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Arduino Applicability Model for the Construction of Flight Controller for Drones

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Abstract — *The aim of this study was to develop a flight developer for an unmanned aeronautical vehicle (UAV) with copyright technology. The project takes into account several aspects of Mechanical Engineering, as well as knowledge of aircraft dynamics, remote control, sensing and electronics, composing a multidisciplinary work of Electronics, Mechatronics and Aeronautical Engineering. In this project, the UAV is divided into its fundamental components: structure/base , engines, propellers, flight controllers, batteries, sensors and radio, each one being studied and specified for the integration of a full system. Simulation tools and calculation softwares are used to estimate the main features of the final product. We presume that this article serves as a reference for a drone project in general and a guide to the physical production of such a drone, from the initial design with specifications to the selection and integration of components for future work and research projects, becoming a valuable tool of great added value.*

Keywords — Unmanned Aeronautical Vehicle, Drone, Flight Controller and Arduino.

I. INTRODUCTION

The use of unmanned aerial vehicles (UAVs) has grown steadily in recent years due to the ease of acquisition and advancement of the technologies involved, such as controllers, transmission systems, sensing and engines [3].

According to the National Civil Aviation Agency (ANAC), the unmanned or remotely controlled air vehicle is a machine capable of sustaining itself in the atmosphere due to air reactions, excluding those ones against the Earth’s surface. They are intended for remote operation, differing them from aeromodels that are intended for recreation only and must obey the existing resolutions [1].

The history of the Remotely Piloted Aeronautical Systems (SARP) emerged over a hundred years ago, when technologies were studied and developed for reconnaissance and attack aircraft that could be controlled from the ground [2].

The first documented use of unmanned aerial vehicles (UVAs) took place on August 22, 1849, when the city of Venice was attacked by the Austrian army through balloons containing explosives [8].

Another Record occured in the midst of the World War II, when the Germans employed flying bombs (UAV), to attack targets at a distance without exposing their pilots. The technology continued to be used in the numerous conflicts that followed. However, in 2003, in the Second Gulf War, which became more known, especially with the dissemination and diffusion through the Internet, when the U.S. army employed technology for the monitoring of enemies, designation of targest and weapons lauching and guided projectiles. After this conflict, several countries began to become interested and exploit the technology hardly [8].

The first UAV registered in Brazil was the BQM1BR, manufactured by the extinct CBT (Brazilian Company of Tractors), of jet propulsion. This prototype would serve as an aerial target, making flight in 1983. Another UAV known is the Blue Bird, produced by Embravant. The aircraft had more than 4 meters of wingspan, with autonomy for up to 3 hours of flight. The first two prototypes of the Blue Bird performed several tests in flight, operating by means of radio control [5].

Unmanned aerial vehicles may be classified according to the quantity of engine they use, as can be seen in the table in Figure 1. The main influence of the number of engines is the propulsion force and support of the drone.

Number of Engines	8	6	4	3
Nomenclature	octacter	hexacopter	quadcopter	tricopter

Fig.1: Classification of the UAVs

In this study, a quadcopter was used Brushless Motors of 935v 860g thrust type. Brushless is a non-toothed DC motor, which has as main features the emition of low noise, durability (absence of wear ofthe brushes) and the total EMI reduction (Electromagnetic interference).

In the Brazilian Regulation of Special Aviation autonomous UAVs can not fly without an Authorization

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Certificate for Experimental Flight (ACEF). In this document are described the three operating classes that separate the unmanned aerial vehicles according to the maximum take off weight, as shown in Figure 2:

Fig.2: Operating classes according to the weight.

Since landing in Brazil in 2013, drones have proven to be an equipment capable of operating in several segments: safety, agriculture, and product delivery. There are more than 34,000 equipments in the country, according to data from National Civil Aviation Agency (ANAC) , the number refers to the quantity of drones registered according to the sector regulation [5].

Drones are also commonly used for rescues in places of difficult accesses, such as areas of disasters in which occurred floods, fires, collapses, interdicted buildings, among others. The choice of using this technology is due to the fact that devices transmit images and vídeos in real time , thus contributing to the success of the rescue teams. A drone can capture better angles for photos and footage while keeping the camera stable for longer, thus facilitating video production as well.

These technical valences allow a marked reduction of the financial costs and risks of incidents in filming by TV broadcasters and cinematographic companies, considering the fact that they previously use helicopter for such purposes.

Among other activities, in which its use stands out, we can mention forest mapping, industrial transport, goods deliveries, border inspection and surveillance, monitoring suspicious people, in order to avoid attacks or cases of vandalism. As a highlight in civil use, we can emphasize the use by photographers and videographers at birthday parties, weddings or events in general.

The unmanned aerial vehicles industry has, in recent years, presented a series of technological innovations and optimizations that can be noticed in the evolution of the hardware and software used, increasing the interest of programmers, professionals and investors to use and exploit such technologies.

A Bussiness Insider recently published a new growth forecast for the drone industry, estimating that its market will move around $ 12 billion until 2021.

This elevation of the projection, according to the report, is due to the popularization of the remotely piloted civilian aircraft and the convergence of the regulatory environment to a model less restrictive to the use of these artifacts[7].

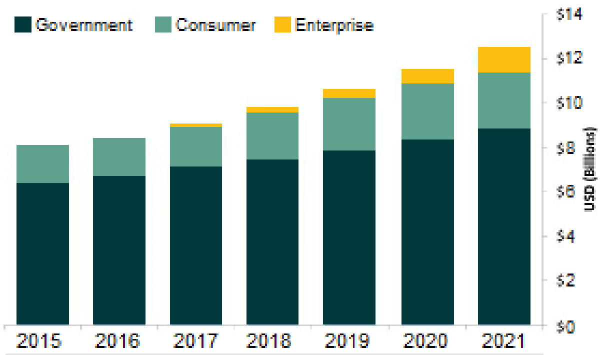

Fig.3: Growth forecast for the Drones sector [7].

It is, therefore, noted that by the year of 2021, governments will continue to be responsible for the largest share of the market, due to the power of military and public security industries concerning the use of remote and autonomously controlled applications. It is also noticed that the civil areas will present a more expressive growth.

Constant improvements in data processing hardware and software solutions, such as autonomous anti-collision systems, aiming to improve systems, reliability and efficiency, are being developed and disseminated on a global scale through students and researchers from different areas, impacting significantly on the market potential of drones and reducing costs from construction and acquisition.

Although the most common is to relate unmmanned aerial vehicles with a very limited number of tasks, such as filming audiovisual parts or military uses, the usefulness of these machines goes far beyond.

The use of drones can represent a value of 127 billion dollars in different industrial segments. Among the sectors that can use the most technology, we highlight infrastructure, agriculture and transport, as can be seen in the graph of Figure 4 [7]:

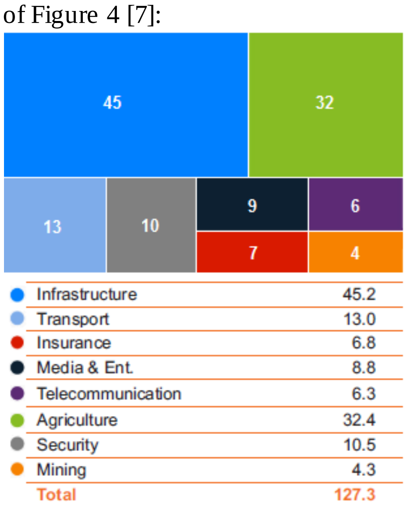

Fig.4: Prediction of investment in Drones by economic sector [7].

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In line with the previously elucidated context and in order to disseminate the technical and scientific knowledge about the technology of construction of drones, which is still incipient, this article aims to elucidate the implementation of a model of applicability of Arduino for flight controller construction for drones.

II. THEORETICAL REFERENCE

2.1 LEGISLATION

On May 02, 2017, it was announced by the National Civil Aviation Agency (ANAC) the approval of the regulations for the use of drones. This was a very important step for the market that awaited this decision eagerly. The regulations were posted to public hearing in September 2015 and it is already needed some updates [4].

One such update is concerned with the certification of pilots to operate unmanned aerial vehicles above 400 feet (120 meters). According to the regulations, a driver's license will be required. There is also the need to implement some measures, but this is a natural process. First the National Telecommunications Agency (ANATEL) regulated the frequency of radios, then the Department of Airspace Control (DECEA) released the flight rules for drone to access the airspace and following the National Agency of Civil Aviation (ANAC) has signed the regulation of use [4].

The new regulation of ANAC classifies unmanned aerial vehicles in aeromodels, drones used for recreational purposes and remotely piloted aircraft (RPA): used for commercial, corporate or experimental operations [10]. The summary of the regulations can be seen in figure 5:

	RPAS1	RPAS2	RPAS3	AEROMODELS
Aircraft registration?	Yes	Yes	BVLOS: Yes VLOS: Yes	Yes
Approval or authorization	Yes	Yes	Only BOLS or above 400 ft	Not
Age limit for operation?	Yes	Yes	Yes	Not
Medical certificate?	Yes	Yes	Not	Not
License and activation?	Yes	Yes	Operations over 400 ft	Operations over 400 ft

Fig.5: Summary of the ANAC Regulation [10].

For design purposes there are still no specific technical standards on remotely piloted aircraft. At the beginning of 2015 was created the ISSO/TC 20/SC 16, subcommittee of unmanned ISSO aircraft, with the aim of establishing new design standards. In addition to the ISO initiative, there are local proposals from governments and regulatory bodies without, however, a general technical standard.

2.2 STRUCTURAL COMPONENTES OF AN UAV

There are 6 main components related to an UAV, which must be cited due to its relevance: engines, structural base, propellers, speed controllers, flight controllers and batteries.

• Engines

UAV engines have the function of making the propellers turn and generate momentum, enabling the flight. The classification of the engines can be divided into several ways, but the two main models are the brushes and brushless ones [10].

Brushless DC Motors (BLDC) are also known as synchronous electric motors powered by inverter through normally low voltage direct current power. Compared to brushless motors, they stand out for greater reliability and durability, lower noise and total reduction of electromagnetic interference. In contrast, its cost is higher, because it requires MOSFET devices, used for the construction of the electronic speed controller and an integrated circuit with more resources.

Simply put, a brushless motor contains a group of electromagnetics (coils) that are connected together in specific pairs. The motor controller, commlonly known as electronic speed controller or ESC, will be responsible for activating and disabling specific sections of electromagnetics at very specific times to cause the engine rotor to rotate due to the magnetic force. These electromagnetics are connected in three main sections, which is why brushless motors have 3 wires coming out from them.

III. MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 PROGRAMMING LANGUAGE

The programming language used in this study was C.

3.1.2 DEVELOPMENT ENVIRONMENT

The Arduino version 1.8.2 was used as an integrated development environment, as can be see in figure 6:

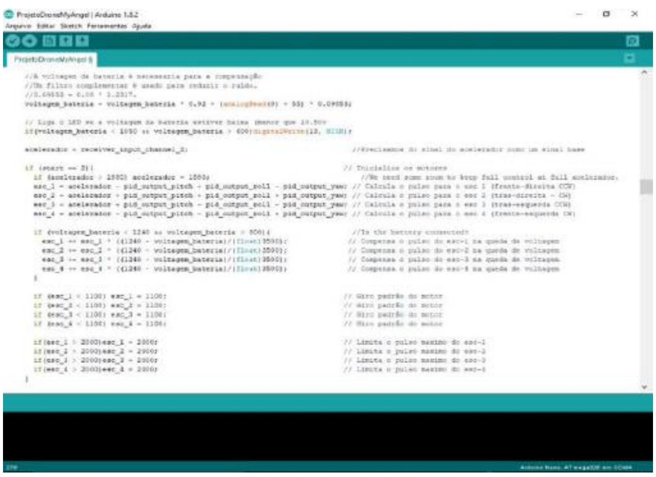

Fig.6: Development environment.

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3.1.3 ENGINE

The engine used in this project was Brushless, Emax brand and model Mt2213, as can be seen in figure 7, chosen mainly for offering extremely high efficiency with high load capacity for its small weight of 53g. They are maintenance free and have a very long service life.

Fig.7: Motor brushless

3.1.4 ELETRONIC SPEED CONTROLLER (ESC)

It was used in this project, the ESC of EMAX brand, model BLHeli of 30A Bec 5V/2A and weighing 28g each unit, as can be seen in figure 8. The quality of the equipment coupled with the ease of programming was determinant for the choice of this technology.

This component is necessary so that the system can regulate the speed of the motors in order to allow takes-off and vertical landings , as well as the other directional movements, forward and backward, inclinations and manoeuvres. Each engine must have its controller, because it is precisely the combination of different speeds of the motors that allow this variation of movements.

Fig.8: EMAX ESC.

3.1.5 SENSORS AND ACESSORIES

The DJI and model F450 load dividing plate was used, as can be seen in figure 9. A 3-axis accelerometer was used, with operations: +/-2g, +/-4g, +/-8g, +/-16g and gyro of also 3 axes with operation: +/-250 ,500, 1000 and 2000º/s.

Fig.9: Load Divider Plate.

The microcontroller board used was Arduino UNO R3, basedon the ATmega328 (data sheet), as can be seen in figure 10. It has 14 pin digital input/output, of which 6 can be used as PWM outputs, 6 analogic inputs, a 16MHz oscillator crystal, a USB connection, a power input, an ICSP connection and a reset button. It contains all the components needed to support the microcontroller, simply connects to a computer through the USB port or power supply with a source or with a battery.

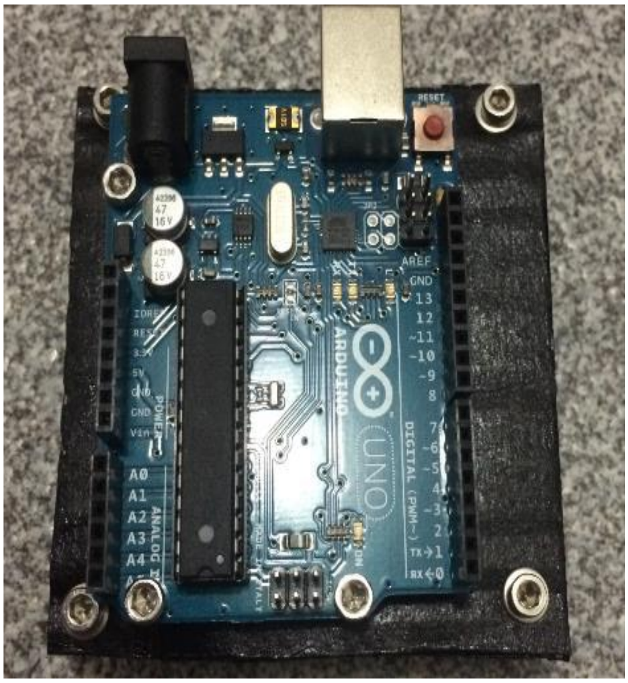

Fig.10: Arduino Uno R3 Microcontroller Board.

The low-voltage alarms have been installed and configured, as shown in figure 11.

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Fig.11: Alarm Flags.

We used the radio receiver of the brand Turmigy, model 9X8C-V2, with frequency of 2,4GHz and containing 8 channels, as can be seen in figure 12.

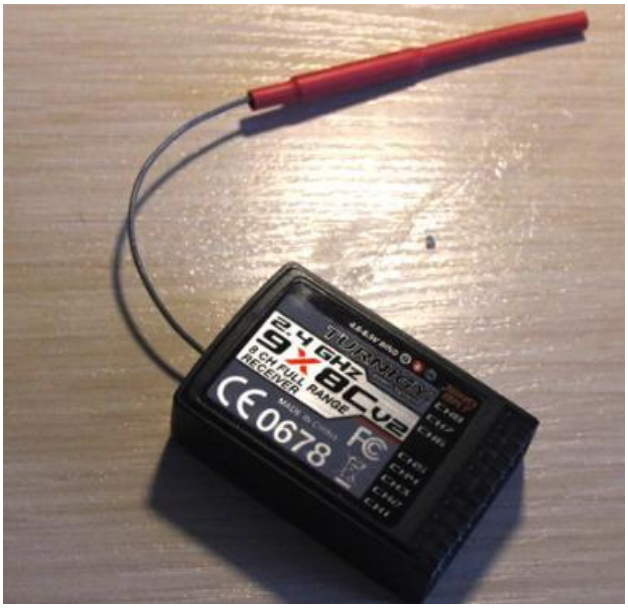

Fig.12: Tumigy Radio Receiver.

The radio transmitter used was the Tumigy brand, model RF9X-V2, with frequency of 2,4GHz , containing 9 channels, as can be seen in figure 13. This component which is generally a radio transmitter with remote control is what allows a (pilot) operator to send navigation commands to the UAV. A receiver compatible with the radio transmitter must be part of the drone navigation system.

Fig.13: Tumigy Radio Transmitter

Propellers of 10 X 4, 5cm were used, as can be seen in figure 14. The number of propellers must correspond to the number of engines. However, it is necessary to have pairs of propellers designed to rotate clockwise and pairs that turn countercolckwise. This feature is what allows the quadricopter to remain stable in flight.

Fig.14: Propellers

The connection of the motors with the ESCs was performed through 3,5mm bullet type connectors. The integration of BECs with the flight controller was carried out through the 4-pin JST-XH type connectors. THe

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battery connection with the main circuit was carried out via XT¨60 connector.
The drone has a radio frequency transmitter of 2,4GHz, using 9 channels being 8 PCM or 9PPM with telemetry. It also has 4 electronic speed controllers (ESC) of BEC 5v/2A (Battery Eliminator Circuit).
The material used for the central plates, the arms and the brackets for the motors were PA66 + 30GF, possessing high strenght. The power distribution frame was installed based on phenolite, with copper tracks, as well as screws and stainless steel base bracket.
To power the entire system is necessary to term a battery. The Lipo 3s 5200mah 11, 1v weighing 415g battery was used. In general , the most used are the lithium polymer, called Lipo (Lithium Polymer) batteries. This type stands out for its relative low weight and efficiency, however, require certain care as to the correct use and recharge process, so that they are not damaged or not to become dangerous.

3.1.6 TECHNICAL ESPECIFICATIONS

Codinome:
My Angel
Frame:
- Model: F450 DJi
- Weight: 282g
- Width: 450mm
- Height: 55mm
- Color: 2 Red Arms, 2 White Arms and Black Cent
- Base dividing plate integrated in base

Motor:
- Model: EMAX MT 2213
- Type: Brushless
- Rotação: 935Kv
- Availability: 4
- Amperage: 15,1A
- Motor Buoyancy: 860g
- Drilling: Standard 12N14P
- Weight: 53g
- Diameter (Stator):22mm
- Height (Statror): 13mm
- Spinner: 4x, Red
- Motor shaft: 3mm
- Plugs: Bullet 3,5mm Male

Hélice - Propeller
- Propeller 10x4,5 cm CW
- Propeller 10x4.5 cm CCW

Controlador de velocidade - Speed Controler
- Model: ESC EMAX 30A BLHelo Bec 5V / 2A
- BEC: Yes
- Width: 26mm
- Height: 7mm
- Depth: 52mm
- Weight: 28g
- Amperage ESC: 30 A
- Amperage Burst: 40 A
- Amperage Bec: 02 A
- Voltage Bec: 5V
- Battery Cells: 2s - 4s
- Plugs: Bullet 3,5mm Female
- Firmware: Simonk
- Programmable: Yes
Alimentação - Power Supply
- Bateria LiPo 3s 5200mAh 11,1v
- Weight: 415g

Controladora de voo - Flight controller
- Name: My Angel
- Gyroscope: 3 Axes
- Accelerometer: 3 Axes
- Gyro Operation: +/- 250 500 1000 2000º/s
- Gyro Operation: +/- 2g, +/- 4g, +/- 8g, +/- 16g
- Accelerometer and Gyroscope Dimensions: 20x16
- Arduino UNO v3
- Arduino Weight: 28g

Fig.15: Technical Specifications.

3.2 METHODS

We used the basic and applied research methodology, construction of the entire controller during the project, without a brand or commercial model.
Basic research aims to generate knowledge that is useful for science and technology, without necessarily having a practical application aimed at obtaining profit.
The applied research seeks to generate knowledge for practical application. It is aimed at solving problems that

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contain previously defined goals, whether they are medium or long term.

All simulations were performed in the development environment. The equipment and accessories were obtained in aeromodeling and electronics stores. The connection of the motors with the ESCs used bullet type connectors of 3,5mm. The integration of the BECs with the flight controller used the 4-pin JST-XH type connectors. The battery connection with the main circuit used XT60 connector.

The drone has a radio frequency transmitter of 2,4GHz, using 9 channels being 8 PCM or 9PPM with telemetry. It also has 4 electronic speed controllers (ESC) of BEC 5v/2A (Battery Eliminator Circuit).

The material used for the central plates, the arms and the brackets for the motors were PA66 + 30GF, possessing high strenght. The power distribution frame was installed based on phenolite, with copper tracks, as well as screws and stainless steel base bracket.

IV. RESULTS AND DISCUSSIONS

4.1 CONSTRUCTION PROJECT

A modelo of applicability of the Arduino was built for the construction of the flight controller for drones, using its own technology. The aircraft had a total weight of 1081g, as can be seen in the table in figure 16.

Description	Amount	Weight(g)	Total(g)
Frame	1	282	282
Motor	4	53	212
Propeller	4	5	20
ESC	4	28	112
Power supply	1	415	415
Flight controller	1	40	40
Receiver Radio	1		0
Total weight			1081

Fig.16: Drone Weight Description.

The selection of the engines mainly considered the propulsion force, because the aircraft depends solely on their strength to perform maneuvers and maintenance of the flight. However, the necessary propulsion can not be estimated without knowing, for instance, the total weight of the aircraft.

To control the rotation of an engine it is imperative to use a power circuit with several inverters, sensors and a circuit that is capable of controlling the drives.

Figure 17 shows an integration scheme for all components and the connections that must be made to the functioning of the UAV:

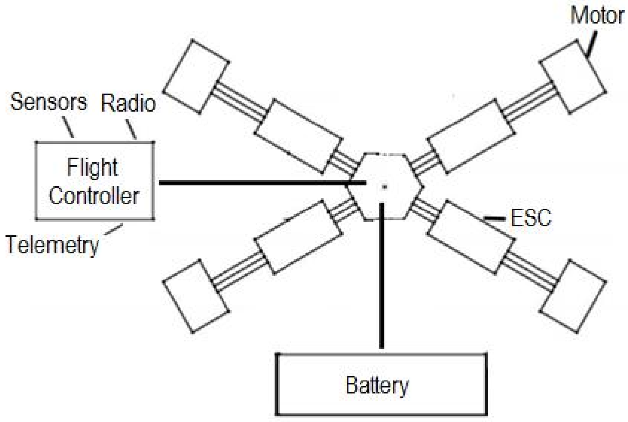

Fig.17: Drone Integration Scheme

For models with 4 engines we use the form of an "X", as can be seen in figure 18, but the form depends on the flight characteristics we want to give to our UAV. Generally, an "H" format structure allows for faster maneuvers, so they are common in drones targeting high-speed uses.

Typically, the "X" format allows smoother maneuvering and greater stability in tasks that require the drone to hover over a certain point.

Fig.18: Drone built.

4.2 COSTS ASSESSMENT

As a result the general cost table was generated, with the selected components and a price estimate for the consumable materials and connectors.

The final value of the drone is also indicated in the table in figure 19:

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Description	Amt	Value Un.	Value Tot.
Frame F450DJi	1	R$ 129,00	R$ 129,00
Cargo Dividing Plate	1	R$ 0,00	R$ 0,00
EMAX Brush. Motor Xa2212 980Kv 15.1A CW + Spinner Shaft 3mm	2	R$ 60,00	R$ 120,00
EMAX Brush. Motor Xa2212 980Kv 15.1A CW + Spinner Shaft 3mm	2	R$ 60,00	R$ 120,00
Propeller 10x4,5cm CW	2	R$ 18,00	R$ 36,00
Propeller 10x4,5cm CCW	2	R$ 18,00	R$ 36,00
Plugs Bullet 3.5mm female to ESC	12	R$ 0,00	R$ 0,00
Shock Absorbers	4	R$ 0,10	R$ 0,40
ESC (25ah - 30ah) ESC EMAX 30A BLHeli Bec 5V / 2A	4	R$ 67,00	R$ 268,00
Flight Controller Board	1	R$ 84,80	R$ 84,80
Radio tx-rx kit	1	R$ 698,00	R$ 698,00
Battery Pack: Lipo 3s 5200mah 11.1V 80C	1	R$ 250,00	R$ 250,00
Charger and Balancer	1	R$ 280,00	R$ 280,00
Low Battery Alarm	1	R$ 17,00	R$ 17,00
Total			R$ 2.039,20
			US$ 520,15

Fig.19: Drone Cost Description

The values entered in the table were the lowest found after quotation in three different vendors.To make a comparison of the costs of a drone of this type, with four engines and containing similar characteristics, a search of commercial models for sale available on internet store sites was conducted. The table below shows a comparison between bussiness models and the drone proposed in this article.

We use price per charge [R$/kg] , as a comparison parameter, as can be seen in the table in figure 20:

Model	Battery [mAh]	Controller	Price [US$]	Useful Load [Kg]	US$/Kg
Proposed	5200	Emax	520,15	3	173,38
DJi F550	5500	DJi Naza	1.745,22	3,8	459,27
Tali H500	5400	Walkera	1.874,90	2,7	1.008,18
DJi S900	16000	A2	6469,43	5,8	1.115,42

Fig.20: Comparison between Freight Costs [R$/kg].

V. CONCLUSION

Throughout the study, we explored the origins and history of unmanned aerial vehicles (UAV) and their change of purely military equipment to become a new technology reliable for civilian use, offering very different configurations, which vary greatly in size and performance.

We effectively addressed the implementation and importance of an Arduino applicability model for the construction of the drone flight controller, which has the main function of contributing to the safe and economical operation of the drones.

With the advent and mastery of electronics and control techniques, mechatronics devices supporting pilotage are being studied and implanted in projects with greater vehemence, from electromechanical actuators to advanced robotic systems with potential to carry out landings and takesoff of commercial aircrafts, whether cargo or passenger transport.

The use of drone has grown exponentially, presenting several possibilities in the field of teaching, research and development. However, in contrast, there are not many relevant theoretical studies regarding drone spectrum. There is an urgent need to create norms and regulations.

The article made evident that the construction and development of this project took into account several parameters, from the programming language to the installation of the high power electric motors.

The drone presented, in tests, with capacity to sustain load up to three kilos, which can be used to load sensors, cameras and other equipment.

Regarding the scope of the project, the product met the needs satisfactorily, achieving its objective of eluciding the implementation of a model of applicability of the Arduino for the construction of the flight controllers for drones, availing parameters, techniques, study methodologies and selection of its components.

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