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Dissertation of Master Degree

Theme

Realization of Quadcopter

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Examination board

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Dedication

I dedicate this work to ***my parents*** *who provided me with moral and material support during my studies years, until having this work done.*

A lovely dedication goes also to my ***brother*** *and my little* ***sister*** *for their kind and special help to me.*

For my supervisor ***Pr. BOUMAHRAZ Mohammed****, who guided every work step I did in this dissertation.*

For my friends who have supports me enough throughout this process, especially ***ZERARKA Ramzi*** *for his help to develop my technical skills.*

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I also place my record my acknowledgement to all the faculty members, teachers and classmates for their help and encouragement extended to me.

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List of abbreviations

BEC: Battery Eliminator Circuit

BLDC: Brushless Direct Current

CC: Continuous Current

CCW: Counter Clockwise

CW : Clockwise

I/O : Input /Output

EEPROM: Electrically Erasable Programmable Read-Only Memory

ESC : Electrical Speed Controller

FLV : First Person View

GPS : Global Positioning System

I2C : Inter-Integrated Circuit

IMU :Inertial Measurement Unit

KV : Constant Velocity

LCD : Liquid Cristal Display

LED: Light Emitting Diode

LIPO : Lithium Polymer

MCU : Micro Controller Unit

MEMS : Micro Electromechanical systems

M1,M2,M3,M4 : Moteurs 1,2,3 et 4

NiCd : Nickel cadmium

NiMH : Nickel-metal hydride

Pb : Plomb

PID : Proportionnal – Integral- Derivatif

PWM : Pulse Width Modulation.

RC : Radio Commande

RPM : Rotation Par Minute

SCL : Serial Clock Line

SDA : Serial Data Line

Set : Setting

UAV : Unmaned Areal Vehicle

Abstract

A Quadcopter can achieve vertical flight in a stable manner; it can control or collect data in a specific region such as loading a mass.

Technological advances have reduced the cost and increased the performance of the low power microcontrollers that allowed the public to develop their own quadcopter for the use .They used for that a quadcopter kit that included many components such as frames, motors, electronic speed controllers ….etc. Then those components tested individually to enhance the performance of the quadcopter, so it could stabilize itself and do its missions properly like ; determine GPS locations , store log data…etc.

The goal of this project is design and compose an autonomous quadcopter, which means going through the process of researching for the previous studies to extract all the necessary informations to design our project. Technical approaches to use for the design after we determined the type, the size and the suitable materials for the project, we determined four primary steps ; calculations, purchasing individual parts, composing an Arduino based controllers and finally putting everything together to get our project done and ready to be controlled with hand movement simulation.

Key words: **Quadcopter**, Drone, Hand gesture, Aircraft, Unmanned aerial vehicles.

الملخص:

يمكن لطائرة كوادكوبتر تحقيق رحلة عمودية بطريقة مستقرة؛ كما يمكنها التحكم في البيانات أو جمعها من منطقة معينة مثل تحميل كتلة.

أدت التطورات التكنولوجية إلى خفض التكلفة وزيادة أداء المتحكمات الدقيقة منخفضة الطاقة التي سمحت للجمهور بتطوير كوادكوبتر خاص بهم للاستخدام. وقد استخدموا لذلك، مجموعة كوادكوبتر تضمنت العديد من المكونات مثل الإطارات والمحركات وأجهزة التحكم في السرعة الإلكترونية ... إلخ ثم تم اختبار هذه المكونات بشكل فردي لتحسين أداء المروحية الرباعية، حتى تتمكن من الاستقرار والقيام بمهامها بشكل صحيح مثل؛ تحديد مواقع GPS وتخزين بيانات السجل ... إلخ.

الهدف من هذا المشروع هو تصميم وتكوين طائرة كوادكوبتر مستقلة، مما يعني المرور بعملية البحث عن الدراسات السابقة لاستخراج جميع المعلومات اللازمة لتصميم مشروعنا. المقاربات التقنية التي استخدمناها في التصميم بعد أن حددنا النوع والحجم والمواد المناسبة للمشروع، حددنا أربع خطوات أساسية؛ الحسابات وشراء الأجزاء الفردية وتكوين وحدات تحكم قائمة على Arduino وأخيراً تجميع كل شيء معًا لإنجاز مشروعنا والاستعداد للتحكم فيه من خلال محاكاة حركة اليد.

الكلمات المفتاحية: كوادكوبتر، الدرون، حركة اليد، الطائرات، طائرات بدون طيار.

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General Introduction

Introduction

“A helicopter is a collection of vibrations held together by differential equations.” John Watkinson.

The advancement of new technology has been taking place since the beginning of human history. The utilization of unmanned vehicles has become increasingly more popular today and been successfully demonstrated for various civil and military applications.(Das, 2019,p.2)

Unmanned aerial vehicles (UAV) are properly known as drone. Drone is a flying robot working in combination with GPS; this flying machine may be remotely controlled or can fly autonomously by software controlled flight plans in their embedded systems. Drones used and developed initially in the military field, they have experienced profound changes in recent years and they increasingly used in the civilian field with different shapes and sizes. They used for firefighting, rescue as well as in specific applications such as surveillance, attack, aerial photography and video, surveys topographical surveys and research. (Rokibujjaman ,2017)

Quadcopters or Drones in different variations are an inherent part of human life, whether from the perspective of entertainment, monitoring or handling with dangerous substances. Most of the drones based on specialized devices controlled by a radio. There can be a different approach to control drones based on universal microcontrollers itself or in combination with flight controller. The unmanned small-scale quadcopters are particularly suitable for demanding problems, which requires accurate low-speed maneuver, and hovering capabilities such as detailed area mapping. Generally, a certain level of autonomous flight capability is required for the vehicle to achieve its mission; the basic autonomy level is to maintain its stability following a desired path under embedded guidance, navigation and control algorithm.

The aim of this study is to bring out the different concepts of drones, historical overviews, different types, and their technical specifications …etc., to finally reach the point of designing and composing our Quadcopter according to our researches and some different studies approaching with a tests , calculations and programming , as result for an autonomous quadcopter .

1. Research objectives:

- To understand the theory and functional aspects of a quadcopter.
- To identify the components required for the project.
- To develop the quadcopter model using the set of differential equations describing the quadcopter dynamics.
- To implement and test all the quadcopter components.
- To compound and design a quadcopter with a hand control using radio waves.
- To compose an autonomous quadcopter can stabilize itself.

2. Specifications:

The project specifications includes the design and composing a quadcopter. The quadcopter should be controlled with a hand controller. The design phase includes, obtaining the theory behind the kinematics and dynamics of a quadcopter, understanding what components are required for the quadcopter as well as understanding how to use the various sensors. The most important aspect of this phase is composing the quadcopter system as well as designing the controllers for the system and maintaining to his stability. Thereafter the quadcopter needs to be ready.

3. Dissertation outline:

This section presents the dissertation's organization, which consists of three chapters, in addition to a general introduction, which describes the context of the research. It is organized as follows:

General introduction: In this part, we attempt to highlight in brief our subject (quadcopter) then; we mentioned what is fundamental for our research as objectives to be achieved at the end of the dissertation.

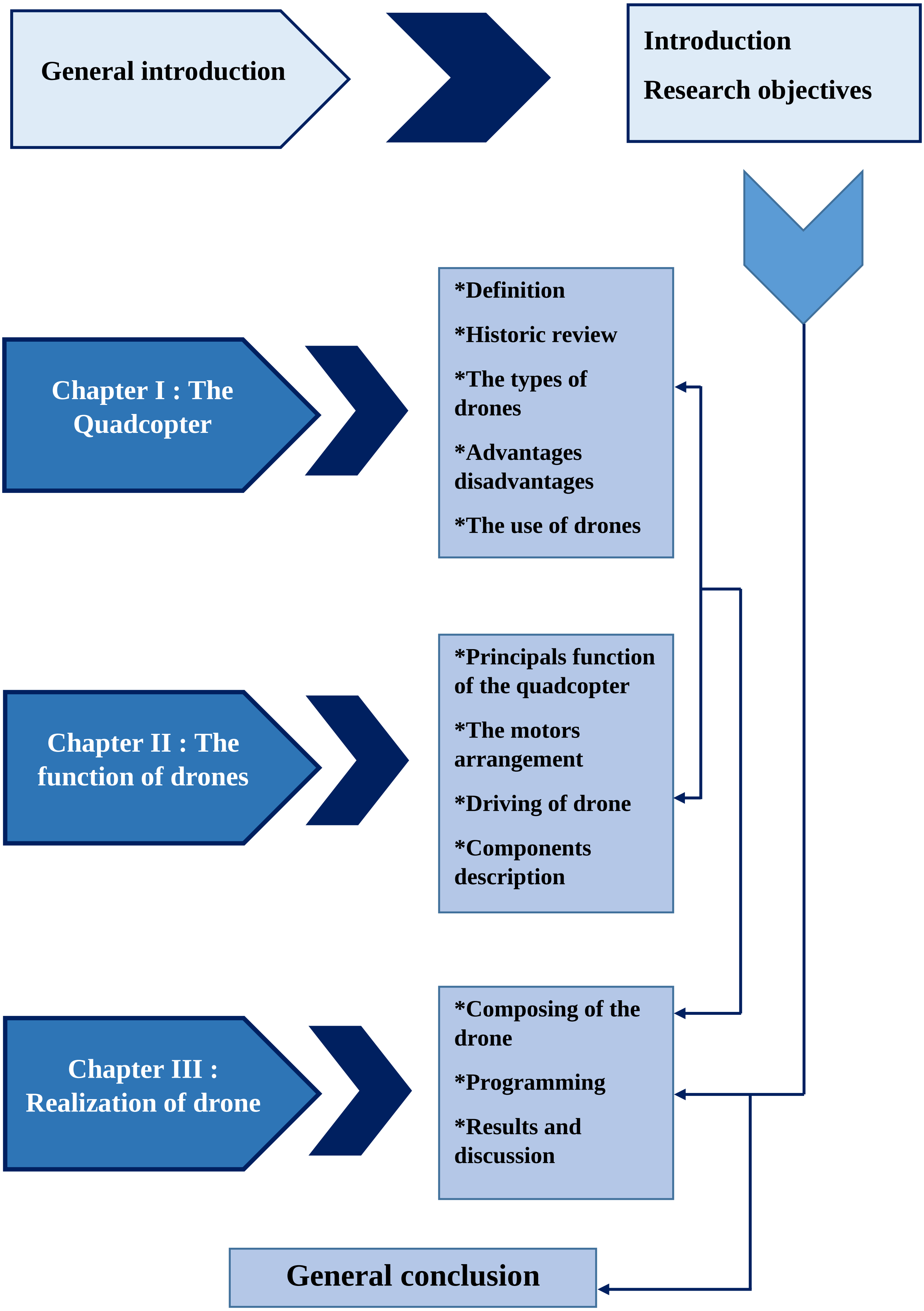
Chapter I The quadcopter: this chapter is focused on the different concepts of the Quadcopter beginning with a definition, a historic review, mentioning its different types and what they used for , then we finishing with some advantages and disadvantages of the drone .

Chapter II The function of drones: In this chapter, we attempt to explain all the functional parts of the drones including its components requirements.

Chapter III Realization of the drone: this practical part treat the fundamental objective of the research, which is the realization steps of the drone and finally our results discussion about all the process.

In general conclusion, we attempt to highlight all the process of designing and composing our project including our perspective or suggestion for the future studies in the same concept.

4. Research structure:



CHAPTER I:
THE QUADCOPTER

Introduction

Recent advances in sensor, in microcomputer technology, in control and in aerodynamics theory have made small Unmanned Aerial Vehicles (sUAV) a reality.The small size, low cost and maneuverability of these systems have made the potential solutions in a large class of applications. (Francesco, 2015)

Those Unmanned aerial vehicles, known also as drones, are used frequently in recent years, in order to accomplish a certain mission in a controlled way by Ground Control Station (GCS) or autonomously (Howard, 2013).

Unmanned aerial systems have high potential in civil and military applications such as mapping, reconnaissance, search and rescue, and agriculture. Recently, many embedded systems have become available for multirotor vehicles at reasonable cost. Quadcopters are the most basic and common platform of multirotor systems and the necessity of modeling and simulation is increasing with their applications. Quadcopters are the most basic and common platform of multirotor systems and the necessity of modeling and simulation is increasing with their applications.

The aim of this chapter is to highlight all the theories and studies about this concept as definition, reviews types ….etc. in order to gather all the necessary informations for our subject.

I.1 - Drone:

I.1.1 – Definition of the drone:

Drone commonly known as an Unmanned Aerial Vehicle (UAV), is an aircraft without a human pilot aboard. Drone technology can be also referred to as Unmanned Aerial Systems (UAS). They are becoming increasingly popular due to their flexibility and ease of traveling to places unreachable for humans. (Stanislaw, 2016)

Drones in different variations are an inherent part of human life, whether from the perspective of entertainment, monitoring or handling with dangerous substances. Most of the drones are based on specialized devices and controlled by radio. There can be a different approach to control drones based on universal microcontrollers itself or in combination with flight controller. (Šustek; Úředníček, 2018, p. 1).

The size of these aerial vehicles can range from a few centimeters for miniature models to several meters for specialized drones (surveillance, intelligence, combat, recreation). Their flight autonomy ranges from a few minutes to over 40 hours for long endurance drones. (Sedini; Cherigui, 2019).

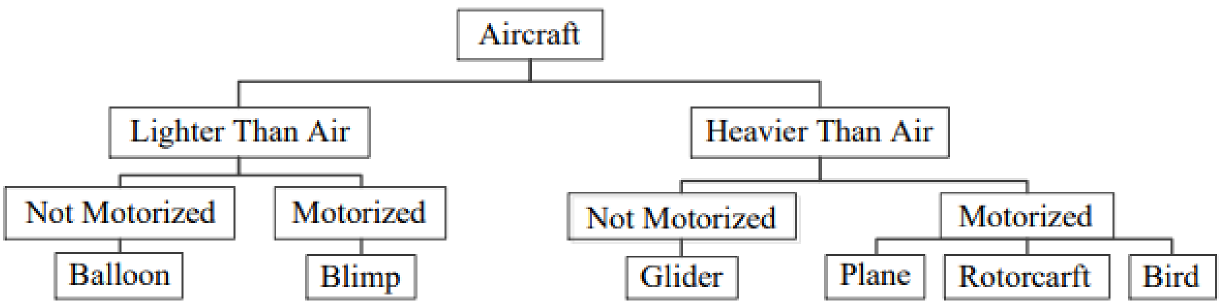


Figure I_1: Aircraft classification depending on the flying principle and propulsion mode.

(**Source :** international journal on smart sensing and intelligent systems, 2016)

I.1.2 – Historic review of the drones:

The design of drones began during the First World War: prototypes were proposed, with attempts of "aerial torpedoes" (such as the **Kettering Bug**) remotely controlled by wireless telegraphy and carrying a gyroscope, but never be operational on the ground. In 1916, in the United Kingdom, the Aerial Target, a target aircraft project, was designed by engineer Archibald Low. (Sedini; Cherigui, 2019).

Figure I_2: Kettering Bug.

(**Source :** Sedini ; Cherigui, 2019)

Figure I_3: Aerial Target.

(**Source :** Sedini ; Cherigui, 2019)

On July 2, 1917 in France, pilot Max Boucher flew a “Voisin plane” without human intervention for 1 km. At the beginning of 1918, an "unmanned aircraft" project was launched, after the improved autopilot system, the Voisin BN3 aircraft flew for 51 minutes over a 100 km course. (Idem 1, p. 5).

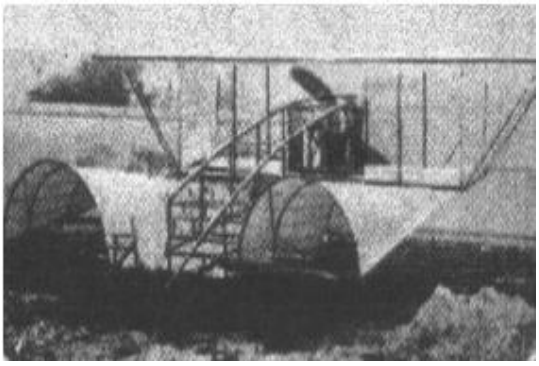


Figure I_4: Voisin plan BN3.

(**Source :** Sedini ; Cherigui, 2019)

In 1941, the US Navy ordered more than 1,000 copies of a new model called Target Drone Denny 1 (TDD-1). In 1938, the German army developed research on remotely guided vectors in the form of anti-ship hovering bombs, radio-guided anti-tank bombs and above all, fi log-guided tracked vehicles. (Idem 2, p. 6).

Figure I_5: Drone Denny 1 (TDD-1) .

(**Source :** Sedini ; Cherigui, 2019)

In the 1990s, the doctrine of the "zero death" war led to the development of armed drone projects around the world, but the very first use of these took place during the Iran-Iraq war where Iran deployed a six-armed drone. RPG-7. (Idem 3, p. 6).

Figure I_6: Predator-and-hellfire.

(**Source :** Sedini ; Cherigui, 2019)

In the 2000s, the drone was used in all conflicts and peacekeeping operations, including in Kosovo or Chad, during the American air attacks in Pakistan or against maritime piracy, by the Americans who introduced it in 2009. (Idem 4, p. 6).

In the past 10 years, many small drones have entered the market that include the DJI Phantom and Parrot AR Drone. This new breed of drones are cheap, lightweight. In the 20th Century, military research precipitated many widely used technological innovations. Surveillance satellites enabled the GPS-system, and defense researchers developed the information swapping protocols that are fundamental to the Internet. Drone fall into a similar category. Designed initially for reconnaissance purposes, their para-military and commercial development was often out of sight of the public. (Das, 2019, p .12)

Figure I_7: Parrot AR drone.

(**Source :** www.digitaltrends.com, 2020)

I.1.3 – Drone's classification:

Different drone's classification schemes have been proposed to help differentiate existing systems based on their operational characteristics and their capabilities. Several of these schemes are also of regulatory importance since the metrics used directly correlate with risk from ground impact or mid-air collision accidents. UAV classification is not only used to help differentiate existing systems but has regulatory importance. (Das, 2019, p. 13).

I.1.3.1 – According to size and weight:

It is not easy to classify aerial systems, because there are several categories of aerial drones ranging from the nano-drone of a few grams to the heavy drone capable of carrying out missions of more than 24 hours at several thousand kilometers from its base. (Sedini; Cherigui, 2019).

Other important studies about drone's a size and weight such as Clarke (2014) distinguishes large drones and small drones, but divides the small drones in multiple subcategories. Clarke also adds minimum weight indicators to the drone categories. The lower weight limit of large drones is 150 kg for fixed-wing drones and 100 kg for multirotor drones.

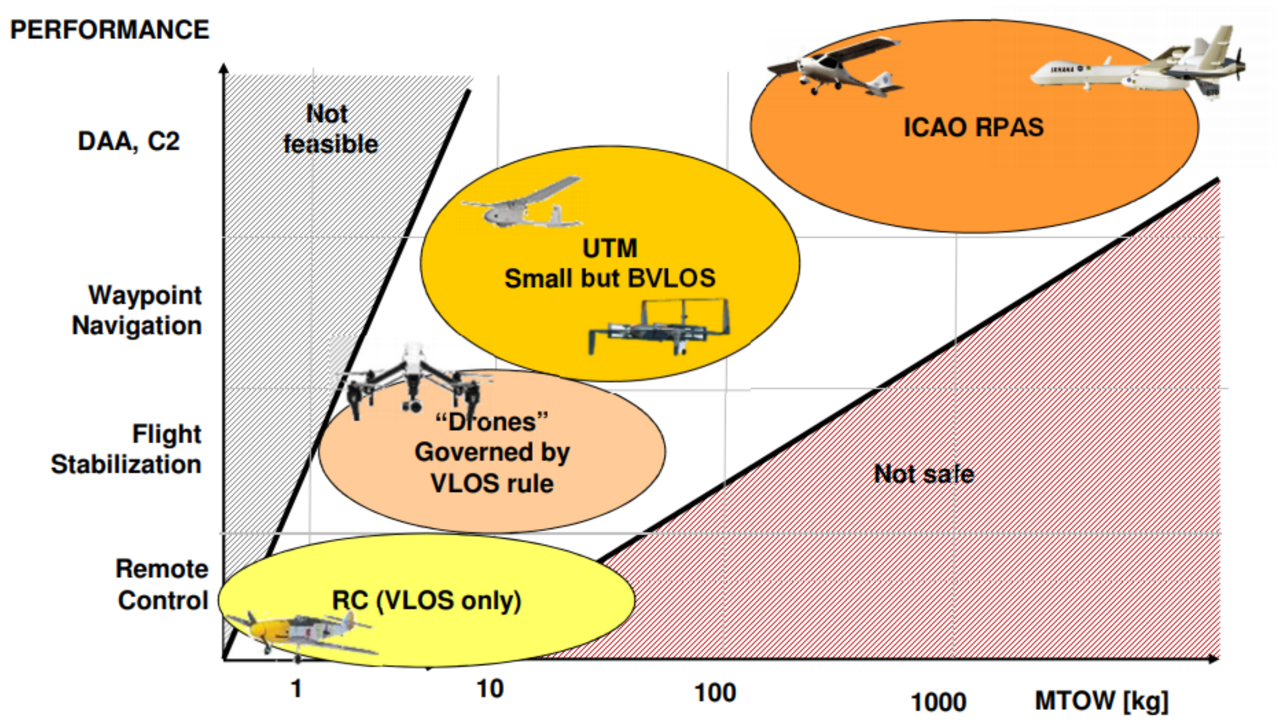


Figure I_8: drone's classification.

(**Source :** www.digitaltrends.com, 2020)

In this section, we attempt to explain three main families of drones according to their performance (flight range, range or operating altitude) and then we are going to explain the different types of drones according to the size and weight.

- **MALE (Medium Altitude Long Endurance) :**

Characterized by their long flight durations at operational medium altitude, having great autonomy. Like the Eagle 1 (EADS), MALE drones can fly at altitudes between 5 km and 12 km for a range of up to 1000 km. (Idem 1 ,p . 7).

Figure I_9: Eagle 1 (EADS) **.**

(**Source :** www.airliners.net**,** 2020)

- **HALE (High Altitude Long Endurance):**

These are large drones, most often with fixed wings. Characterized by their very long flight time and collect information over very long periods (12 to 48 hours) at high altitude. Such as the Global Hawk (Northrop Gumman), the size of an airliner and flying at altitudes of up to 20 km with a range of several thousand km. (Goraj , 2004 , p . 175).

Figure I_10: Hawk **.**

(**Source :** www.meta-defense.fr**,** 2020)

- **Tactical drones :**

Such as the Sperwer (SAGEM) or the Aerostar (Aeronautics Defense Systems), used for reconnaissance or battlefield supervision missions and flying at an altitude between 200 m and 5 km, for a radius action of 30 to 500 km. (Coban; Oktay, 2017, p. 32)

Figure I_11: Sperwer (SAGEM) .

(**Source :** www.meta-defense.fr**,** 2020)

- **Mini MUAV drones (Mini Unmanned Aerial Vehicle):**

With a flight time of a few hours and dimensions of the order of a meter, the minidrones can fly up to an altitude of 300 meters, with a diameter of about 30 kilometers carrying a very light payload. This type of device is generally electrically powered. Figure I_12 shows the Hovereye mini drone [Pflimlin2007], developed by Bertin Technologies. (Abdallah, 2019)

Figure I_12: Sperwer (SAGEM) .

(Abdallah, 2019)

- **Micro drones MAV (Micro Aerial vehicle) :**

Drones that have wingspan of 150 mm. It is a small-sized drone, which represents the 3rd generation of drones. In addition, these small aerial vehicles can perform tasks that larger vehicles cannot .They have an endurance of about thirty minutes, a weight less than 500 grams and can be contained in a sphere of 30 centimeters in diameter. These types of drones can only be launched by hand and must fly slowly in urban environments within buildings. (Abdallah, 2019)

Figure I_13: Micro drone .

(Abdallah, 2019)

I.1.3.2 – According to the propulsion:

The type of propulsion provides a further category of classification, of which three families can be distinguished:

- **Fixed wings drones :**

Fixed-wing is a term mainly used in the aviation industry to define aircraft that use fixed, static wings in combination with forward airspeed to generate lift. Examples of this type of aircraft are traditional airplanes, kites that are attached to the surface and different sorts of gliders like hang gliders or paragliders. Even a simple paper airplane can be defined as a fixed-wing system. (Vergouw & al 2016, pp.4-5).They can be:

- Heavier than air: airplane type.
- Lighter than air: airship type that uses helium to generate vertical thrust and rotors to generate torque. (Sedini; Cherigui, 2019)

Figure I_14: Fixed wings drones .

(**Source :** www.precisionag.com, 2020)

- **Flapping Wing Drones:**

Inspired by insects, the construction of this family of drones consists of the flapping of the wings that allow hovering flights and mimic the trajectories of insects. (Sedini; Cherigui, 2019)

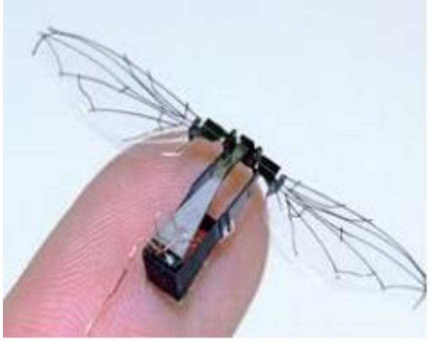


Figure I_15: Flapping wings drones .

(Sedini ; Cherigui, 2019)

- **Fixed Wing Hybrids :**

Fixed wing hybrids or Rotary-wing drones are characterized by their Vertical Take-o ff and landing aircraft (VTOL), so they do not need a runway to take off or land. They are used in several applications such as surveillance and data collection thanks to their hovering flight at low speed and low altitude. This type of drone differs according to the number of its propulsions. (Das, 2019, p. 16)

Figure I_16: Fixed wing hybrids drones .

(Das, 2019)

I.1.3.3 - According to the number of rotors:

The most common types of drones in this category are:

- **Mono-rotors:**

The most common example in this configuration is the airplane called 3D, which has a single motor as the main actuator, and which must be powerful enough to take off vertically, and ailerons with a large area, which ensure a large torques control in order to control the aircraft easily. (Sedini; Cherigui, 2019).Also another type, Helicopters are very common in manned aviation but are rarely used in the drone community. Single rotor helicopter drones generate thrust more efficiently over multi-rotors and can be powered by a gasoline engine for longer flight times. (Das, 2019, p. 15)

Figure I_17: 3D airplane.

(Sedini ; Cherigui, 2019)

Figure I_18: Single Rotor Helicopter Drones.

(Das, 2019)

- **Birotors:**

This type of configuration includes two types of drones, those with one or two swash plates like the classic helicopter and those with fixed pitch blades. In the case of the helicopter, we have a main rotor and a tail rotor. There is also the tandem helicopter, which has two rotors that rotate in the opposite direction but in different axes. (Sedini; Cherigui, 2019)

Figure I_19: classic helicopter.

(Sedini ; Cherigui, 2019)

Figure I_20: Tandem helicopter.

(Sedini ; Cherigui, 2019)

- **Multirotor:**

This type of aerial vehicle consists of several rotors with a direction of rotation reversed two by two to compensate the reaction torque, changing the speeds of the engines properly ensures the movements of the vehicle. Multirotor drones are the most popular types of drones that are used by hobbyists and professionals. Common applications of multirotor are varied, but includes aerial photography, video surveillance. (Das, 2019, p. 13)

Figure I_21: Multirotor drone.

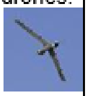
(**Source :** marketresearch.biz , 2020)

I.1.3.4 - According to autonomy level:

Because of the absence of a pilot, drones always have a certain level of autonomy. An important distinction within the concept of autonomy is the difference between automatic and autonomous systems. An automatic system is a fully pre-programmed system that can perform a pre-programmed assignment on its own. Automation also includes aspects like automatic flight stabilization. Autonomous systems, on the other hand, can deal with unexpected situations by using a pre-programmed rule set to help them make choices. Automatic systems cannot exercise this 'freedom of choice.' in this section; the focus is on autonomy in flight routes and operations (focusing on drone use technology, communication ….and weight). (Source: www.unog.ch)

Table I_1: Classification of UAVs based on level of autonomy and weight.

(Source: www.unog.ch, 2020, Modified by the author.)

Communication		BRLOS(Comm Relay/Transfer needed)					Remark
		RLOS (In-land120km, sea 200km), Situation awareness limited					
		Visual Line-of-Sight (<500m), No latency					
Control		Level 1 Radio control (fully manual)	Level 2 Semi-automatic (computer stabilized)	Level 3 Waypoint Navigation	Level 4 Task-level Autonomous Flight	Level 5 Intelligent/Fully Autonomous Flight	
Enabling Technology		Micro electronics	Small CPU, MEMS Sensors, Compact Communications				
				SW Technology		Artificial Intelligence	
Weight	Small UAS (<25kg)	Toy/RC 	Small drones for aerial photography 	Some high-end photography drones. Common for fixed wings 	Under Active Research	Under research  Used to be a topic for SF movie, but becoming a reality	Mainly driven by Electronics and ICT
	JARUS <150kg	Not often used (for close-range operation such as take-off and landing only)	Larger Aerial Photo drones and crop-dusting helicopters 	Small UAS			Mainly driven by conventional Aerospace Industries
	>150kg		Used	Many existing UAVs UAVS 	Advanced Recon, UCAV		

The United States Department of Defense distinguishes four levels of autonomy in their roadmap for unmanned systems as follows:

- **Human operated system:**

The most basic level of autonomy in which a human operator makes all the decisions regarding drone operation. This system does not have any autonomous control over its environment. (Vergouw & al 2016, pp.25-26)

- **Human delegated system :**

It is a higher level of autonomy. This system can perform many functions independent of human control. It can perform tasks when delegated to do so, without further human input. Examples are engine controls, automatic controls, and other automation that must be activated or deactivated by a human controller. (Vergouw & al 2016, pp.25-26)

- **Human supervised system :**

The third level of autonomy is a human supervised system. This system can perform various tasks when it is given certain permissions and directions by a human. Both the system itself and the supervisor can initiate actions based on sensed data. However, the system can only initiate these actions within the scope of the current task. (Vergouw & al 2016, pp.25-26)

- **Fully autonomous system :**

The final level of is a fully autonomous system. This system receives commands input by a human and translates these commands in specific tasks without further human interaction. In case of an emergency, a human operator can interfere with these tasks. (Vergouw & al 2016, pp.25-26).

I.1.3.5 - According to the differences in energy source:

This drone characteristic discussed here is the energy source. There are four main energy sources as follows:

- **Airplane fuel (kerosene) :**

It is mainly used in large fixed-wing drones. An example of such a drone is the military Predator drone. This drone is used a lot by the US army and can be equipped with a number of different sensors, but also with rockets and other types of ammunition. (Vergouw & al 2016, pp.26-27).

Figure I_22: Airplane fuel kerosene. (Source : www.planete-energies.com)

- **Battery cells :**

They are mainly used in smaller multirotor drones. These drones are short range and require less operating time than drones using kerosene. These drones are often for recreational use, making it more practical for the drone to run on a rechargeable battery cell. An example of such a drone is the above-mentioned Phantom drone. (Vergouw & al 2016, pp.26-27).

Figure I_23: Phantom drone.

(**Source** : www.planete-energies.com)

- **A fuel cell :**

It is an electrochemical device that converts chemical energy from fuel directly into electrical energy. Because of the lack of conversions in thermic and mechanical energy, this conversion is efficient and environment friendly. Fuel cells are currently rarely used in drones. Only fixed-wing drones can be equipped with such a cell because of the cell's relatively high weight. A major advantage of using a fuel cell is the fact that drones can fly longer distances without recharging. For example, the Stalker drone, which uses a fuel cell, has a flight time of 8 h instead of 2 h. (Vergouw & al 2016, pp.26-27).

Figure I_24: the Stalker drone

(**Source** : defence-blog.com)

- **Solar cells :**

Drones using solar cells are rare in the current drone industry. Drones using solar cells are mainly fixed-wing drones. Because of the low efficiency of current solar cells, these cells are usually suitable for many multirotor drones. However, solar cells are suitable for small ornithopters. Solar cell drones attracted a lot of media attention when both Google and Facebook struck deals with manufacturers of these drones. Their goal was to let solar-powered drone's fly in the atmosphere permanently in order to enable people to connect to the Internet more easily and massively. (Vergouw & al 2016, pp.26-27).

Figure I_25: drone uses solar cells.

(**Source** : diydrones.com)

I.2 – The Quadcopter:

I.2.1 – Definition of the Quadcopter:

A quad copter, also called a quadrotor helicopter or quad rotor is a multirotor helicopter that is lifted and propelled by four rotors. Quad copters are classified as rotorcraft, as opposed to fixed-wing aircraft, because their lift is generated by a set of rotors (vertically oriented propellers). (Prabhu, 2019, para 1).

The quadcopter is a type of drone, which has the particularity of having four arms, each of them connected to a motor to fly, navigate and stabilize. The front of the drone is usually placed between two arms (x configuration), but can also be located along an arm (+ configuration).

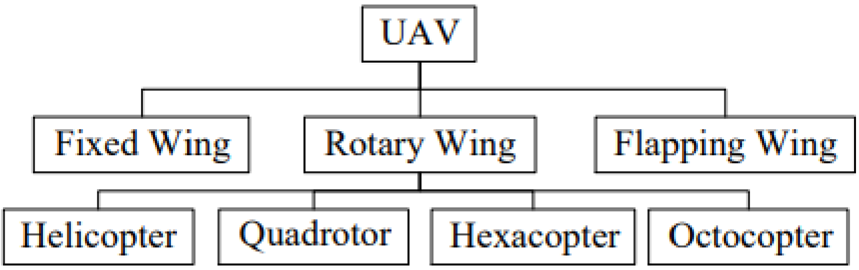


Figure I_26: UAV classification.

(**Source :** international journal on smart sensing and intelligent systems, 2016)

A quadcopter is a popular form of UAV (Unmanned aerial vehicle). It is operated by varying the spin RPM of its four rotors to control lift and torque. The thrust from the rotors plays a key role in maneuvering and keeping the copter airborne. Its small size and swift manoeuvrability enables the user to perform flying routines that include complex aerial manoeuvres. But for conducting such manoeuvres, precise angle handling of the copter is required. The precise handling is fundamental to flying by following a user defined complex trajectory-based path and while performing any type of missions. This paper serves as a solution to handling the quadcopter with angular precision by illustrating how the spin of the four rotors should be varied simultaneously to achieve correct angular orientation along with standard flight operations such as taking-off, landing and hovering at an altitude . (Rokibujjaman, 2017).

Figure I_27: the quadcopter.

(**Source :** www.digikala.com ,2020)

I.2.2 – Historic review:

Quadcopters and drones have a very interesting story. The idea of a quadcopter had existed since the beginning of the 20th century. The first experimental attempts to build a rotating wing were made in 1907 by Jacques and Louis Breguest, two brothers from France, who built Gyroplane, but their design proved to be very unstable and therefore impractical. (Das, 2019, p. 9)

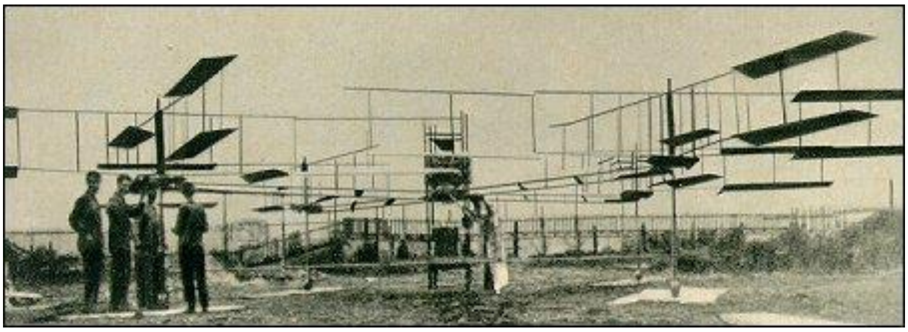


Figure I_28: Jacques and Louis Breguest Gyroplane .

(**Source :** Das, 2019)

Then Etienne Oehmichen was the first scientist to experiment with a rotating wing in 1920. Among the six models he designed, it was the second one that managed to take off successfully (Figure I_ 27). This model was constructed from steel tubes on the ends of which the four double blade motors were based. He also placed five double blade motors laterally to ensure that it is stabilized. The aircraft had a significant degree of stability, was fully controllable, and made more than a thousand test flights during 1920. Until 1923, it was able to stay for several minutes in the air and on April 14, 1924, it managed to travel a distance of 360 meters, thus defining a world record for an aircraft of this type at that time. Finally, after many pilot flights, it managed to complete a flight in a distance of 1 kilometers in 7 minutes. (Sedini; Cherigui, 2019)

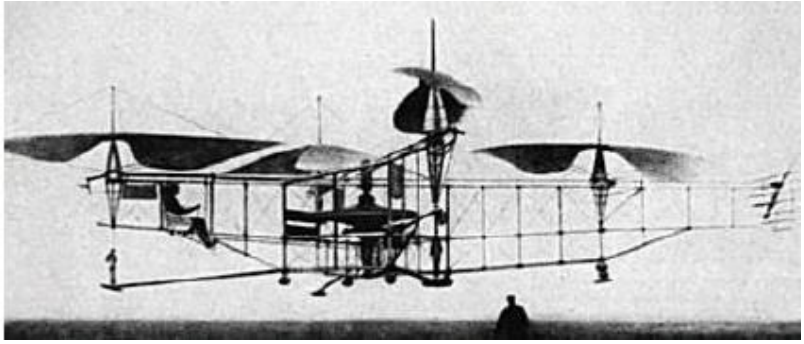


Figure I_29: Oehmichen Quadcopter N°2 .

(**Source :** Das, 2019)

After Oehmichen, engineers George de Bothezat and Ivan Jerome developed their own X-shaped aircraft (Figure I_ 30), which consisted of four six-wing blades, and unlike that of Etienne Oehmichen, they added wheels at the bottom in order to achieve smoother take-off and landing. It made its first flight in October 1922 and until the end of 1923, it successfully completed 100 flights, with a maximum height of 5 meters. (Sedini; Cherigui, 2019)

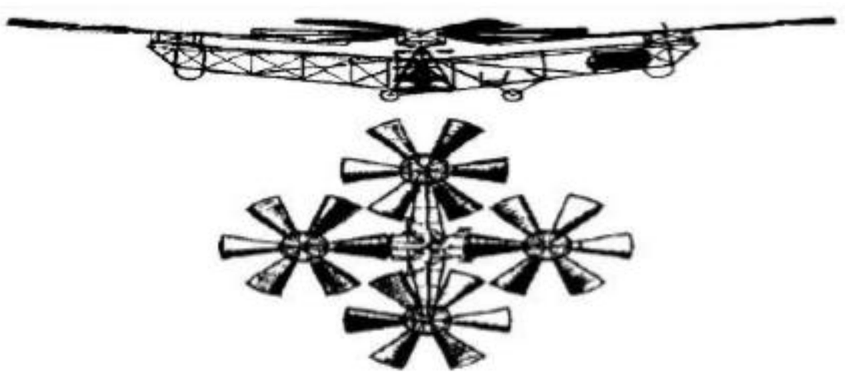


Figure I_30: George de Bothezat and Ivan Jerome Quadcopter .

(**Source :** Sedini ; Cherigui, 2019**)**

Over the years, there has been a significant improvement in the stabilization and control of quadcopters. In 1956, D. H. Kaplan had further refined his own aircraft (Figure I_31) and demonstrated the ability to control the aircraft attitude using a different thrust between the engines. The aircraft incorporated four double blade motors and were mounted in an "H" like structure. The control mechanism was extremely simplified, it was not necessary to have a tail motor and the control was achieved by differential thrust change between the engines. It successfully made several flights and was the first quad–rotor aircraft to perform forward movement. However, due to the lack of orders for commercial or military use, the project was terminated. (Das, 2019, p. 11)

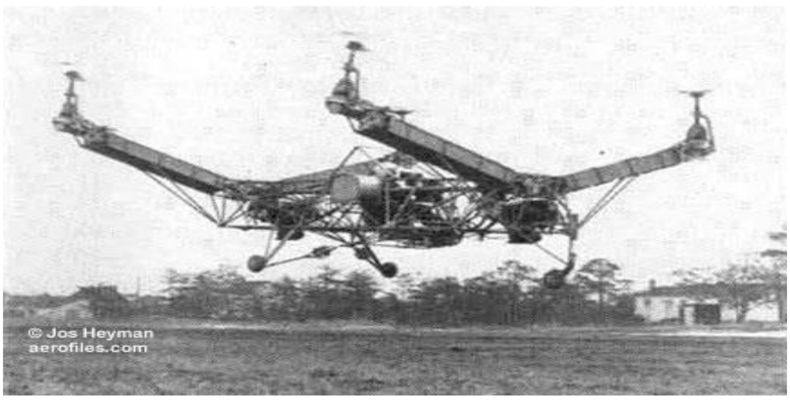


Figure I_31: D. H. Kaplan model A Quadcopter**.**

(**Source :** Das, 2019**)**

In January 2016, the Chinese company Ehlang based in Guangzhou presented a quadcopter drone capable of carrying a person up to 100 kg, at an altitude of 500 meters.

Today, small-unmanned aerial vehicles have been used for many applications. The need for aircraft with greater manoeuvrability and greater ability to hover has led to an increase in research on quadcopters. Some current programs include:

- **The Bell Boeing Quad Tilt Rotor** , concept from Bell takes the fixed quadcopter concept a Step further by combining it with the pendulum rotor concept for a proposed C-130 size military transport.
- **Aero Quad and ArduCopter** are open-source software and hardware projects based on Arduino for building quadcopters.
- **Parrot AR.Drone** is a small radio-controlled quadcopter, equipped with cameras, built by Parrot SA, designed to be controlled by a smartphone or tablet. (Sedini; Cherigui, 2019)

Figure I_32: Flying prototype of the Parrot AR.Drone**.**

(**Source :** Sedini ; Cherigui, 2019**)**

Figure I_33: Parrot AR.Drone 2.0 take-off, Nevada, 2012**.**

(**Source :** Sedini ; Cherigui, 2019**)**

I.3 – Applications of drones:

The main goal of the UAVs or Drones is to fulfil a mission that could be military, scientific, economic, or even commercial in nature. The interest in the control and navigation of drones is due to their use in hazardous environments (Ollero & Maza, 2007). The aerial vehicles were firstly developed in the military domain for the 3D missions known as ‘Dull, Dirty and Dangerous’. These missions were too long and dangerous for the presence of pilots in the aircrew. Aircraft without radio-controlled pilot firstly appeared during the First World War in order to decrease the number of pilot diseases (Jobard, 2014). However, the real appearance of military drones does not come into place until the wars of Korea and Vietnam where they were used for stealth surveillance. In the 90’s, the doctrine of ‘zero death’ had emerged allowing for the development of army drones and for their use in every army conflict from the 2000s. The prosperity of these war machines is due to the miniaturization of the avionics vehicles' size in addition to their long distance communication. It ought to be noted that 11 states officially possess military drones: the United States, Israel, the United Kingdom, Russia, Iran, Turkey, France, Germany, Italy, India and China. It is appropriate to enumerate some military applications in which we refer to the use of the UAVs: (Abdallah, 2019)

I.3.1 - Military applications (Navy, Army and Air Force):

- Electronic intelligence.
- Reconnaissance.
- Radar system jamming and destruction.
- Relaying radio signals.
- Shadowing enemy fleets.
- Surveillance of enemy activity.
- Target designation and monitoring.
- Elimination of unexploded bombs.
- Decoying missiles by the emission of artificial signatures.

In the 90's, after the emergence of UAVs in the military domain and the rapid development of this technology, they have been known for a new role in Earth monitoring and emerged to the civilian domain (Luong, 2013). Civil applications have increased nowadays and we can cite:

I.3.2 - Civil applications:

- Aerial topography for geographical researches
- Agriculture spraying and monitoring
- Search and rescue - Meteorological Measurements
- Firefighting and forestry fire detection
- Surveillance for illegal imports
- Pollution Studies and land monitoring
- Pipelines and Power line inspection
- Oil and gas search - Delivery of parcels
- Urban planning
- Detection of mobile vehicles on the ground

I.3.3 – Advantages and disadvantages of drones:

- **Advantages :**

• Does not require a qualified pilot.

• Can enter any environments.

• Can stay in the air for up to 30 hours.

• Can be programmed to complete the mission autonomously.

- **Dis-advantages**

• Costly compared to manned vehicles

• Limited abilities

• More hardware complexity

I.4 – Applications of quadcopter:

I.4.1 - Research platform:

Quad copters are a beneficial gadget for researchers to test and evaluate new ideas in different fields, including flight control system theory, AI implementations. In recent times, many universities have shown quad copters performing increasingly complex flying manoeuvres. (Das, 2019, p. 5)

I.4.2 - Military and law enforcement:

Quad copter are used for surveillance and reconnaissance by military and law enforcement agencies (FBI, CIA, KGB). It use as well as search and rescue missions silently in urban and risky environments. Canadian company Aeryon Labs, Created a small UAV named “Aeryon Scout” that can silently hover in place and use a camera (Night Vision and Heat Sensor) to observe people and objects on the ground. Quad rotor played an important role in a drug raid by providing visual surveillance. (Das, 2019, p. 6)

I.4.3 - Journalism:

In 2014, The Guardian reported that major media outlets have started using drones for reporting and verifying news on events that include natural disasters, protests and wars, live telecasting. Some media outlets and newspapers are using drones to capture photography of celebrities, Politicians.

I.4.4 - Drone-delivery:

The first drone payload delivery was done in December 2013. A Micro drone (md4-1000) quadcopter carries a payload-contained medicine over Rhine River and deliver it. It is known as project Parcel copter, in which the company tested the shipment of medical products by drone delivery. After few days, Amazon announced a plan to use quad copter for delivery products in the nearby area. This service known as Amazon Prime Air. So it is clear that domestic usages of UAV has vast future Possibility. (Das, 2019, p. 6)

I.4.5 - Humanitarian operations:

Quad copters are being used for humanitarian applications from disaster relief to animal conservation. During flood and earthquake, it is use to delivery necessary payload and medicine for fast response. (Das, 2019, p. 7)

I.4.6 - Sport:

Quad copters are used drone racing and freestyle events. This type of quad copters are built for speed, agility and quick response. Those are small in from factor, typically distance between propeller shafts 250 mm and use 5-6 inch propellers for fast manoeuvre. (Das, 2019, p. 7)

I.4.7 - Photography:

The largest use of quad copters has been in the field of photography and videography. Quad copter are suitable for this because of their autonomous nature and huge cost savings and capability of reaching high altitude and taking impressive wide-angle shot. DJI M600 can carry several Zen muse cameras and gimbals make it ideal for professional aerial photography and industrial application. (Sedini; Cherigui, 2019)

I.4.8 - Advantages and disadvantages of quadcopter:

Among the advantages of the quadrotor, we can cite: the speed of delivery in ca se of emergency, this extreme fast delivery would be a huge advantage for a customer (whether for work, for a leisure…)

In addition, the aerial drone is a much less complex aeronautical machine than airplanes or helicopters. To advance an airplane, the wings must be controlled by a pilot, and to control a helicopter it is necessary to change the inclination of the propellers or their speed. While drones bring together the best parts of planes and helicopters. Indeed, it has several motors and propellers that allow the drone to move just by changing the speed of rotation of the motors. The drone is also composed of a simple mechanical part, which makes it an object with a simplicity of construction. Finally, there is also the ecological advantage. Indeed, the drone distributor uses electricity to move forward.

Among the disadvantages of the quadrotor, we can cite: the autonomy of the drone is very low. Indeed, the drone can only move for 16 kilometers before it needs to be recharged, also the saturation of space in the air. Imagine that all companies use this concept, so the airspace would be saturated.(Sedini ; Cherigui, 2019)

Conclusion

This chapter allowed us to have a general view on drones, their history and different types within the classification. We have also described quadrotor its history, their appearance and their advantages and applications. In the following chapters, we will try to explain the functional parts of drones and their requirements and all the practical information we can gather to finally build our project.

CHAPTER II:

THE FUNCTION OF DRONES

Introduction

The quadcopter is one of the most complex flying systems because of the physical phenomena that influence its dynamics. In order to realize a controller robust flight, we must first understand the movements of the system and its dynamic. This understanding is necessary to ensure that simulations of the craft will portray behaviour, as close to reality as possible, so that is what we are going to see in this chapter.

II.1 – Functioning principle of quadcopter:

Working principle of quadcopter is mainly consisting of increase and decrease the speed of the motors, to drive the quadcopter (drone). A quadrotor hovers or adjusts its altitude by applying equal thrust to all four rotors. Rotation of motors are shown in Figure II_34.

Quadcopters generally use two pairs of identical fixed pitched propellers, two clockwise (CW) and two counter-clockwise (CCW). These uses independent variation of the speed of each rotor to achieve control. By changing the speed of each rotor, it is possible to specifically generate a desired total thrust; to locate for the center of thrust both laterally and longitudinally and to create a desired total torque, or turning. (Chandrakanth, 2017)

Figure II_34: Four rotors of quadcopter.

Source : Chandrakanth, 2017

II.1.1 - Arrangement of motors:

The sections below show motor order for each frame type (the numbers indicates the connected autopilot output pin) and the propeller direction (clockwise (CW) motors are shown in green and take pusher propellers, counter clockwise motors (CCW) are shown in blue and take puller propellers. Propeller force. Figure II_ 35 and Figure II_36 Use the diagram for your frame type, and wire the motors as shown in bellow:

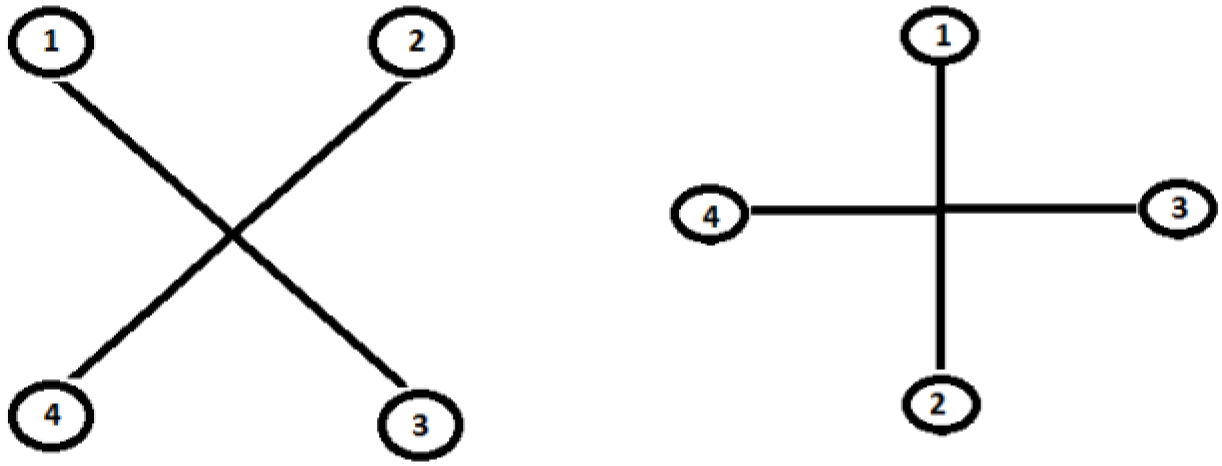


Figure II_35: Legend for motor-order diagrams of Quadcopter

Source : Chandrakanth, 2017

Place motors on quad copter frame any model. But, will place all motors have an equal distance from a center point; it is like a triangle, square, hex, etc. There is alternating arrangement of motors on drone. We Use Figure II_36 is an acceptable model to build a drone frame. (Chandrakanth, 2017)

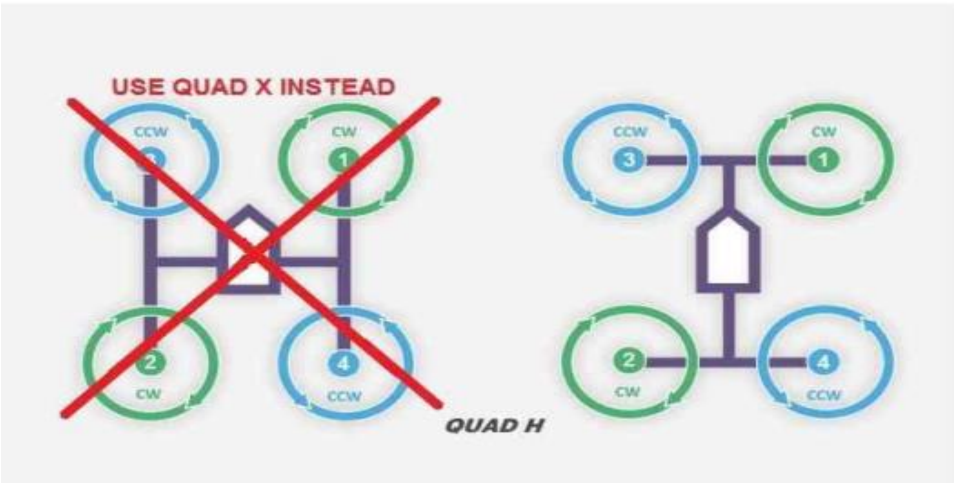


Figure II_36: Legend for a quadcopter frame

Source : Chandrakanth, 2017

II.1.1.1 - Attach propellers:

Find your frame in the motor order diagrams above. Clockwise motors are shown in green, marked CW, and take pusher propellers. Counterclckwise motors are shown in blue, marked CCW, and take puller propellers. We Use the Figure II_36 for our frame type, and attach propellers to your vehicle as shown. For copters, attach propellers with the writing facing towards the sky. For more information on recognizing the different types of propellers, see in bellow Figure II_37:

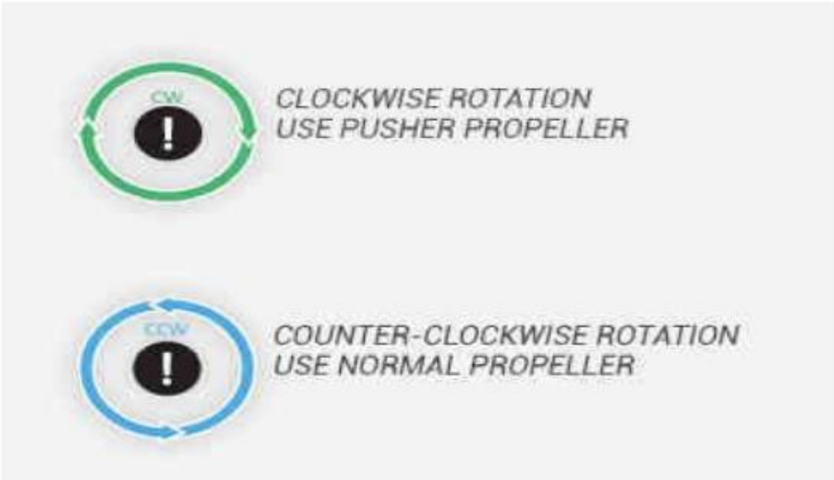


Figure II_37: different types of propellers

Source : Chandrakanth, 2017

II.1.1.2 - Recognizing clockwise and counter clockwise propellers:

In this part bellow, it shows two types of propellers: clockwise (called pushers) and counter clockwise (called pullers). Pusher propellers are often marked with a P. However not all propellers are marked and both types are often available in either rotational direction. Therefore, it is most reliable to recognize the correct propeller type by its shape as shown below. Reminder that the propellers below have the edge with the shallow consistent curve at the leading edge in direction of rotation and the more radical scalloped (and usually thinner edge) as the trailing edge. We can use these features to recognize propellers of the correct direction of rotation. Recognize of propellers are shown in Figure II_38. (Chandrakanth, 2017)

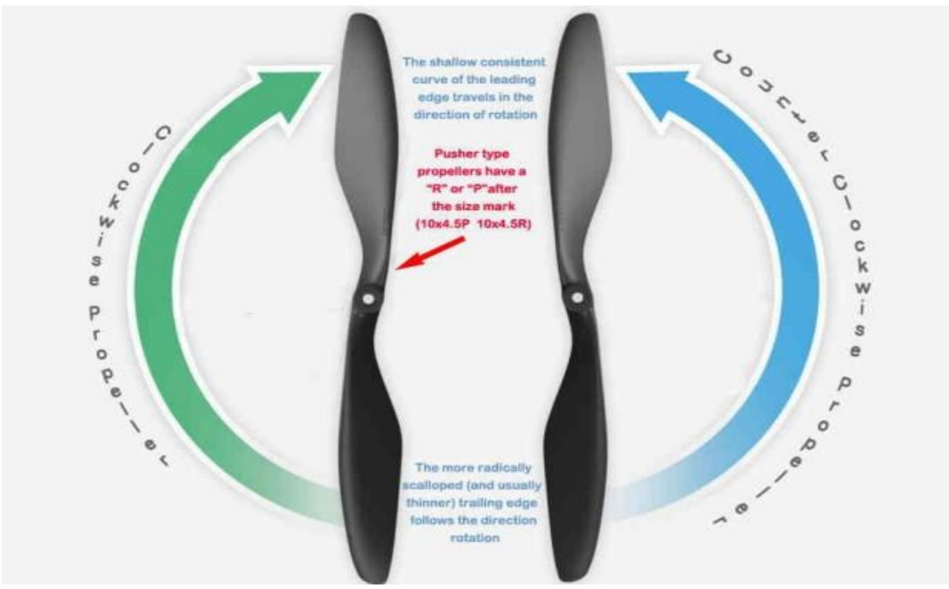


Figure II_38: Propellers rotation

Source : Chandrakanth, 2017

To arrange propellers on motors, then controlling of drone (quadcopter) will easy. If all motors are rotating single direction the vehicle will not controllable. The force which is generated by one direction rotating motors will be compensating by the other direction rotating motor's force, at this time drone is stable, easy to control and it not dangers to environmental. (Chandrakanth, 2017)

II.2 – Driving and movements of drone (Quadcopter):

This is quadcopter placed upon an H or X shaped frame. In this bellow Figure II_39 we are using quad copter that will be placing motors like H shape as and X shape. Both two shapes are used for drone motors. Four motors A, B, C, and D are placed in equal distance from the center of its body shape. If motors of drone does not place according into Figure II_ 39 the forces generating by motors are not compensating each other. (Chandrakanth, 2017)

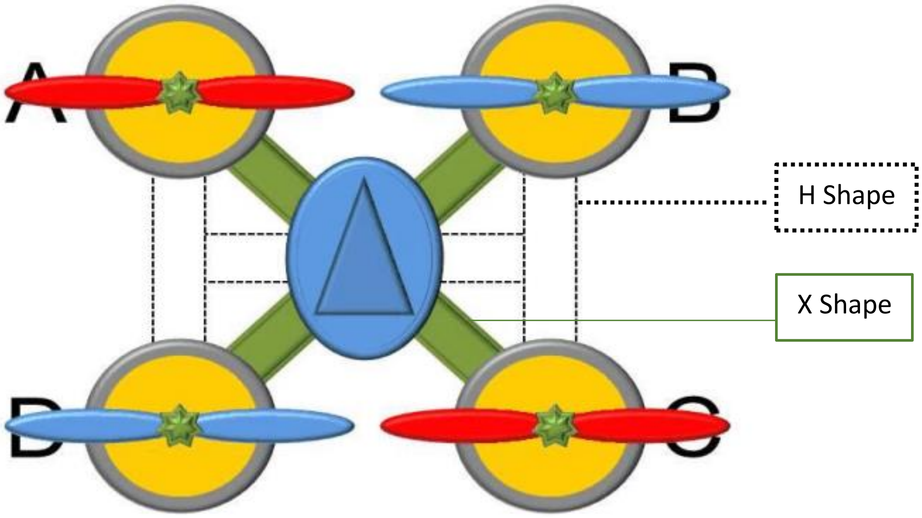


Figure II_39: placing of motors

Source : Chandrakanth, 2017

Varying the speed of each rotor will produce thrust, and therefore effect movement. The quad-copter tilts in the direction of the slower rotor, and then translates along that axis. Therefore, it is the tilt that allows the quad-copter to translate, which means that a change in the speed of a rotor translates into motion in at least three DOFs. For example, increasing the speed of the front engine will result in a pitching motion. So we can control the six quad-copter DDL with the four main movements. (Sedini; Cherigui, 2019)

II.2.1 - Hovering and hoisting movement:

Hovering and hoisting movements are the most basic form of motion for a four-rotor vehicle, as shown figure II_39. When it is flying in the air, air resistance through the rotor to produce anti-torque effect on the body, anti-torque rotation direction and the direction of rotation of the rotor is just the opposite, and its role with the size of the increase in speed increases. The motors A and C rotate counter clockwise, and the motors B and D rotate clockwise. Since the rotation speed of the four motors is the same, the rotor produces the same lift force, so the counter-torque just cancel out each other, and then stabilizes horizontal. (Rokibujjaman, 2017)

For hovering a balance of forces is needed. If we want the quadcopter to hover, SUM (Fi) must be equal m·g. To move the quad-copter climb/decline the speed of every motor is increased/decreased. (Chandrakanth, 2017)

- SUM (Fi) >m•g<=> climb
- SUM Ӽ (Fi) = m•g<=> hover
- SUM (Fi) <m•g<=> decline

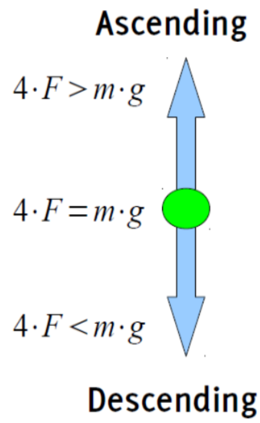


Figure II_40: balance of forces

Source : Chandrakanth, 2017

II.2.2 - Quadcopter (drone) tilting movement:

Now let's take a look on what is happening when we tilt the quadcopter. For simplification, only two of the four rotors are shown. We see that the force is divided in two different parts. FL1 and FL2 are the part of the force used to lift the quadcopter. FT1and FT2 represents the part used for the translation. It is obvious that the lift part becomes smaller with increasing **φ**. Tilting of drone is shown in Figure II_ 41. (Chandrakanth, 2017)

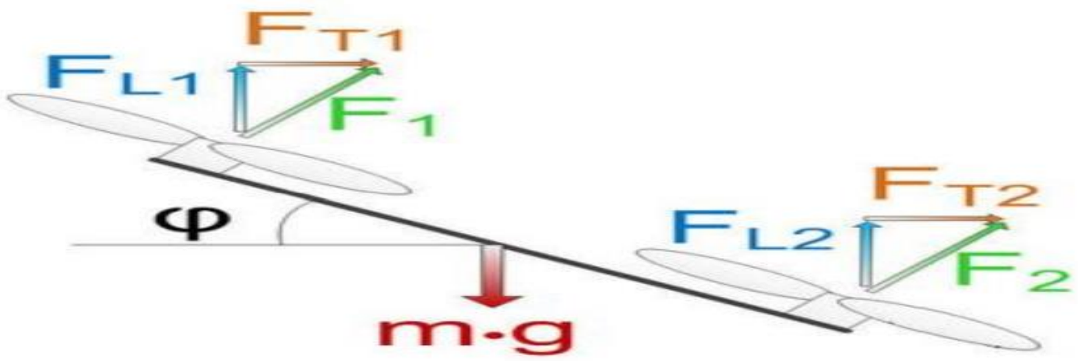


Figure II_41: Tilting of drone

Source : Chandrakanth, 2017

II.2.3 - Yaw movement:

The yaw axis is a vertical axis through the aircraft, and it is more complex than controlling the pitch or roll. The quadcopter motor configuration is such that the adjacent motors spin in the opposite direction. This is to neutralize or eliminate the rotors influence to make the quadcopter rotate.

Therefore, in order to rotate the quadcopter about the yaw axis, the opposite pair of rotors needs to be slower relative to the other pair to cause the quadcopter to rotate. (Govender, 2014)

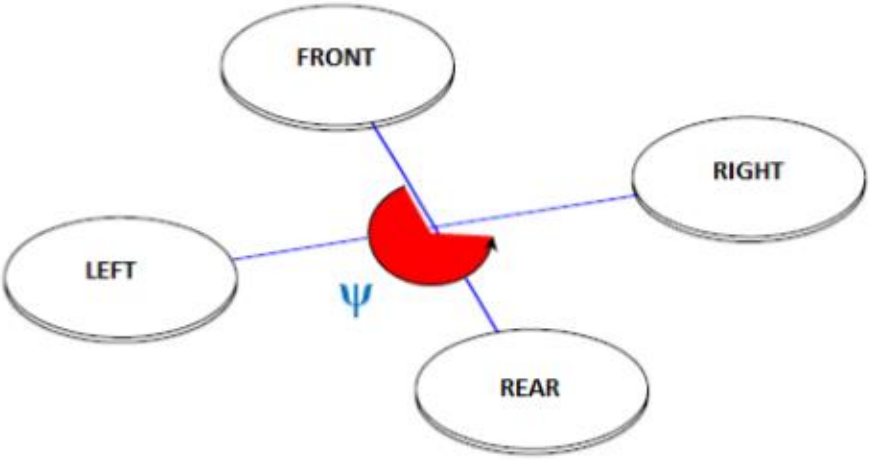


Figure II_42: Yaw direction of drone

Source : Author, 2020

II.2.4 - Pitch movement:

Pitch is the movement of quadcopter both forward and backward. Forward Pitch is achieved by pushing the aileron stick forward, which makes the quadcopter tilt and move forward, away from you. Backward pitch is achieved by moving the aileron stick backwards (towards you), making the quadcopter, come closer to us. (Chandrakanth, 2017)

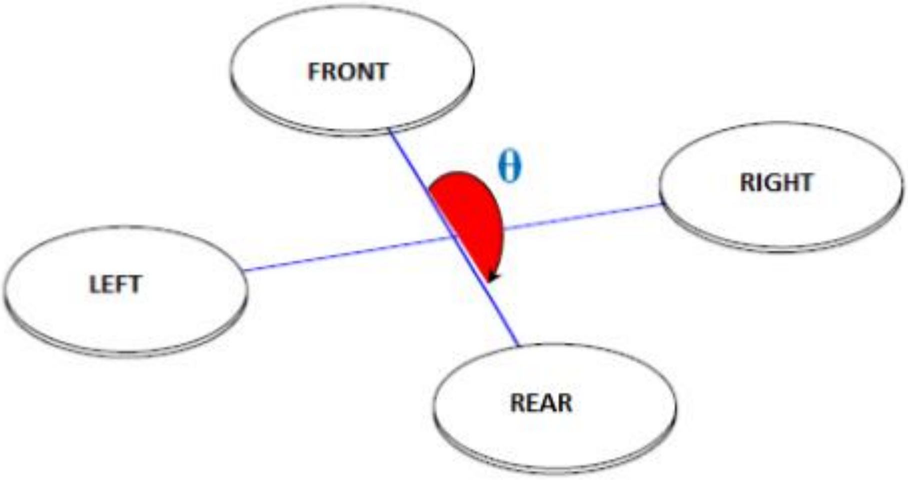


Figure II_43: Pitch direction of drone

Source : Author, 2020

II.2.5 - Roll movement:

This movement is achieved by changing the speeds of the front and rear thrusters which apply torque around the y axis. This movement is coupled with a translational movement along the x axis. (Sedini; Cherigui, 2019)

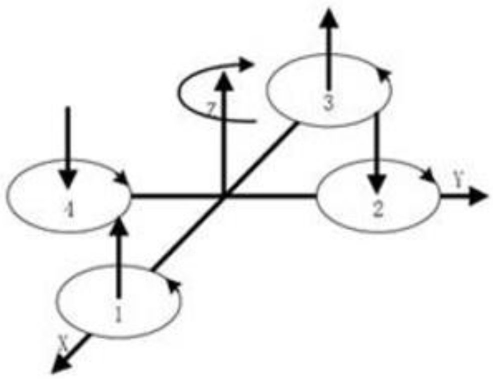


Figure II_44: Roll movement

Source : Author, 2020

II.2.6 – Vertical movement (take –off / landing):

In order to glide, all the lift force should only be along the z axis with a magnitude exactly opposite to the force of gravity. Therefore, the thrust produced by each rotor must be the same. The upward and downward movements are obtained by varying the speed of rotation of the motors as a consequence of the thrust produced, if the lift force is greater than the weight of the quad-copter the movement is ascending, and if the lift force is less than weight of the quad-copter the movement is downward. (Sedini; Cherigui, 2019)

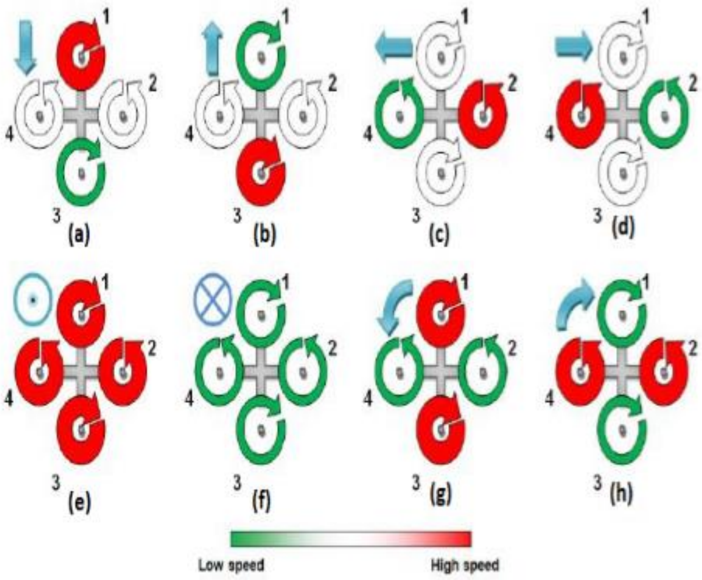


Figure II_45: movements of quadcopter

Source : Author, 2020

II.3 – Components of quadcopter:

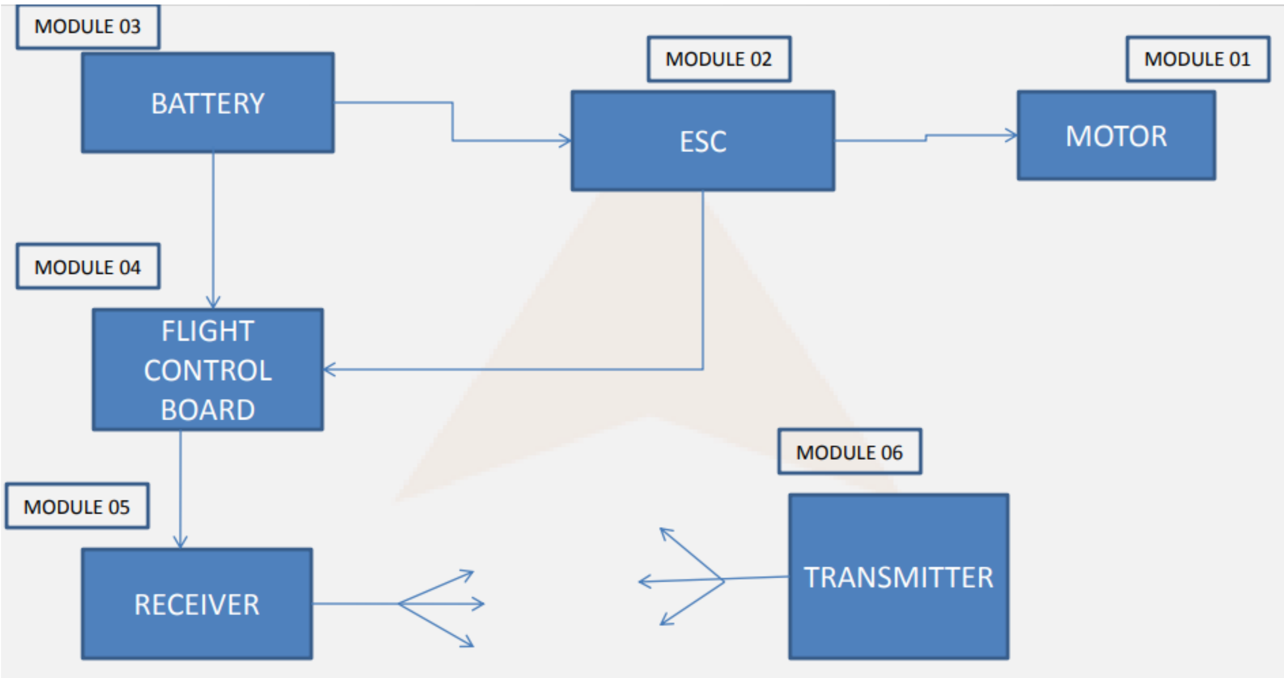


Figure II_46: block diagram of quadcopter

Source : Author, 2020

II.3.1 – Arduino:

Arduino Uno is an open source physical computing platform used for building digital devices and interactive objects that can sense and control objects in physical world. It's a micro controller, based on AT mega 328P which consist of 14 digital input/output pins (out of which 6 pin are used as PWM output), Six analogy inputs, a USB connector,16 MHz quartz crystal, power jack, an ICSP header and a reset button. Arduino board consist of everything needed to work with microcontroller. Arduino IDE (Integrated Development Environment) is use to upload programs to the Arduino boards and further these programmed boards can be used to perform intended tasks. (Kishor & Singh, 2017, p.14)

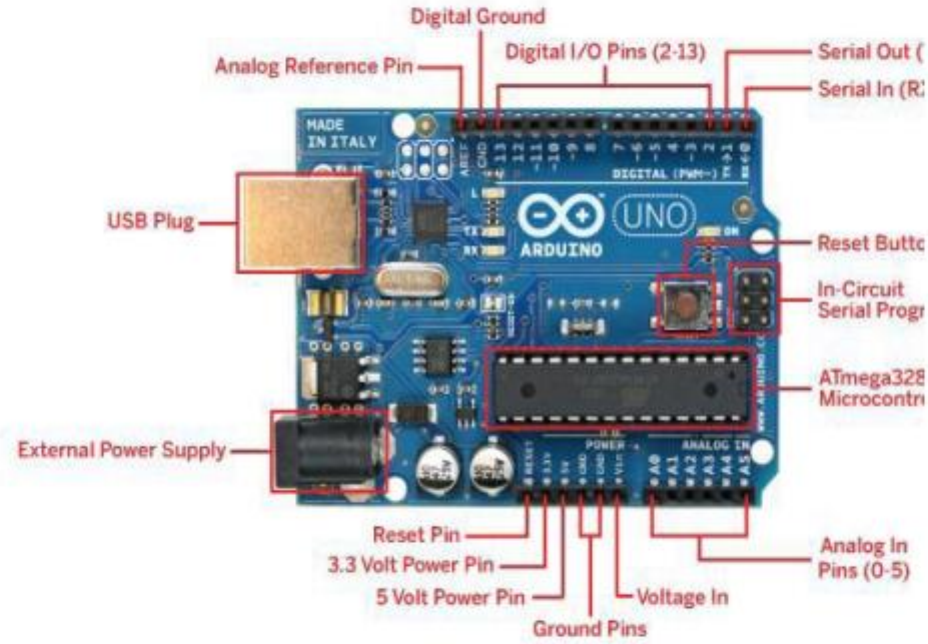


Figure II_47: diagram of quadcopter components

Source: international journal of engineering and manufacturing science, 2017

II.3.2 – Motors (BLDC motors):

Quadcopter Motors is a Brushless DC electric motor (BLDC motors) also known as electronically commutated motors (ECMs, EC motors) are synchronous motors that are powered by a DC electric source via an integrated inverter switching power supply, which produces an AC electric signal to drive the motor. In this context, AC, alternating current, does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform. (Chandrakanth, 2017) The motors chosen should meet the following specifications:

- Lightweight.

- High speed and torque.

- PWM speed controlled.

We chose A2212/13T (2450KV) brushless motor

Figure II_48: Brushless motor

Source : Chandrakanth, 2017

II.3.3 – ESC (Electronic Speed Control):

The term ESC stands for an "electronic speed control is an electronic circuit used to change the speed of an electric motor, its route and also to perform as a dynamic brake. These are frequently used on radio controlled models which are electrically powered, with the change most frequently used for brushless motors basically providing an electronically produced 3phase electric power low voltage source of energy for the motor. An ESC can be a separate unit which lumps into the throttle receiver control channel or united into the receiver itself, as is the situation in most toy-grade R/C vehicles. Some R/C producers that connect exclusive hobbyist electronics in their entry-level vehicles, containers or aircraft use involved electronics that combine the two on a sole circuit board. (Das, 2019, p.38)

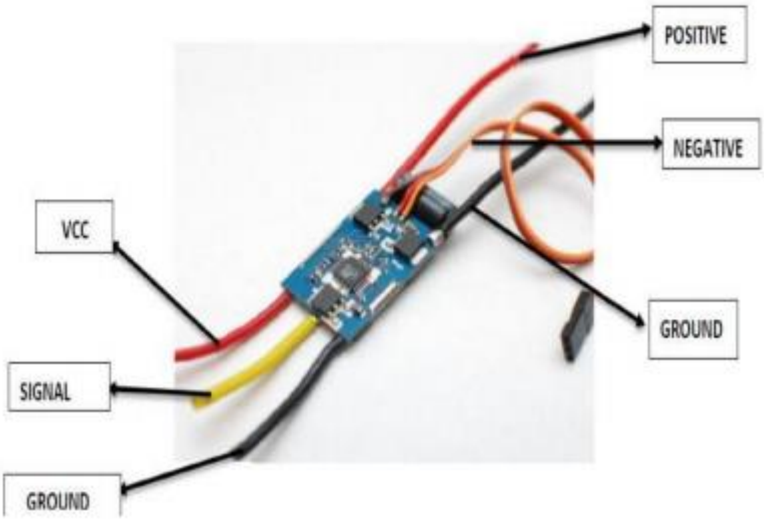


Figure II_49: ESC's (Electronic speed controller)

Source: international journal of engineering and manufacturing science, 2017

II.3.4 - NRF24l01Transceiver Module (transmitter and receiver):

Radio transmitter uses radio signal to remotely control quadcopter in wireless way, the commands given by transmitter are received by a radio receiver connected to flight controller. The no of channels in transmitter determine how many actions of aircraft can be controlled by pilot. Minimum of four channels are needed to control a quadcopter (which includes pitch. Roll, throttle, yaw).The stick control on radios transmitter is known as gimbal. RC receiver used operates on 2.4GHz of radio frequency (unless you do not have any specific need for a different frequency). (Kishor & Singh, 2017, p.16)

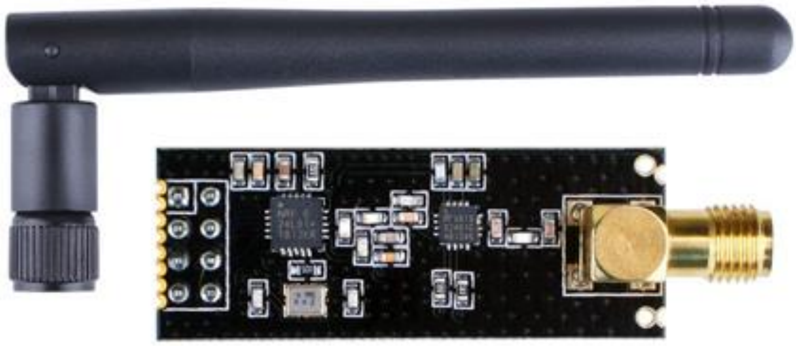


Figure II_50: Transmitter and receiver

Source: international journal of engineering and manufacturing science, 2017

II.3.5 - MPU6050 Accelerometer and Gyroscope:

- **Gyroscope:**

A gyro is a microchip, secondary to the main processor, which senses the angular velocity or the speed at which a quadcopter rotates in the roll, pitch and yaw axis. Using calculus mathematics and gyro inputs, the FPV Drone Flight Controller can estimate the distance a quadcopter has rotated and whether its rotation is accelerating or decelerating. (Das, 2019, p.44)

- **Accelerometers**

An accelerometer is another separate sensor chip and can detect the acceleration of a quadcopter in the roll, pitch or yaw axis. Because the accelerometer can also detect the constant acceleration of gravity, the FPV Drone Flight Controller is able to use this information to calculate the quadcopter's precise angle from the horizon. This is used for flying a quadcopter in horizon/self-levelling mode which is the flight mode most beginners start with.(Das , 2019 p.45)

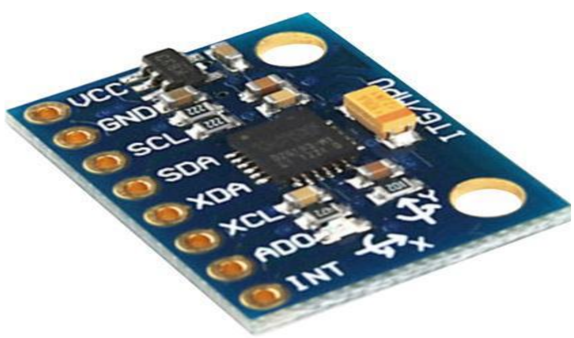


Figure II_51: Mpu 6050 module

Source: international journal of engineering and manufacturing science, 2017

II.3.6 – Battery:

Quadcopter battery is the power source that drives all the systems on our drone and allows it to fly. Like gas in a car, once we run out of power, we are not going anywhere. When we first start flying quadcopter, we need to have a basic understanding of how a quadcopter battery works.

- **Lithium Polymer Batteries**:

Lithium polymer batteries are modern batteries that are commonly used in consumer electronics such as our smartphone, laptops, and tablets. The two main possible alternatives to LiPo batteries are Nickel Metal Hydride (NiMH) and Nickel Cadmium (NiCd) batteries. LiPo (lithium polymer) batteries offer significant advantages over other types of batteries. The advantages that LiPo batteries offer over NiCd and NiMH batteries are:

-LiPo batteries have higher capacities which allows them to hold more power

-LiPo batteries have higher discharge rates allowing faster power transfer

-LiPo batteries are lighter and can be made in different shapes and sizes However, LiPo batteries also have some drawbacks. These include:

-LiPo batteries have a shorter lifespan of about 300 to 400 cycles, as compared to NiMH and NiCd batteries

-If the battery gets punctured and vents into the air, there is a possibility that this could result in a fire

-Some extra care needs to be taken when charging, discharging, or storing LiPo batteries.

(Chandrakanth, 2017)

Figure II_52: LiPo battery

Source: international journal of engineering and manufacturing science, 2017

II.3.7 – Propellers:

Propeller is a one kind of mechanical device which is also called rotors. This device is used for propelling a boat or aircraft which is consist of revolving shaft that can be two or more broad. Angel blades are attached to it. Most important purpose of rotors are to generate thrust and torque to keep the quadcopter fly and to manoeuvre. Propellers generates upward thrust force. This force is measured in pounds or grams. The upward thrust need to be equal to the weight of the quadcopter so that the quadcopter can fly at a hover. To get the right ratio of thrust and weight The TWR (thrust divided by weight) rule has been used which indicates how much thrust quadcopter can generate. TWR to be at least a value of two. (Das, 2019, p.39)

Figure II_53: propellers

Source: international journal of engineering and manufacturing science, 2017

II.3.8 – Flight board controller:

Flight controller used in quadcopter is the main functioning body of our aircraft. It’s a circuit board that that are equipped with sensors which senses any change in orientation. It can receive different commands sent by user to control speed of motors so that quadcopter could be stable in fly mode. Here we have used Arduino Uno as our flight controller board. ESCs and Flight Controller board work together in following ways:

• ESCs receive command from micro controller circuit board and further give command to the motors for rotation.

• FCB generates various commands for ESC and motors according to the need of user. The whole system is controlled by this controller board. (Das, 2019, p.43)

II.3.9 - Frame:

Just as important as good electronics, multi-rotors depend on sturdy, lightweight hulls for mounting components. There are countless frame designs of varying shapes, dimensions, and materials. Stiffer frames confer better flight characteristics, since less warping and bending can occur. If a frame is too brittle, though, your inevitable crashes will resulting more frequent repair sessions. Frames need to be both strong and stiff, whilst being light enough to hop around in the sky with ease. One of the most common materials for multi-rotor frames is carbon fibre. A great many of its physical properties are perfectly suited to the hobby. The only catch is that carbon fibre is known to block radio signals, which is obviously not ideal for a hobby that depends on multiple transmissions. It can be used though and is often. Just be aware that blocked signals are a possibility. Frames can also be built at home using aluminium or balsa sheet. But results will vary from manufactured frames, both aesthetically and in terms of flight attributes. (Chandrakanth, 2017)

II.3.10- Arms:

Arms can be built at home using aluminium or hard plastic tubing. However, for many hobbyists, it's preferable to go with pre-built arms. These components are relatively cheap and easy to replace. Therefore, they're generally considered a pre-determined breaking point. In the event of a crash, the arms should be the first to give, preventing damage to motors or expensive electronics on the frame. You actually want them to be a bit brittle, particularly on a heavier, crash-prone quad. (Chandrakanth, 2017)

Figure II_54: Arm

Source : Chandrakanth, 2017

Conclusion

So we have seen in this chapter all thing about Function of the quadcopter and his movement lows and forces (yaw pitch….)

Then we have seen the components and we have discussed each one independently and present their characteristics

In the next chapter will test each component like Arduino MPU605 the nRF24L01 and wire it together we need to calibrate this component and programming it after that all of this need to stabilisation using PID ,All of this we will talk about it one by one I the third chapter

CHAPTER III:

REALIZATION OF THE DRONE

Introduction:

This chapter presents two parts, the first (hard part) concerns the drilling, welding, frame assembly, mounting, fixing and wiring of components, design and so on, the second part (Soft part) concerns the programming. And finally will talk about the Hardships of this project and what we hope to developing in the future.

III.1 - Mounting the drone:

III.1.1 Wiring of the ESC:

Before using the ESCs, we must go through the calibration operation to balance and allow the motors to operate correctly (same speed of rotation).This operation is carried out by several methods, among which we have chosen that of programming through the Arduino serial port.

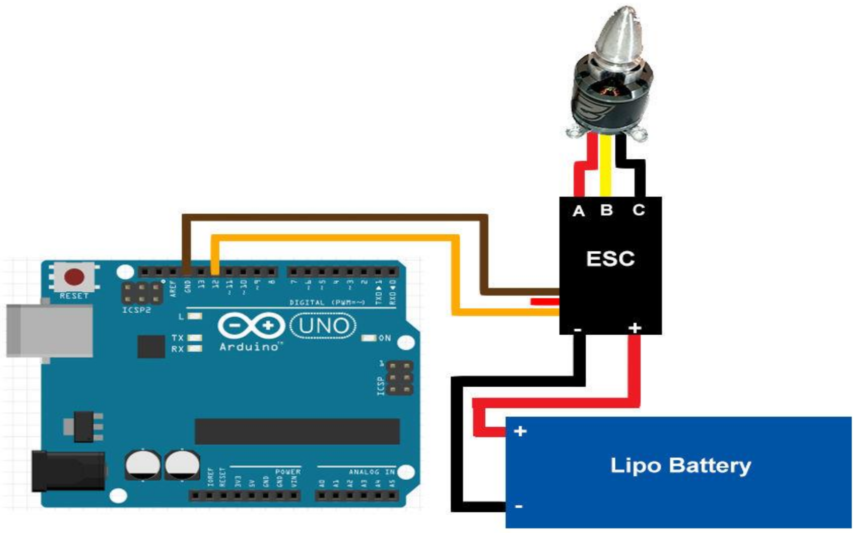


Figure III_55: assembling the ESC

Source: Author

We have talked about the rotation of the motors. Should change the wire to change the direction like the figure below. (See figure III_56).

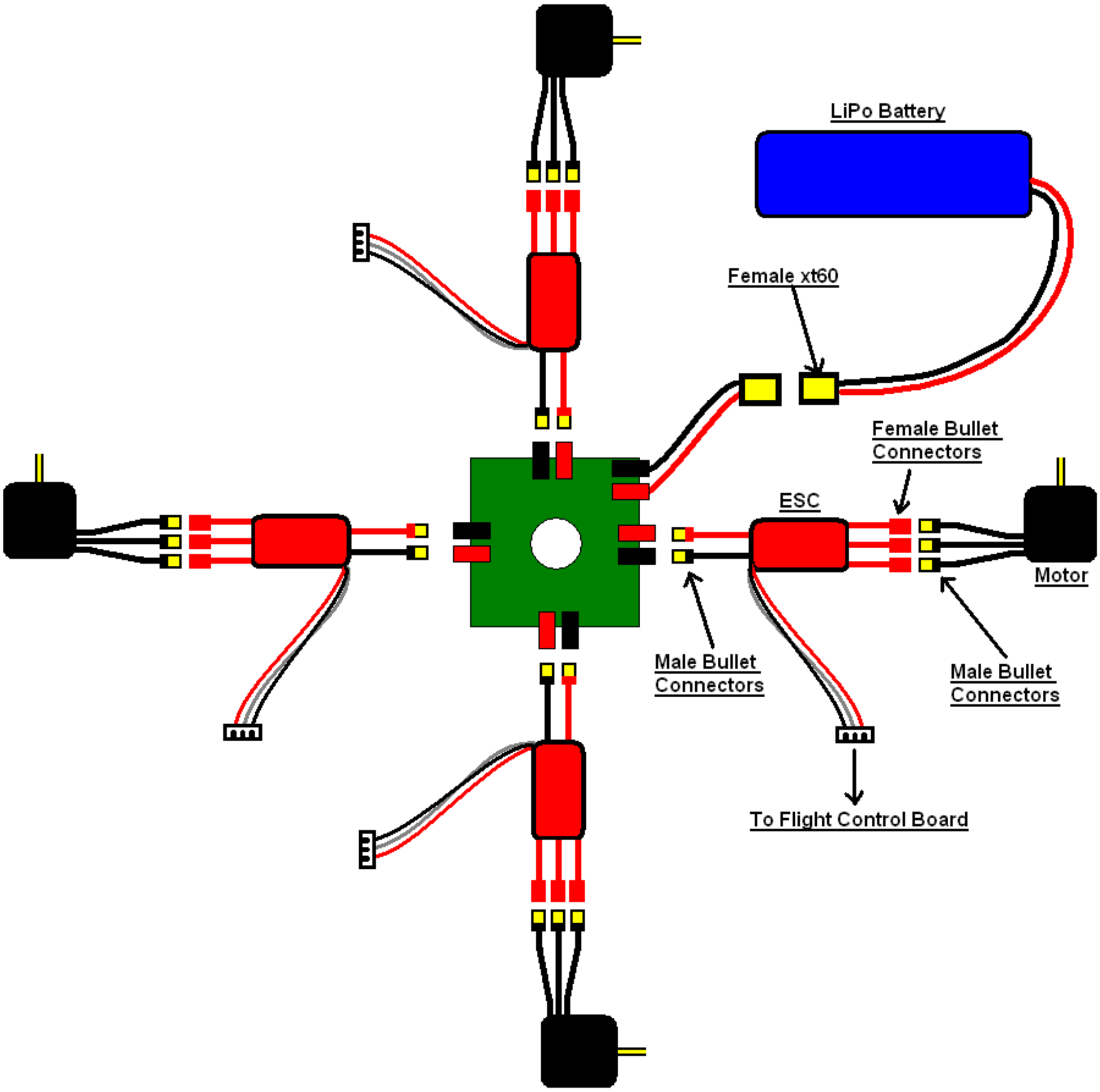


Figure III_56: wiring of motors and ESC to flame

Source: Author

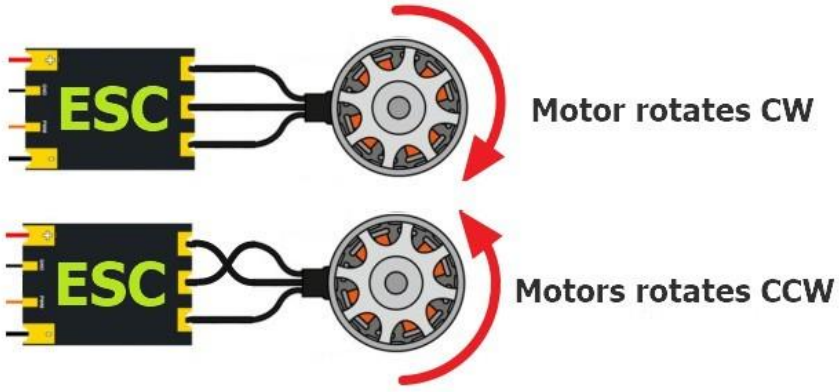


Figure III_57: Wiring ESC to Motors

Source: Author

III.1.2 - Calibration of the ESC:

Now that everything is setup, chances are that you motor might not rotate, or might rotate only forward, or might rotate only to 80% of the throttle (forward and reverse) and then stop: all these are symptoms of lack of calibration, or a calibration done with a different range of PWM signals.
More or less all ESCs have a similar calibration procedure:
Power up the ESC while the having maximum forward throttle applied. You'll hear a tone and some beeps and after a while (usually 2 seconds) you'll hear a confirmation tone and the led will blink a few times with a different color: this indicates that the ESC has measured the wavelength of max throttle.
At this point apply zero throttle (in a fwd. /reverse ESC this means full throttle reverse), wait again few seconds for the tones and led to blink: full reverse measured. Then move to central (only for fwd./reverse ESCs) and wait again for the tone and blinks. Have fun with the motors .Another possibility is that even after that procedure, the motor will not turn immediately in reverse, or will only go 50% of forward speed: that's because ESCs are programmable, and you can change many of their behaviours via either a programming card or via, again as with the calibration, hearing and decoding beeps and blinks.

```
#include<Servo.h>
ServomotA, motB, motC, motD;
char data;
voidsetup() {
Serial.begin(9600);
motA.attach(4, 1000, 2000);
motB.attach(5, 1000, 2000);
```

```
motC.attach(6, 1000, 2000);
motD.attach(7, 1000, 2000);

displayInstructions();
}
voidloop() {
if (Serial.available()) {
        data = Serial.read();

switch (data) {
// 0
case48 : Serial.println("Sending 0 throttle");
motA.write(0);
motB.write(0);
motC.write(0);
motD.write(0);
break;
// 1
case49 : Serial.println("Sending 180 throttle");
motA.write(180);
motB.write(180);
motC.write(180);
motD.write(180);
break;
// 2
case50 : Serial.print("Running test in 3");
delay(1000);
Serial.print(" 2");
delay(1000);
Serial.println(" 1...");
delay(1000);
test();
break;
        }
```

```
    }
}
voidtest()
{
for (inti=0; i<=180; i++) {
Serial.print("Speed = ");
Serial.println(i);
motA.write(i);
motB.write(i);
motC.write(i);
motD.write(i);
delay(200);
    }
Serial.println("STOP");
motA.write(0);
motB.write(0);
motC.write(0);
motD.write(0);
}
voiddisplayInstructions()
{
Serial.println("READY - PLEASE SEND INSTRUCTIONS AS FOLLOWING :");
Serial.println("\t0 : Sends 0 throttle");
Serial.println("\t1 : Sends 180 throttle");
Serial.println("\t2 : Runs test function\n");
}
```

III.1.3 - Wiring the MPU6050:

The MPU6050 module consists of 7 pins that are broken out: VCC, GND, SCL, SDA, XDA, XCL, ADO, and INT. You can use M/F jumper wires or 30 AWG wire wrap. Connect VCC and GND to +5Vdc and GND pins on the 4×26-pin female connector, respectively. We used pin A20 for +5Vdc and A21 for GND. Next, connect SCL and SDA to Uno pins A5 and A4, respectively. Finally, connect INT to pin 2 on the Uno. A wiring diagram is shown in the image below.

NOTE: The MPU6050 can be addressable at addresses 0x68 and 0x69 via the AD0 pin. If it is left unconnected, the I2C address will be 0x68, and if it is wired to VDD, the address will be 0x69. This is useful if you want to have two MPU6050s on the I2C bus.

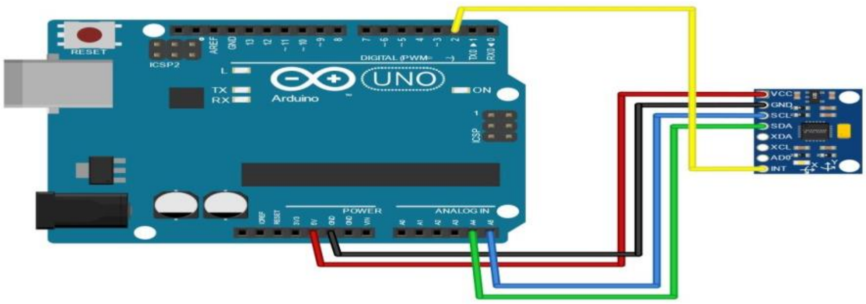


Figure III_58: Wiring MPU6050 to Arduino Uno

Source: Author

III.1.4 - Test of the MPU6050:

The MPU6050 is working perfectly and we have get the data in the serial monitor as we see in figure bellow

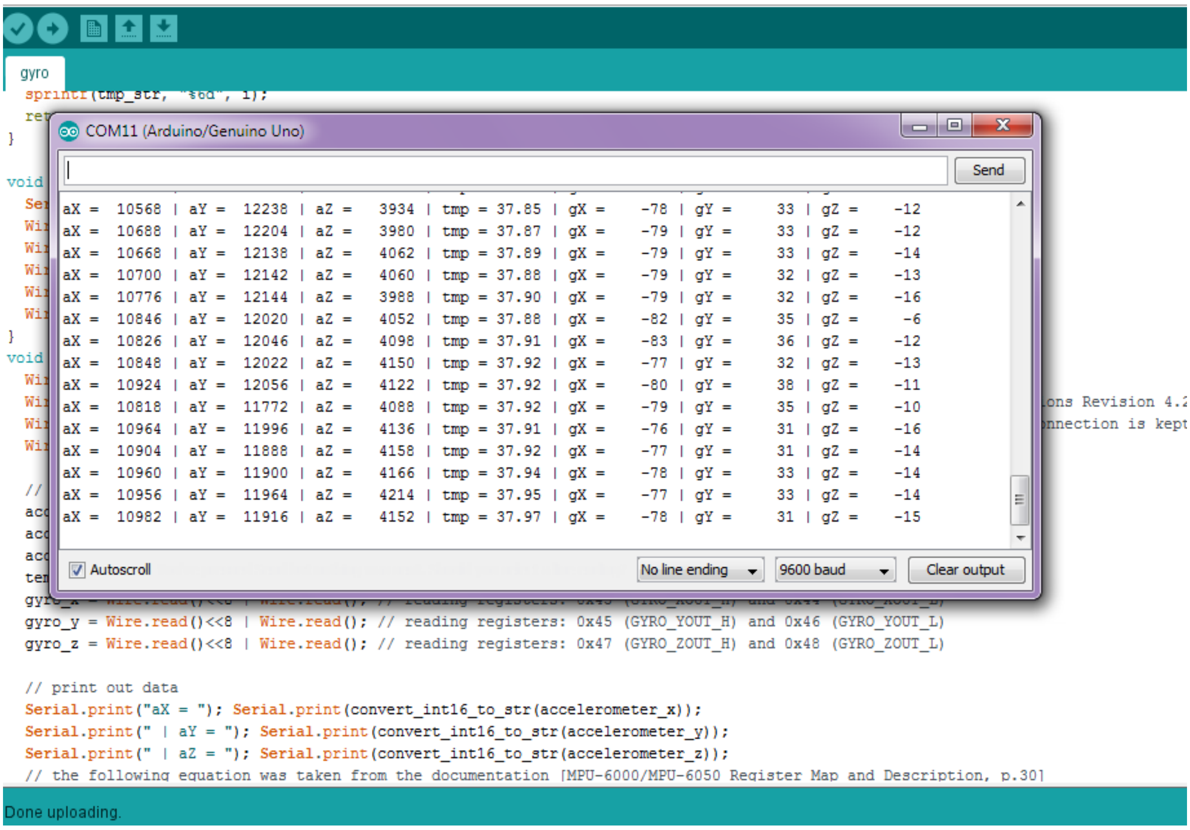


Figure III_59: Test of MPU6050

Source: Author

III.1.5 - Wiring the NRF:

To connect the nrf24l01+ to an Arduino, there are very specific pins that are required. This is due to the serial communications that are required. Fortunately, most of the serial is abstracted away during code, but the following pins must be hooked up to the same pins on your Arduino; MOSI, SCK and MISO. Vcc and Gnd are connected to 3.3v and ground, CE and CSN can be attached to any pin (we will default to 9 and 10 respectively) and IRQ is not used when communicating with Arduinos. We will be using an Arduino Uno, so the pins we connect will be based on that A wiring diagram is shown in the image below.

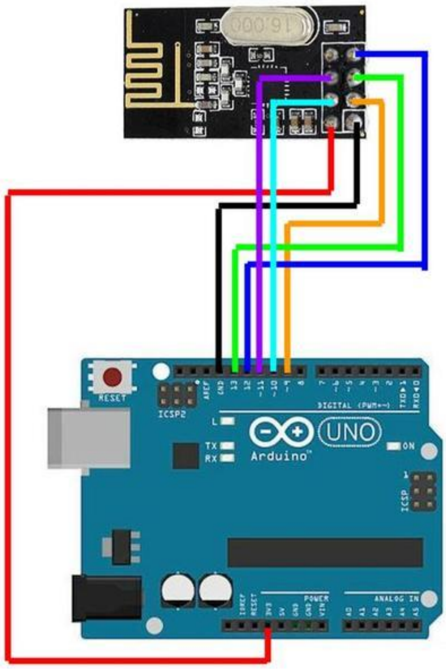


Figure III_60: wiring of nrf24l01with Arduino

Source: Author

To test it, simply set up two different Arduino's with nrf24l01 and run the pin pair code found in the github repository. And I use two different computers to read the different serial lines, and if done right one should be pinging and one should be ponging. (One of the Arduinos should have their 7th pin ground to set it to a different mode than the other one).

III.2 - Hand Gesture Controlled Drone:

III.2.1 - Hard Part:

So we going to build a **gesture-controlled Of Drone using Arduino**, MPU6050 Accelerometer, nRF24L01 Transceiver pair, we will design this Drone into two parts. One is the Transmitter, and the other is the Receiver. Transmitter section consists of an Arduino Uno, MPU6050 Accelerometer and Gyroscope, and nRF24L01 while the Receiver section consists of an Arduino Uno, nRF24L01, For

Brushless motors and ESC. The transmitter will act as remote to control the Drone where the Drone will move according to the gestures

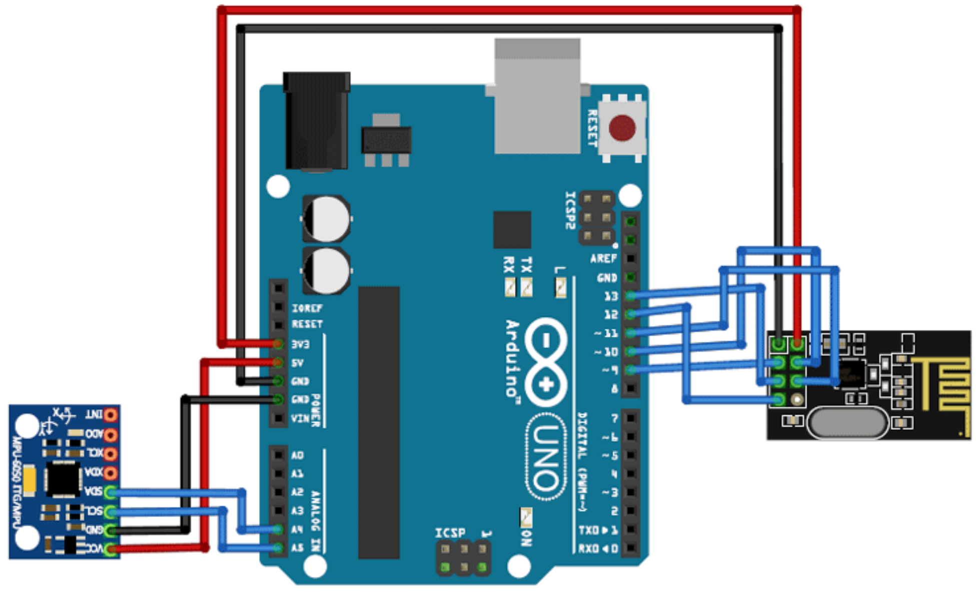


Figure III_61: wiring of hand gesture

Source: Author

The MPU6050 Accelerometer sensor reads the X Y Z coordinates and sends the coordinates to the Arduino. For this project, we need only X and Y coordinates. Arduino then checks the values of coordinates and sends the data to the NRF Transmitter. The transmitted data is received by the NRF Receiver. The receiver sends the data to the receiver side's Arduino. Arduino passes the data to the ESC and ESC turns the motors in the required direction.

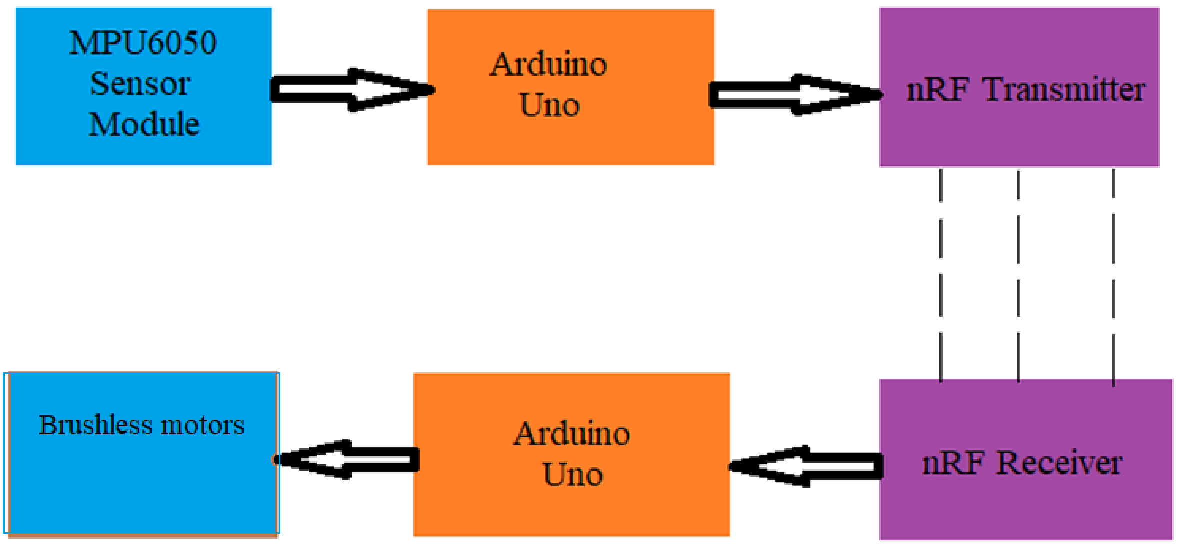


Figure III_62: diagram of Hand Gesture Controller

Source: Author

III.2.2 - Programing Part:

In this program, Arduino reads the data from MPU6050 and sends it to NRF 24L01 transmitter.

Begin the program by adding the required library files given bellow.

SPI.h

NRF24L01.h

Wire.h

MPU6050.h

```
#include <SPI.h>
#include <nRF24L01.h>
#include <RF24.h>
#include "Wire.h"
#include "I2Cdev.h"
#include "MPU6050.h"
```

And we need to define the Radio pipe addresses for the communication and nRF transmitters CN and CSN pins.

```
Const uint64_t pipeOut = 0xE8E8F0F0E1LL;
RF24 radio (9, 10);
```

Inside the void setup function, begin the serial monitor. And also initialize the wire and radio communication. Radio. Set Data Rate is used to set the data transmission rate.

```
void setup()
{
Serial.begin(9600);
Wire.begin();
mpu.initialize();
radio.begin();
radio.setAutoAck(false);
radio.setDataRate(RF24_250KBPS);
radio.openWritingPipe(pipeOut);
```

```
}
```

Read the MPU6050 sensor data.

```
mpu.getMotion6(&ax, &ay, &az, &gx, &gy, &gz);

data.X = map(ax, -17000, 17000, 0, 255 );

data.Y = map(ay, -17000, 17000, 0, 255);
```

Finally, transmit the sensor data using radio. Write function.

```
radio.write(&data, sizeof(MyData));
```

Now we need to test it using multiwii software platform :

Figure III_63: Test of the Hand Gesture

Source: Author

The hand Gesture that we made is working perfectly .the MPU 6050 is doing well and the data was sent to receiver via nRF24L01 successfully.

III.3 - Quadcopter Flowchart:

The operation flow of the quadcopter is illustrated in figure below demonstrating steps at which quadcopter flows in order to fly and satisfy pilot commands

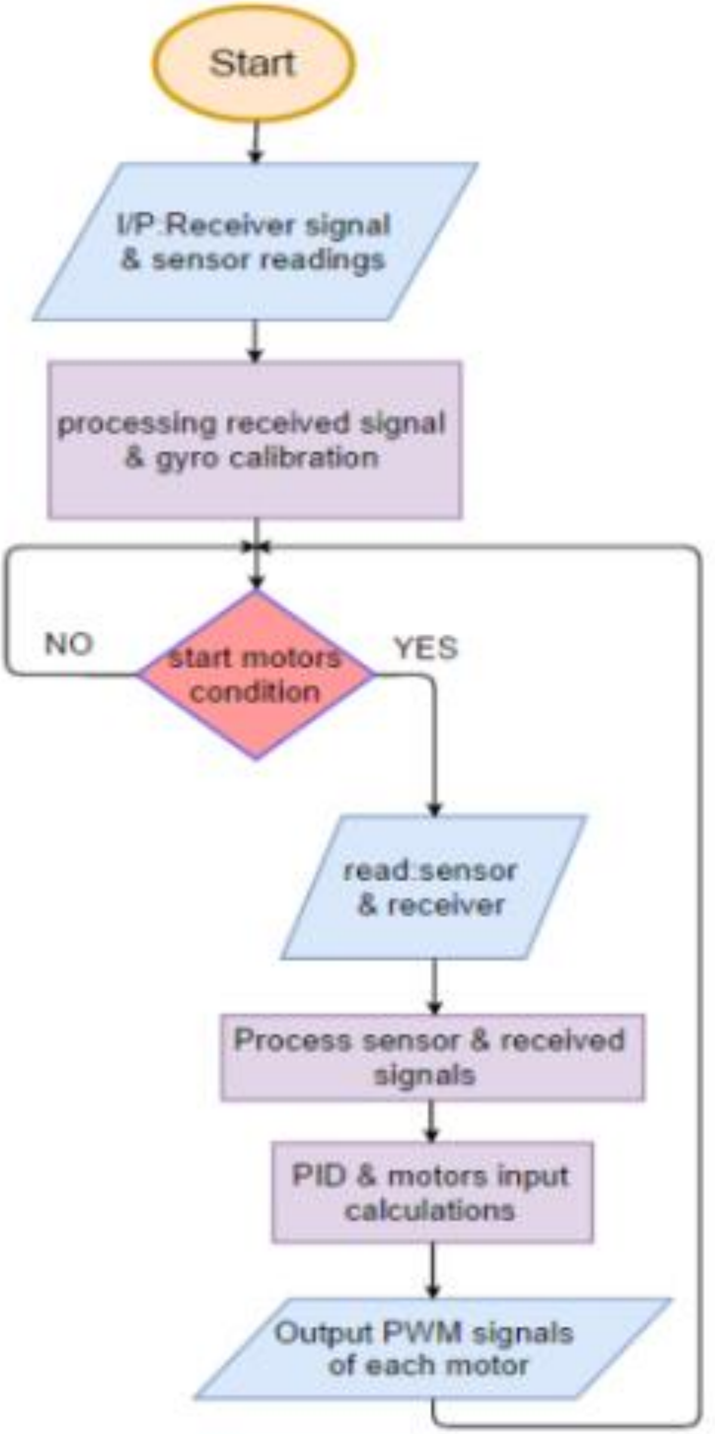


Figure III_64: Quadcopter flow chart

Source: Author

III.4 - PID (Proportional Integral Derivative) controller:

Most quadcopter software including allows users to adjust PID values to improve flight performance. In this post I will try to explain what PID is, how it affects stability and handling of a drone, and also share some tips on how to tune PID.

III.4.1 -What Is PID in a Quadcopter?

PID stands for Proportional, Integral, and Derivative, it's a part of a flight controller software that reads the data from sensors and calculates how fast the motors should spin in order to retain the desired rotation speed of the aircraft.

The goal of the PID controller is to correct the "error", the difference between a measured value (gyro sensor measurement), and a desired set-point (the desired rotation speed). The "error" can be minimized by adjusting the control inputs in every loop, which is the speed of the motors.

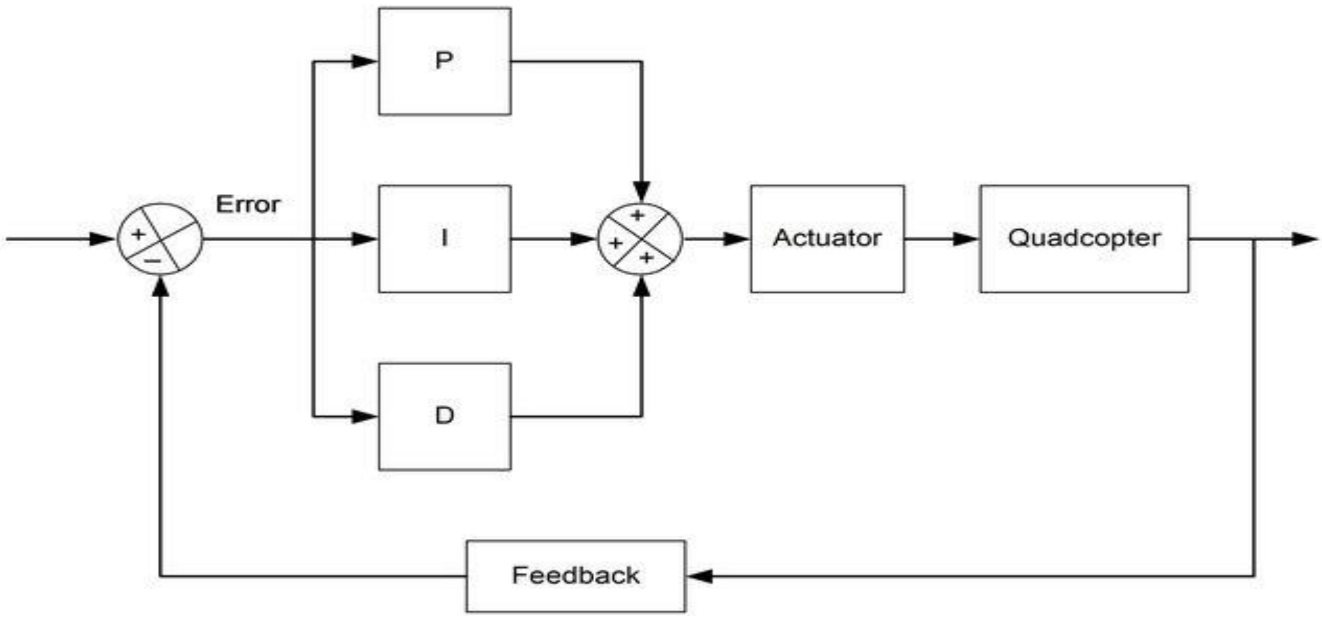


Figure III_65: PID controller diagram

Source: Author

There are 3 values in a PID controller, they are the P term, I term, and D term:

- "P" looks at present error – the further it is from the set-point, the harder it pushes.
- "D" is a prediction of future errors – it looks at how fast you are approaching a set-point and counteracts P when it is getting close to minimize overshoot.
- "I" is the accumulation of past errors, it looks at forces that happen over time; for example if a quad constantly drifts away from a set-point due to wind, it will spool up motors to counteract it.

III.4.2 – Proportional:

The proportional term is obtained very simply by multiplying the error by a constant named "proportional gain". The greater the gain is, the greater the response speed is, but it may be unstable. The smaller the gain is, the more the response speed is "soft" and likely to be ineffective. It is important to find a good intermediate between these two extremes.

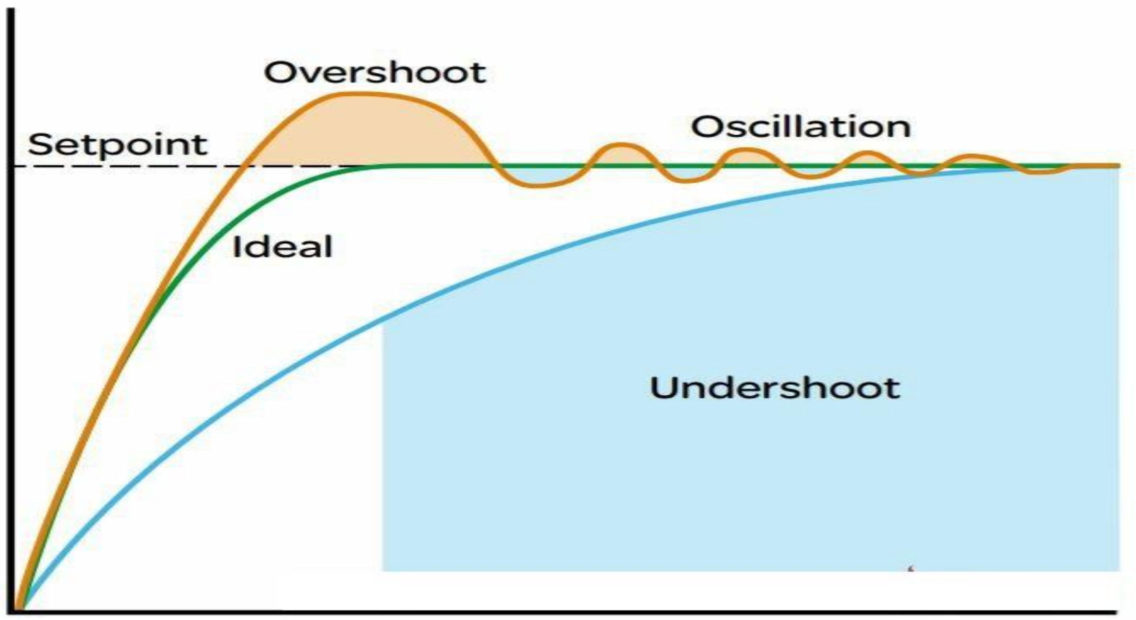


Figure III_66: diagram of PID tuning

Source: Author

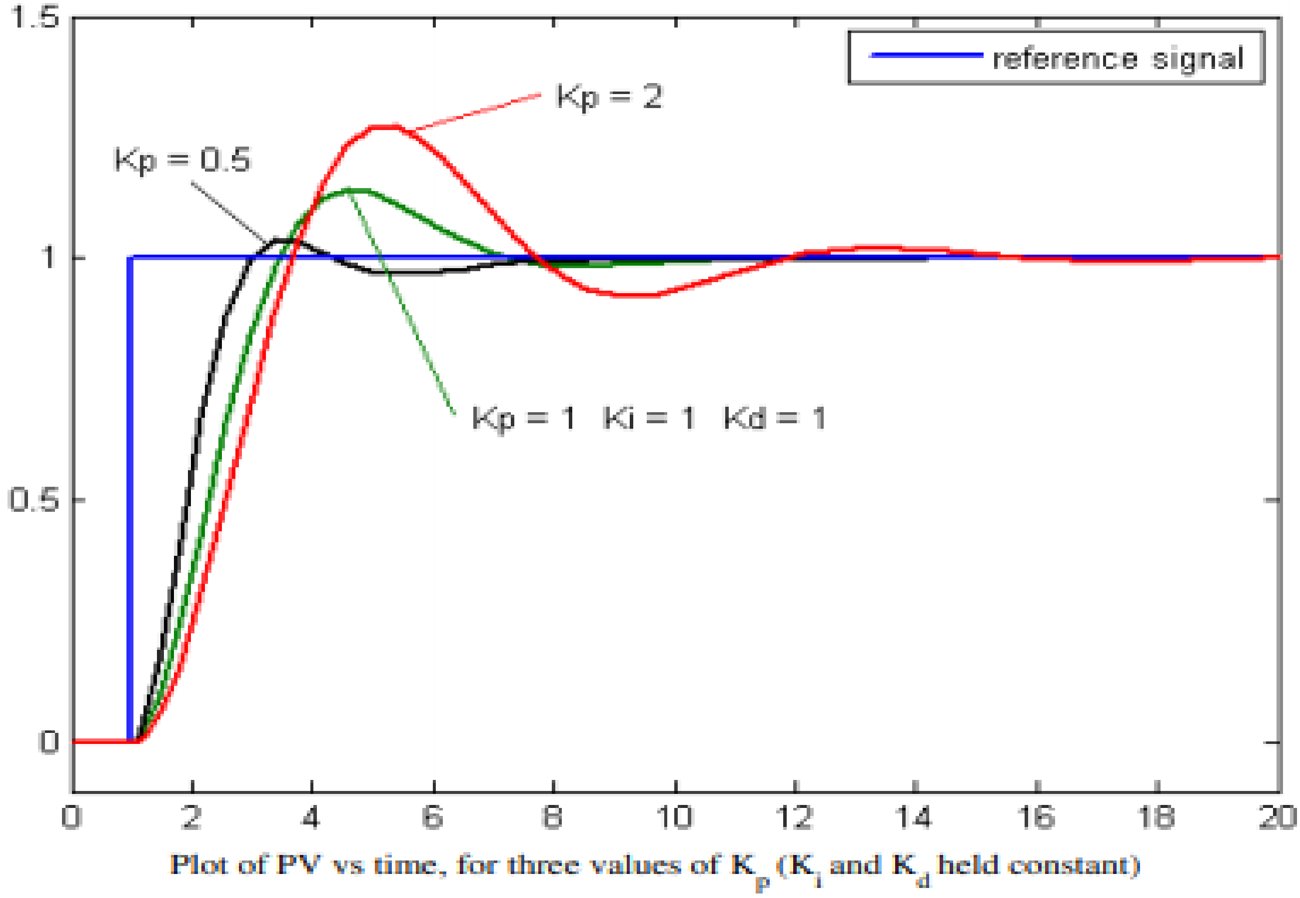


Figure III_67: the diagram of PID

Source: Author

Here we can see that a proportional gain (Kp) that is too large results in a significant overshoot of the desired angle (the blue reference signal).

III.4.3 – Integral:

Unlike a simple proportional control system, the PID controller takes into account the history of angular errors. For this, the integral term is introduced, it is the sum of all the errors accumulated over time multiplied by a constant, the “integral gain” Ki.

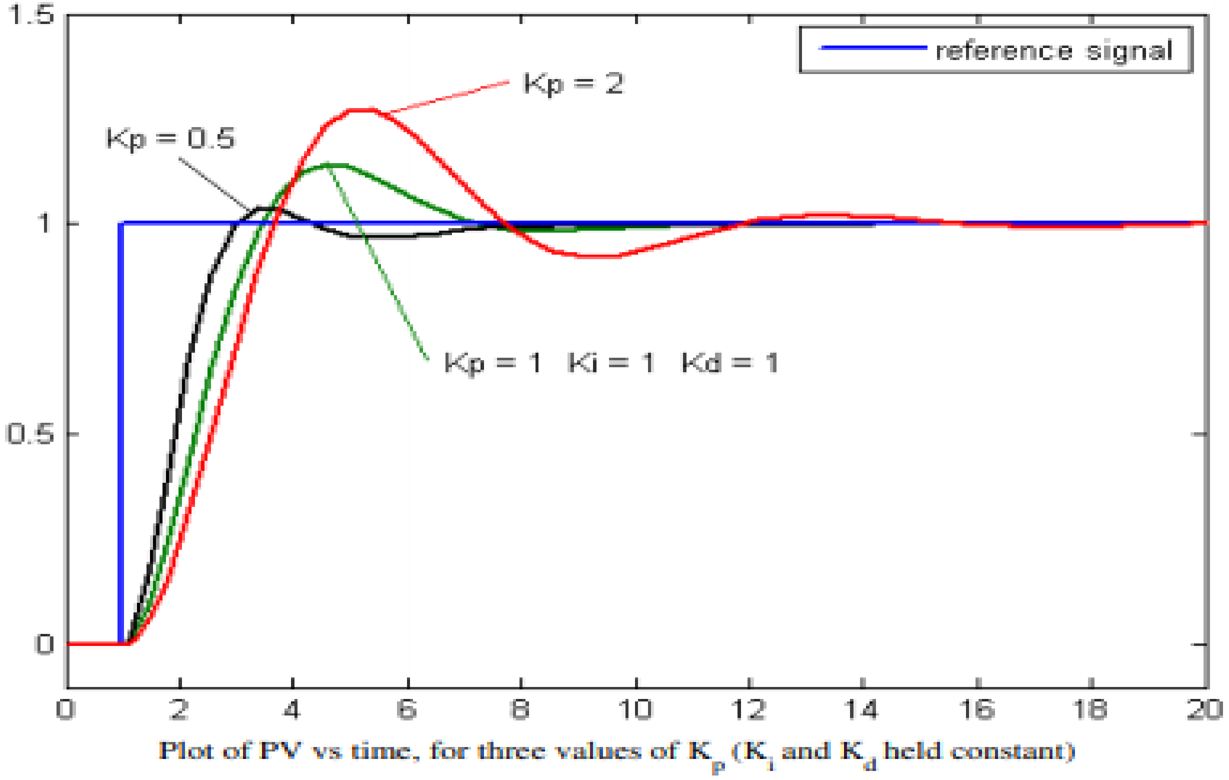


Figure III_68: PID controller diagram Integral (I)

Source: Author

The integral gain directly affects the height (and therefore the number) of the target value overshoots. Too low gain is problematic in certain situations such as when the wind is too strong. However a too high gain causes an oscillation around the desired angle.

III.4.4 – Derivative:

The derivative term is sometimes called "accelerator" since it can compress the response time. It is obtained by subtracting the current and previous errors multiplied by the derivative gain. This term, however, is to be taken lightly because it is very sensitive to data noise.

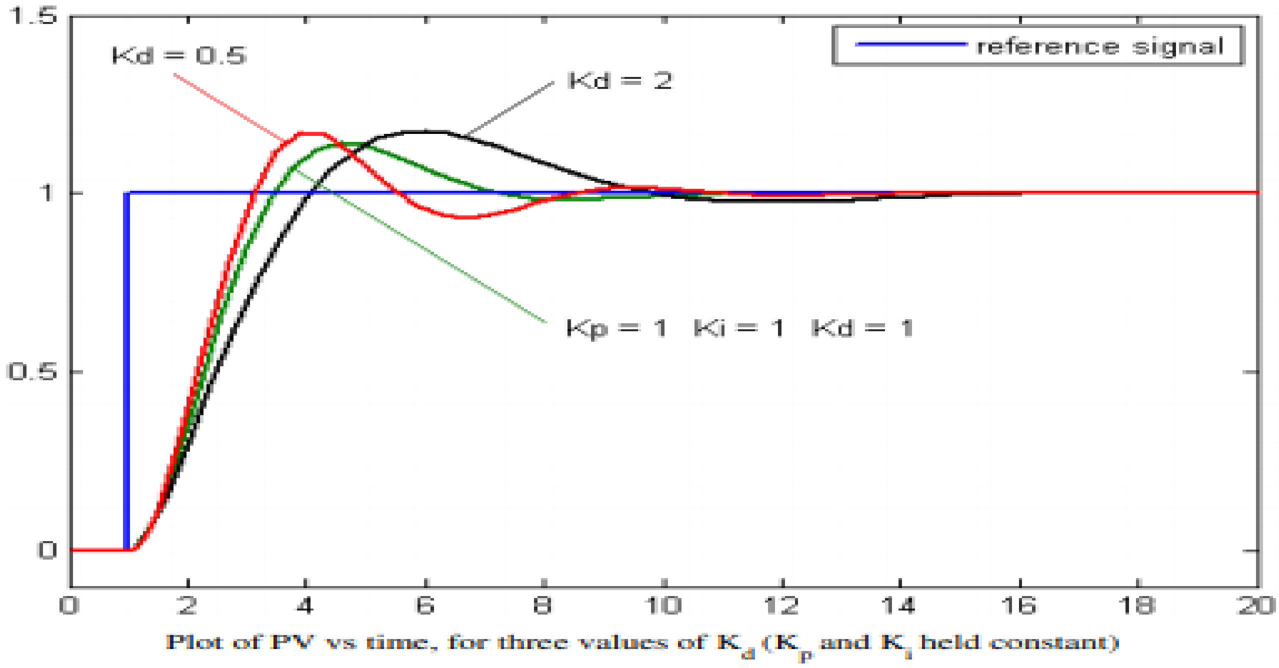


Figure III_69: controller diagram derivative

Source: Author

Once the code of the PID controller implemented it is to determine the three gains of each controller. As every quadcopter has special features, there is no universal PID constants, however the determination of these values is not random either.

First, it should be noted that a rapid determination method, called “Ziegler and Nichols method” exists and provides correct Ki and Kd from the only value of Kp. The gains can then be adjusted more precisely based on parameters seen above.

Moreover, a quadcopter (unlike a tricopter of Hexacopter) is almost symmetrical, so the pitch and roll PID’s gains should be similar.

Finally, it is important to note that for security reasons the testing of these PIDs is never done in real conditions outside. By firmly hanging the quadcopter to a bar parallel to an axis of rotation, we are able to block the rotation of the other angles and work on one PID at a time.

III.4.5 - PID controller algorithm:

So here we have the PID controller algorithm written out on the Arduino IDE.

Double sensed output, control signal;

Double set point;

Double Kp; //proportional gain

Double Ki; //integral gain

Double Kd; //derivative gain

```
int T; //sample time in milliseconds (ms)
Unsigned long last time;
Double total error, last error;
int max_control;
int max_control;
Void setup ()
Void loop ()
PID_Control (); //calls the PID function every T interval and outputs a control signal
void PID_Control()
unsigned long current time = millis(); //returns the number of milliseconds passed since the Arduino started running the program
int delta time = current time - last time; //delta time interval
if (delta time >= T){
double error = set point - sensed output;
total error += error; //accumulates the error - integral term
if (total error >= max_control) total error = max_control;
else if (total error <= max_control) total error = max_control;
double delta error = error - last error; //difference of error for derivative term
control signal = Kp*error + (Ki*T)*total error + (Kd/T)*delta error; //PID control compute
if (control signal >= max_control) control signal = max_control;
else if (control signal <= max_control) control signal = max_control;
last error = error;
last time = current time;
```

Now proceed to explain the code line by line. So first we start off by defining a variables needed for the computation. And you'll notice most of these are of the double data type or floating point. This is needed because it allows more precise computation. Now just to make things easier I kept the computation of the control signal in a separate function called the control. Now in order to make sure that we get a uniform interval of sample time t we first start off by storing the current time the program has been running by using a built in function in Arduino IDE called Millies. This function essentially gives you the number of milliseconds passed since the start of the program. We can keep track of the current time we can compute the delta time by subtracting the current time from the previous time now to get the updated control signal every t seconds.

We have an IF condition whereby if the time interval during the loop equals or exceeds t the control signal is computed and updated. This if condition is what allows the controller to get called FBT seconds and it makes realizing the controller a lot easier. Our error term is simply the set point minus the sensed output the total error refers to the integral term of accumulating the error. Every t seconds the Delta error refers to the derivative term whereas just a current error minus the last error. So what those values are computed and obtain and we can sum them up to form our control signal. And you can see here that the summation is pretty much the same as shown in the discrete expression. So what's the control signals computed. We actually store the error as last error for the next iteration. And the same goes for the time. This pretty much covers how the control algorithm is implemented or on the order.

III.5 - Results and Discussion:

The results that will be discussed in this chapter will include notice of unnatural behaviour by the quadcopter during construction and after unnatural here is defined as any error or fault that can endanger the safety of the quadcopter.

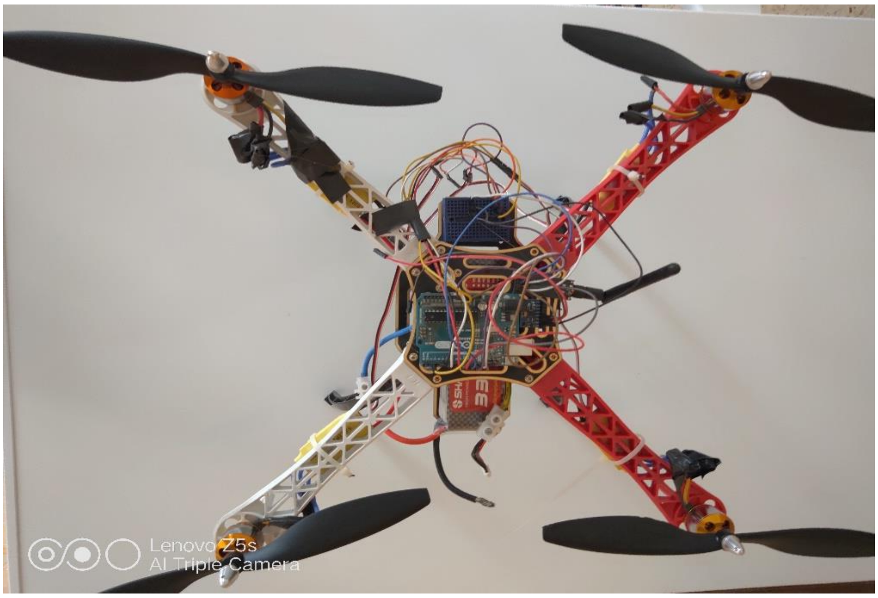


Figure III_70: main quadcopter

Source : Author

It has been noticed that the motors had a variation of speed resulting from the ESCs; the voltage supplied from the battery to the ESCs- with only the battery connected to the ESCs without any software code or even Arduino connected- vary from one ESC to the other, this was resolved by ESC calibration meaning all ESCs start the motors at the same time with the same speed on the condition that all ESCs has the same current rating, if the ESCs had different current rating overheat will if the rating of ESC is less than the others due because it will try to compensate the difference by operating the motor at a higher speed.

A high vibration was clearly noticed in the propellers that was perceived at first to be a vibration problem so the propeller was re-mounted at the center of the propeller shaft and a square piece of duct tape was added to them as load to reduce vibration which reduced the vibration to a minimal value measured by computer code implemented to the quadcopter (Appendix-X).

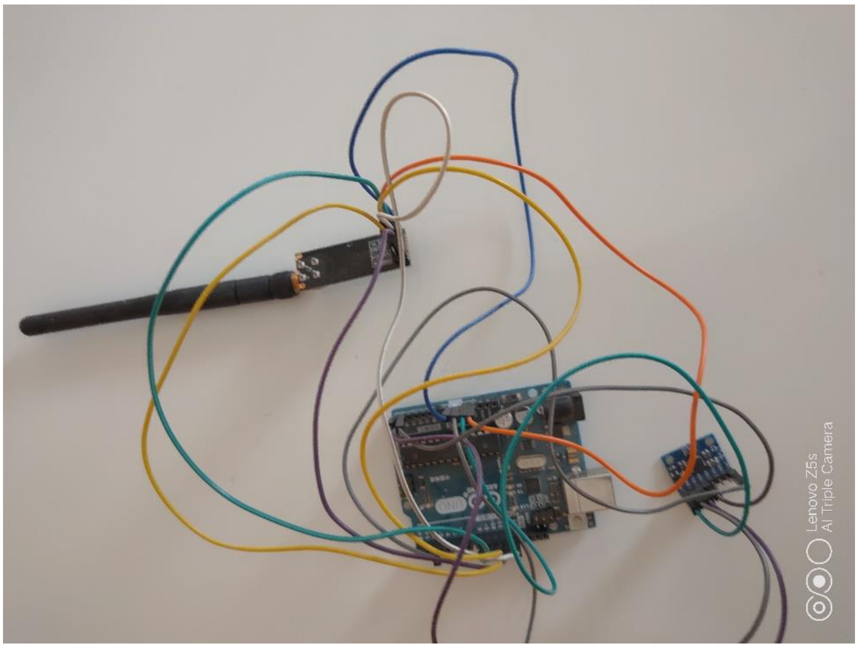


Figure III_71: the hand gesture

Source: Author

The hand gesture is working nice the MPU was calibred and tested many times using multiwii softwar platform and the nRF24L01 transmiting the data to reciever nRF24L01 on the quadcopter sucessfuly but for best control with hand gesture we should use the arduino nano it smale and more easy to take it with hand

The trial and error method in choosing the PID parameters that result in the stability of the quadcopter; the ease of control was noticed in the quadcopter however a negative roll angle kept occurring however a successful flight time of 53 seconds was recorded in the process of finding the suitable PID gains for a stable flight without any drifts.

Conclusion

The research phase of the thesis aided in understanding the mathematical model of the quadcopter which a step is required before control and a background of the PID controller and its operation theory in order to transform its equations to equations that are applicable to the quadcopter and were implemented in the Arduino microcontroller.

The choice of the unity software was made upon the fact that it provided an environment with no limitation on executing and constructing a PID controller with code based on its basic equations and theory of operation. The research phase of the thesis aided in understanding the mathematical model of the Quadcopter which is a step required before control and a background of the PID controller and its operation theory in order to transform its equations to equations that are applicable to the quadcopter and were implemented in the Arduino microcontroller.

The choice of the unity software was made upon the fact that it provided an environment with no limitation on executing and constructing a PID controller with code based on its basic equations and theory of operation.

Hand gesture controller with radio transceiver is very useful in wide area and high-speed data transmitting.

We have been faced a lot of difficulties such as pandemic of corona virus, broken of MPU6050 the NRF24L01 Stop working cause of high voltage and more problems in the Arduino .

In conclusion the construction of the circuit that connected the hardware components and implementation of the software was the initial work however troubleshooting and tuning the PID gains was challenging and the trial and error method proved to be a failure in choosing the proper PID parameters that provide stable flight without any offsets or deviations, now all the hand the gesture and the drone transmit and receive the data and it work normally.

General Conclusion

General conclusion

With the growth in interest in UAVs, the growth in landing and vertical take-off (VTOL) and the need for discreet instrumentation and above all quadcopter has enjoyed great popularity in recent years. This the main motivation for this research. The main objective of the work was to adopt a mathematical model of minimal complexity and to have flight control laws that ensure the stability of a quadcopter, to then apply this ordering law on a practical model. The purpose of the first chapter was to present a state of the art on drones and their different types, among these types we relied precisely on quadcopters, their advantages and application areas. Then in the second chapter we have begun modelling the quadcopter which is an essential step in understanding the laws of physics that govern our system.

The exploitation of the mathematical model that defines the dynamics of the quadcopter, allows us to deduce the state model. Then we were interested in identifying the parameters of the quadcopter so that we could control the different movements using the technique.

Finally, in the third chapter we have seen how to wire of the component of the quadcopter, and we test each component a lone Then we have assembling the hand gesture and programing it and testing it, its work perfectly we have chosen the multiwi platform to see his movement. ID. In the last part, we chose the necessary components for the construction of our quadcopter, the implementation of the PID command on the drone is made by the Arduino Uno elementary map. This card significantly reduces the cost of the application. It doesn't perform as well as a card professional flight but still provided satisfactory results.

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