Design of an Innovative Flight Controller for Quadcopter Robust Handling

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Abstract— **This senior thesis concerns the design and implementation of a quadcopter, which can be navigated from a remote controller. The basic aim of this construction is the development of an unmanned vehicle (quadcopter) equipped with a fully functioned flight control device, which is consisted of an Arduino board and is programmed in C++. There will be also references about the advantages and disadvantages of the quadcopters, further analysis about their operating behavior and also at the individual components I used to implement the quadcopter.**

Keywords—Quadcopter; Arduino;MRAV;Stability control; Drones;

I. INTRODUCTION

Multi-speed air vehicles are known as Multirotor Aerial Vehicles (MRAV) or in one word Multicopters. The general category of vehicles to which it belongs are the rotorcrafts which need one or more swinging wings to produce the necessary boost for buoyancy. The official name for such unmanned vehicles is RUAV (Rotorcraft Unmanned Aerial Vehicles). The RUAVs have a little autonomy in their navigation, because they have an electronic control circuit. But when they are fully autonomous and can navigate without human intervention they are called RUAS (Rotorcraft Unmanned Aerial System). Multirotors are therefore a RUAV with the characteristic that they carry more than two propellers. The control of their movement is achieved by altering the relative speed of rotation between the propellers. However, since this control is quite complicated, it takes on a built-in microcontroller on MRAV, which, with multiple measurements from suitable sensors, manages to stabilize it. The MRAVs typically have three props (trirotor or tricopter), four pros (quadrotor or quadcopter), six pros (hexarotor or hexacopter,) eight props (octorotor oroctocopter).

An Unmanned Aerial Vehicle (UAV) is an aircraft without direct operator manipulation. The flights are either autonomous or controlled via microcomputers, which are inside the aircraft or on the controller. The UAVs are flown by pilots through a controller, but the self-controlling systems are increasingly used with time. The UAVs have been developed primarily for military applications, but there is a gradual increase in their use in civilian applications such as firefighting missions and civilian security, for example in the surveillance of the pipeline of a large facility. Finally, UAVs can be used in search and rescue missions, essentially helping to find missing or trapped people in inaccessible places.
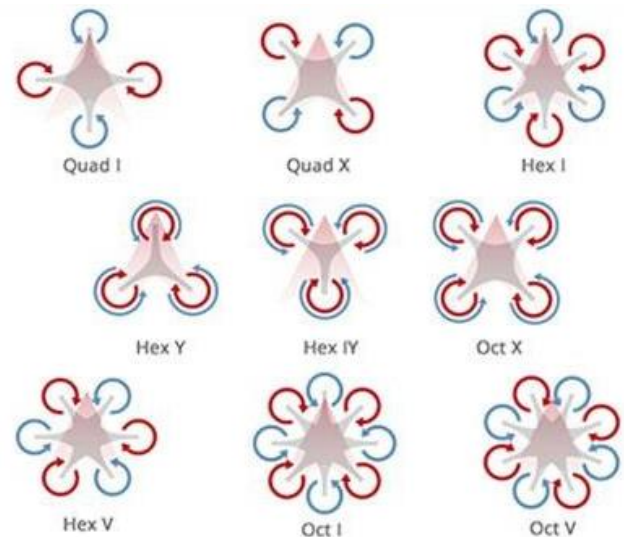

Fig. 1. Multicopters types

Apart from the many advantages offered by your constructions, we have to overcome some drawbacks too. The most important disadvantage is that all sensors produce noise, so their measurements are not so accurate. There is also increased power consumption because of the many motors they have, so expensive batteries are required, otherwise their autonomy is limited. Another problem is the need to use a camera when it is placed in spaces that are not in the pilot's field of vision, which is a burden on the flight time. Additionally, using a camera there might be violations on human rights and privacy.

II. THE QUADCOPTER

At this point, it is necessary to present the basic construction of the quadcopter as well as the way in which it manages and performs its various maneuvers. The quadcopter is a type of helicopter that uses only four propellers, of equal diameter, for lifting and advancing it. These four props are positioned symmetrically on a cross-shaped skeleton, while at the center of the frame there is the payload. Those props are rotated every two vice versa so that the total torque applied to the drone is zero.

Specifically, the front left and rear right rotate clockwise, while the front right and rear left, counterclockwise, as shown in the figure.

Fig. 2.   Quadcopter's front and rear propelers

The movement of the quadcopter helicopter is exclusively controlled by the angular velocities of its four propellers. When his four wires move at exactly the same angular velocity, then the quadcopter is lifted. At the same time its slope is kept constant while it does not rotate around its center of mass because it is completely symmetrical.
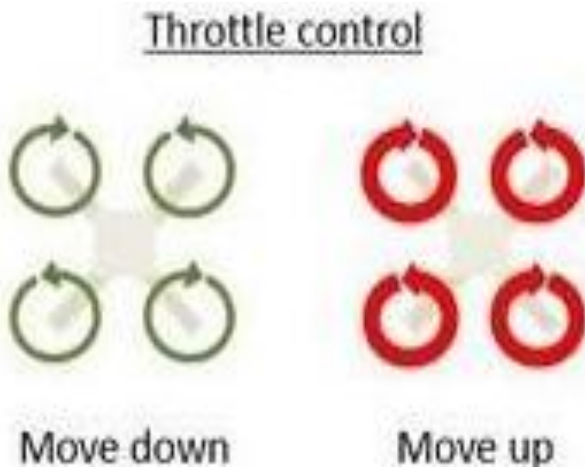

Fig. 3.   Quadcopter's throttle control -

To achieve rotation of the quadcopter around its center of mass, the speed of two identical rotating motors are needs to be varied. When the speed of a motor changes, then its torque changes according to the characteristic torque of the motor-load (load we consider the propeller of the motor). Because, however, due to Newton's third law, the engine rotor torque is equal to the stator torque time, the variation in engine torque is equivalent to a variation in torque that the base receives from the engine. Therefore, the base tends to rotate around its vertical axis when the moments of the four motors are unbalanced. These torques, due to the fact that they are due to air resistance, are also referred to as drag moments. Below it is shown that the quadcopter is rotated about its vertical axis. The clockwise and left-hand rotation are shown.
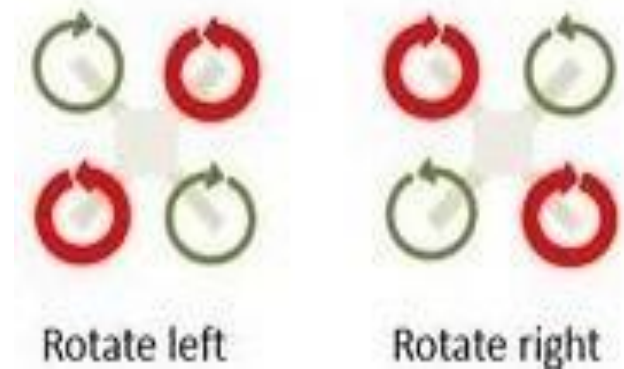

Fig. 4.   Quadcopter's yaw control

The parallel propulsion of the quadcopter is achieved when the quadcopter starting to tilt. This happens when two motors, on the same side, have less speed than the other two. The movement in the horizontal component is shown below.

Fig. 5.   Quadcopter's pitch control

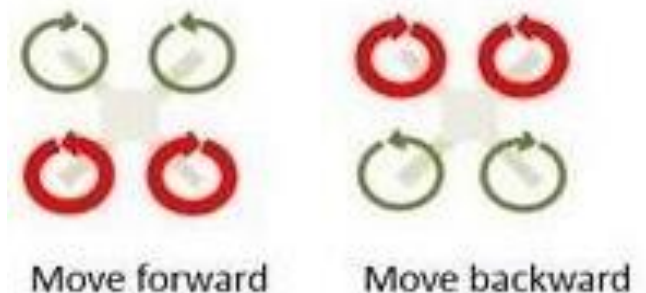While the movement on the vertical axis is shown below.

Fig. 6. Quadcopter's pitch control

III.   QUADCOPTER ACCESORIES

For the construction of the quadcopter, standardized items were purchased from aeromodelling and electronics stores. Their placement was not simple as it had to be done in such a way that the quadcopter was completely symmetrical to the horizontal and vertical axes, and its

center of gravity had to be exactly at the intersection of these axes. The basic elements of this drone are:

A.   • *Model F450 frame*

Fig. 7.   Quadcopter's F450 frame

The base of this frame is made of low weight aluminum and has two parts, the bottom with dimensions 18cm x 11.8cm and the top with dimensions 10.5cm x 10.5cm.

Each of the four legs is made of high-mechanical machined plastic with dimensions of 21.5cm. The legs are screwed together with M3 x 6mm at the bottom and top of the base.

B.   •*980KV EMAX XA2212 Motors*

Fig. 8.   Quadcopter's Emax XA2212 motor

For propeller movement, brushless outrunner DC motors are used for increased performance. They are 4.3cm x 2.7cm. They consist of fourteen poles and include permanent neodymium magnets for high performance. Their outrunner designation indicates that the runner, the moving part of the motor, is the outside and not the interior.

C.   • *30A EMAX Simonk Electric Speed Controllers*

Fig. 9.   Quadcopter's

They are necessary to convert the DC battery to AC to power the motors. They contain a microcontroller as well as a security system for high current values. The selected controllers are designed for a maximum current of 30A.

D.   *Arduino Uno microcontroller board*

Fig. 10. Arduino Uno

The Arduino Uno includes the quad-core microcontroller, ATMega328P. This microcontroller works at 16 MHz, has 32KB Flash Memory for programming. The 31 input pins can be used either as general purpose input ports, or for communication of peripheral systems with the external environment. It is also positioned just above the Arduino Uno an Arduino Shield, to reduce the cable connections that have been made.

E.   *Three-axis angular speed sensor L3GD20H*

Fig. 11. L3GD20H, 3-axix angular speed sensor

It is an electronic device that perceives the angular velocity of the quadricycle. This is done with vibration sensors, which are used to detect angular velocity and are applied to a vibrating element. These sensors provide stability by detecting motion caused by various vibrations.

F. Lithium battery 2200MAh at 11.1Volts

Fig. 12. Quadcopter's lithium battery

The rechargeable lithium polymer battery provides higher energy than other types of lithium batteries and is used in applications where weight is a critical feature. This battery has 3 cells with a capacity of 2200mAh and fully charged provides 11.1Volts.

G. Propellers (4 pieces) of 8x4.5

Fig. 13. Quadcopter's propellers

Propellers are always categorized according to length and pitch. When we talk about a step, we mean the distance traveled by a drone to a single rotation of the propeller. In particular, 8x4.5 props are used here, this means the length is 8 inches while the pitch is 4.5.

H. RadioLink Receiver R7EH-S and RadioLink T6EHP-E Transmitter-Controller

Fig. 14. Quadcopter's RadioLink receiver

These are the basic elements of our communications equipment with the quadriceps. Our receiver has seven channels of communication, with a maximum power supply of 6Volts and a working current of 19-25mA. On the other hand, the control we use has six channels of 2.4GHz.

I. • Other accessories

In addition to the basic components, we are also using two 1KΩ and 1.5KΩ resistors, one 1N4001 diode and one 330Ω LED light.

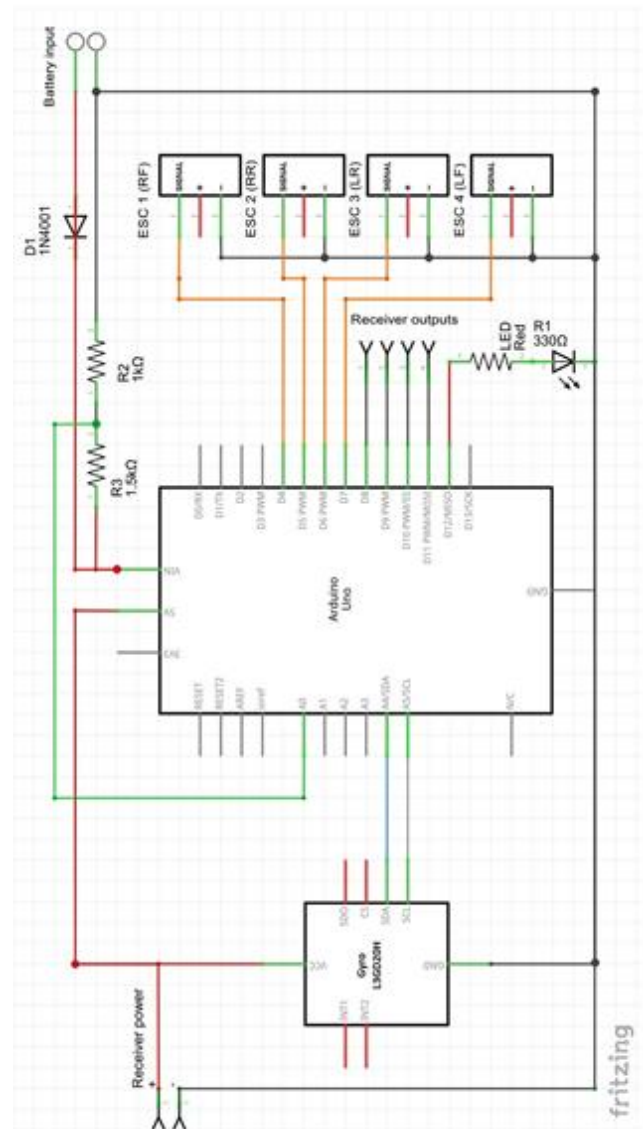Since we have all the components listed above, it's time to connect them with the help of the schematic:

Fig. 15. Quadcopter's electronic circuit schematic

IV. PROGRAMMING

A. SETUP

After connecting all the components, it is time to program our flight controller. This will by uploading 3 different programs to our Arduino board in this specific order. At the beginning, upload the SETUP program via a USB 2.0 cable. For safety reasons, the propellers and the battery must be removed.Then, through the Arduino.exe program, open the serial monitor, set it to 57600bps, and then follow the instructions. These instructions are about

configuring the communication parameters of our drone control unit as well as the gyroscope installed. This information at the end of the program is stored in the EEPROM library for later use in subsequent programs. If by any chance an error will occur the LED will flash and the SETUP program will be terminated. If everything goes well, without any problems during the setup process, then upload our second program named ESC_CALIBRATION.

B. ESC_CALIBRATION

The ESC_CALIBRATION program is required for the simultaneous operation of all four propellers. If this does not be uploaded to the Arduino board, our motors will be rotated at different speeds. When the upload of this program ends, we can pull out the USB cable and place our propellers.
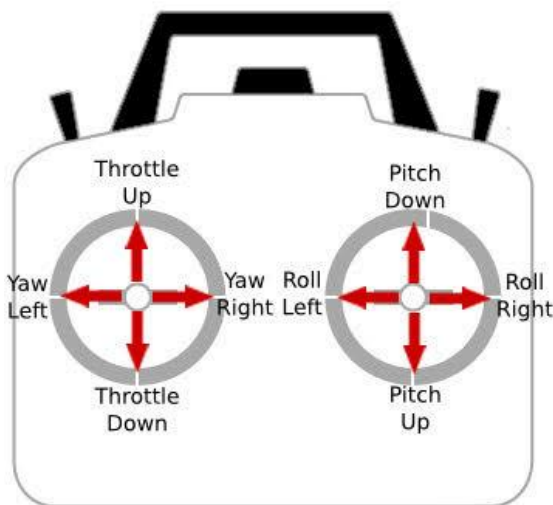

Fig. 16. Quadcopter receiver joysticks function

When this is done, we place the THROTTLE of the controller in the maximum position (Throttle Up) and connect the battery. When ESCs (Electric Speed Controllers) begin to produce a sound, we will put the THROTTLE in the lowest position (Throttle Down). After that, if we place the throttle stick higher than that, the motors will start at the same time. The second part of our installation is completed and immediately afterwards we have to upload the third and final program named FLIGHT_CONTROLLER.

C. FLIGHT_CONTROLLER

To install this program, you just need to upload the FLIGHT_CONTROLLER program on the Arduino board after removing our battery first. After that, we can start our first flight at low altitude, for safety reasons, to see if the quadcopter responds to the given orders.

V. ACKNOWLEDGEMENTS

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