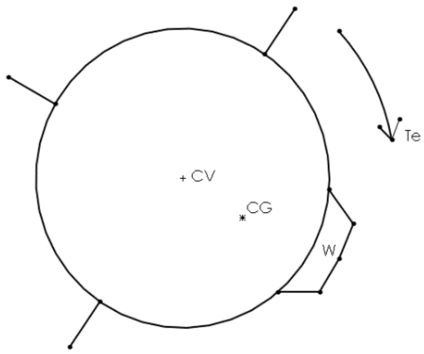

FIGURE 4 TORQUE STABILIZER

2.4 Membrane material

Commonly are used materials such as mylar, PVC and polyurethane, were studied characteristics such as permeability, tensile strength and ultimate elongation.

Permeability that prevents the escape of helium through the material, the final elongation determines the resistance of the material to be penetrated because these materials have the ability to deform reducing its thickness, the values of tensile testing are compared in order to know the limits of burden these materials, because the membrane contains a gas which is filled cold and when the gas reaches room temperature undergoes the phenomenon of expansion and exerts pressure on the walls of the airship [7] , [4]. In selecting the material it took into account that the material out economic and achieving this in the country.

TABLE 1
MECHANICAL PROPERTIES OF MATERIALS [6]

Material	Tensile strenght	Final Strain	Helium permeability
Polyurethane	10 GPa	67%	0.28 cc/(24h)
Mylar	2GPa	11%	0.71 cc/(24h)
PVC	2GPa	50%	0.3 cc/(24h)

TABLE 2
ECONOMIC CHARACTERISTICS OF THE MATERIAL

Material	Colombia Aviability	Price per m^2	Minimum amount of sale m_2
Polyurethane	Yes	8	1
Mylar	No	12	50
PVC	Yes	9	1

Based on these characteristics: final strain, Helium permeability, aviability and cost. It was determined that the best alternative for the membrane is polyurethane [11].

2.5 Instrumentation

In instrumentation selection, design and management of electronic and electrical components [12] was performed [13], as taught in the figure. The system is basically composed of an air station and a land, air station comprises an IMU, camera, motors, microcontroller and communication system.

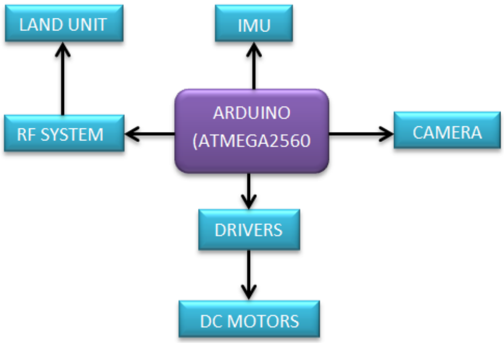

FIGURE 5 SYSTEM ARCHITECTURE

2.6 IMU

It is an electronic device that measures and reports on the angular velocity, orientation and gravitational forces of the vehicle. It consists of an accelerometer, a gyroscope and a compass. This device has a gyroscope dynamic range programmable from ± 250, ± 500, ± 1000 and ± 2000 ° / sec and an accelerometer with a dynamic range of ± 2g, ± 4g, ± 8g and ± 16g has a resolution of 16 - bits, which means that divides the dynamic range 65536 fractions, these apply to the axis X, Y and Z as in the angular velocity.

III. RESULTS

3.1 Accelerometer

It is a sensor that measures acceleration and can be expressed in three axes: X, Y and Z, this detects the earth's gravity which is perpendicular to the floor, thanks to this and the use of equations 1, 2 and 3 is known which is the angle to the X axis or Y axis, in the case that the accelerometer be inclined, the acceleration of gravity is decomposed into two vectors, with which the actual inclination angle is calculated.

FIGURE 6. FORCE OF GRAVITY EXPRESSED IN THE AXIS X, Y & Z [9].

The inclination in which the IMU be calculated based on three trigonometric functions, equations with which it is possible to obtain the degree tilt in the different axes are taught below.

$$\theta = \tan^{-1}\left(\frac{Ax}{\sqrt{Ay^2 + Az^2}}\right) \tag{2}$$

$$\psi = \tan^{-1}\left(\frac{Ay}{\sqrt{Ax^2 + Az^2}}\right) \tag{3}$$

$$\phi = \tan^{-1}\left(\frac{\sqrt{Ax^2 + Ay^2}}{Az}\right) \tag{4}$$

Where,

A_x=Acceleration in x
A_y=Acceleration in y
A_z=Acceleration in z

It is clear that the accelerometer is sensitive and all linear accelerations (linear displacements and vibrations) modify output parameters, which have noise, drift and error during travel as shown in Fig. 7.

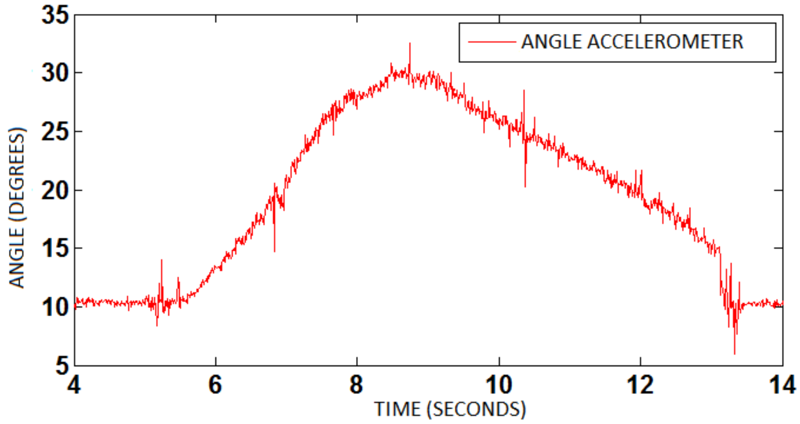

FIGURE 7 CALCULATION TILT ACCELEROMETER

3.2 Magnetic Compass

It is an instrument that provides guidance and points to the earth's magnetic north with this it is possible to take a census how many degrees you turn on the Z Axis Its operation is based on detecting the earth's magnetic field in 3 axes (X, Y and Z) detects magnetic fields in a range from 1 to 8 milli-gauss gauss to obtain guidance from this sensor is used the following equation:

$$Angulo = a\tan 2(Y + X) * \frac{180}{\pi} + 180 \quad (5)$$

Where,

Y=Magnitude of the magnetic field land on the axis Y
X=Magnitude of the magnetic field land on the axis X

At Fig. 8 census data is seen when a spin on the z axis clockwise, these data are the number of degrees of deviation there from magnetic north was held, with 0 being the north and 180 south.

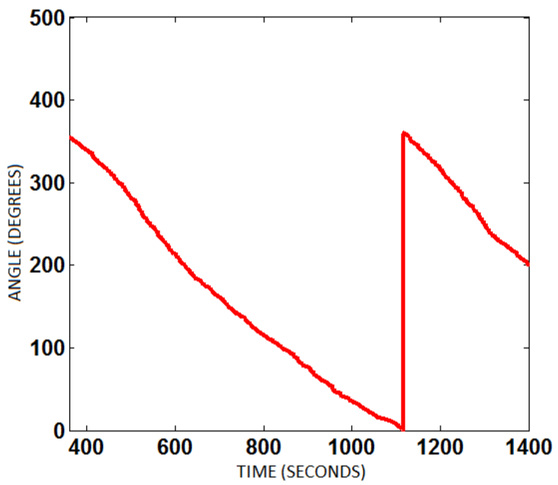

FIGURE 8 TURN 360 ON THE Z AXIS

3.3 Gyroscope

It is an instrument that measures the angular velocity. The angular velocity is the number of degrees which is rotated in a second this on the axes X, Y and Z.

When the position is obtained from this data, we need to perform a mathematical operation but is linked to an error as to obtain the position from the speed must be integrated and this operation causes a cumulative error over time; It is resulting in a false position data as shown in Figure 9, wherein the sensor was static and yet this recorded a movement.

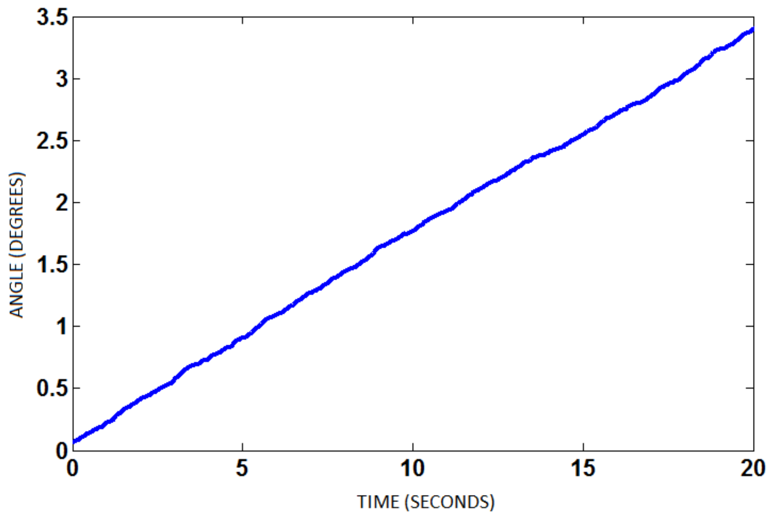

FIGURE 9. CUMULATIVE ERROR POSITION CALCULATION WITH GYROSCOPE

3.4 Supplementary filter

The data provided by the accelerometer and gyroscope are linked to problems such as cumulative error, noise and dfrit. To obtain measures adjusted to reality, you need a medium such as the complementary filter.

To stabilize a UAV arises the need to know the direction and speed of present turn, this is achieved through a complementary filter, using an algorithm Proportional-Derivative (PD),

$$\beta = \alpha * Aa + (1-\alpha) * (Va * \beta * z^{-1}) \tag{6}$$

Where,

β=Actual angle

Aa=Accelerometer angle

Va= Angular velocity

A=Constant

Use of this method requires previous conditioning of the values obtained, first should be eliminated offsets from the sensors. You also need to adjust or scale the data collected by the sensors in a suitable manner, this was done taking into account the sensitivity of these

The complementary filter uses readings gyroscope and accelerometer. Its operation is to act as a high pass filter in the case of the gyroscope and as a low pass filter In the case of the accelerometer, from the union of these a value orientation closer to the real you get.

The complementary filter is simple to operate and because of its low implementation complexity consumes few computational resources.

The complementary filter obtains a good estimate of the angle of orientation of the platform, [14], using this filter reduces noise, drift, and cumulative errors in estimating the delay angle as shown at Fig. 10.

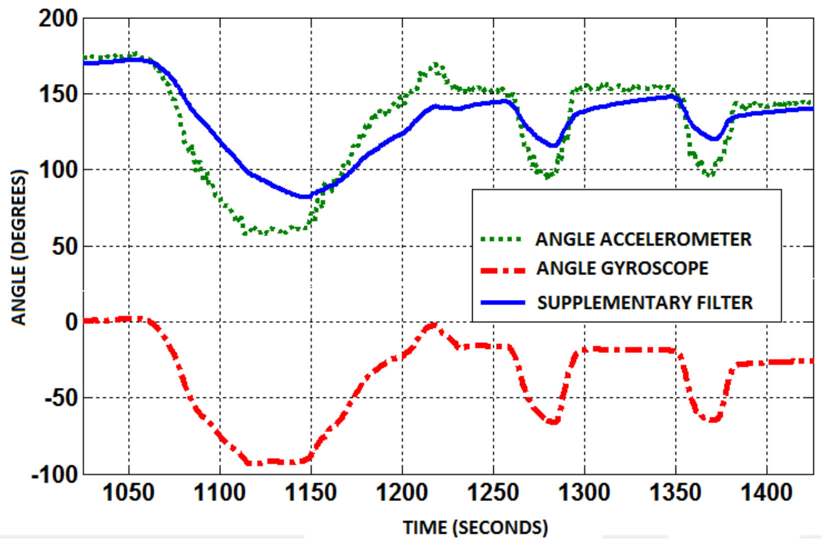

FIGURE 10 RESULT COMPLEMENTARY FILTER

3.5 Control

For control of the airship are uncoupled the systems swivel and height then was performed identifying each of these systems and finally the control design was performed [15].

PID control was developed in closed loop technique and root locus in systems swivel and height, the block diagram shows the controller structure is taught in Fig. 11.

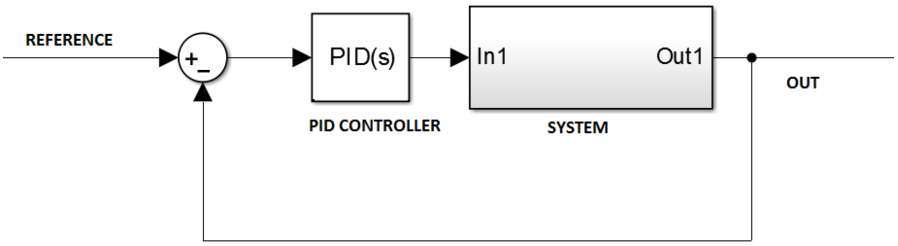

FIGURE 11 STRUCTURE OF THE CONTROLLER

Control turning system has a response time that is about 2 to 3 seconds turns between 35 ° and 65 ° and has an over peak ranging from 10% to 28%, the controller leads to reference the system as It is shown in figure 12 .

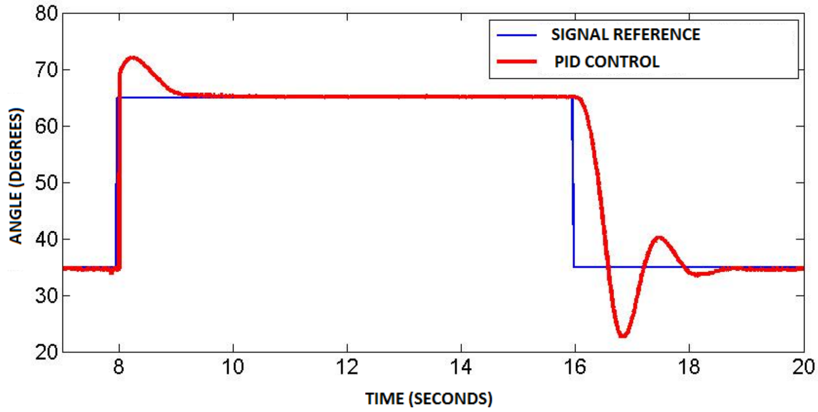

FIGURE 12. RESPONSE TURNING SYSTEM CONTROLLED BY PID ABOUT 30°

When the system was stabilized at 70 cm height was to disturb 90 cm, without making changes to its reference signal. As shown in Figure 13, the height control system has a response time which is about 10 to 15 seconds and has a peak about 10%. This system was disturbing the controller to verify that carry reference height system.

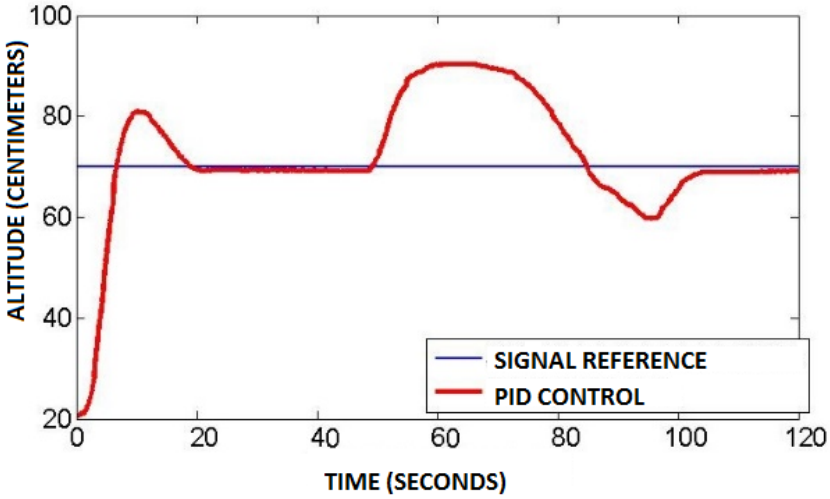

FIGURE 13 RESPONSE HEIGHT SYSTEM, CONTROLLED BY PID AFTER BEING DISTURBED

A PID control is sufficient to ensure tracking the reference signal in both systems.

3.6 Autonomy

The autonomy of the dirigible is approximately 40 minutes with a LI-ION battery of 2000 mah and 3.7 v performing displacement in the X and Y plane, the drone CX-20 has a LI-PO battery 2700mAh and 11.1v which will provides a range of 25 min, exceeding runtime airship with less mah battery as evidenced in Fig. 14.

Worth noting, this drone costs about US $ 439.72, while the airship costs $ 250.

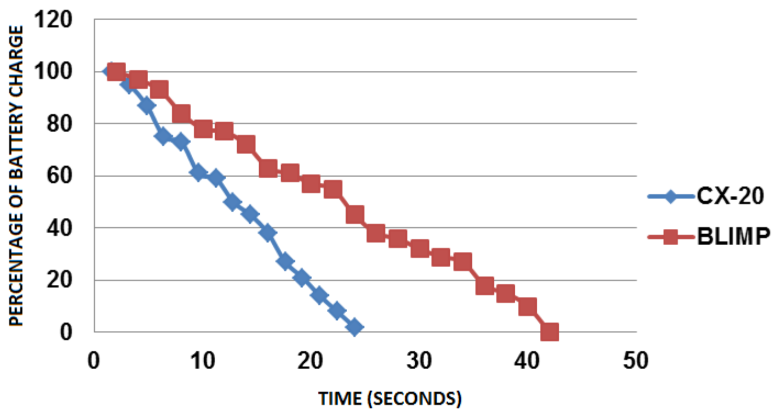

FIGURE 14. AUTONOMY DIRIGIBLE VS DRONE

IV. CONCLUSION

The membrane material allows escapes accounting for 1% of the volume of the airship 168 hours elapsed after causing loss of lift; it is advisable to use a laminate, although the cost would raise Airship.

The airship proves to be stable this is maintained in a specific position which shows that there is no loss of balance and that the charges are located correctly.

For guidance from the IMU it is necessary to implement a complementary filter, so that the noises are eliminated, rolling and obtain a signal without delay.

The efficiency of controller was both simulation and experimental tests, the proposed PID controller was shown to have an efficient performance for controlling the orientation angles.

The autonomy of the dispositive is greater than the majority of UAVs, this was approximately 45 minutes overcoming a quadcoptero in 20 minutes, it can extend the autonomy if the airship be static at a given height.

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