New Designing Approaches for Quadcopter Using 2D Model Modelling a Cascaded PID Controller

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***Abstract*— Currently, UAVs are quite promising and rapidly developing combat and civilian systems. An analysis of the scientific literature devoted to the study of UAVs existing today and developing in the future allows us to determine the fact that today the most effective schemes and layouts for a specific UAV group have been created, the prospects and rationality of which are verified by the experience of various foreign and domestic developers. Recently, there has been an active development of multi-rotor devices, which have the ability to carry photos or video equipment. The relevance of the study is to ensure the movement of the device along a given route and to control the stabilization of the device in air in an angular position in two-dimensional space.**

Keywords — quadcopter; modeling; control; regulator; control system

I. Introduction

Quadcopter – an aircraft with four rotors, diagonally rotating in opposite directions. Flying devices with an arbitrary number of rotors are called multi-copter. Multi-copters began to develop at the dawn of helicopter manufacturing, but the further development of this direction was hindered by the complexity of the design transferring the rotation of one engine to all the screws and the invention of the skew apparatus for classic helicopters. The rapid development of multi-copters have begun in the 21st century, but as unmanned aerial vehicles. Due to simplicity, multi-copters designs are widely used in amateur modeling. They are equipped with cameras and GPS receivers, which allows fairly high-quality terrain from a height, the presence of GPS allows directions on autonomous. Multi-copters are movement and they are small in size, light, very maneuverable, relatively cheap and easy to use. These qualities are prerequisites for use and serve as prerequisites for the use of these aircraft in the army, rescue services, research, delivery of small cargo and so on.

Already now amateur multi-copters are used by some armies to correct mortar(weapon) shelling and reconnaissance. Confirmation of this can be found in numerous videos from various resources on the Internet. But multi-copters have one huge minus – small flight time. Due to the fact that most of multi-copters are equipped with powerful brushless electric motors, one for each screw, energy Stocked battery splurge fast. The low battery capacity is one of the most important problems that stands in the way of widespread in multi-copters. Multi-copters average flight time per battery charge is 20 minutes, which is a small indicator.

Quadcopter is actually classified as a helicopter with four screws that can be used to track and research tasks. Quadcopter also known as UAV. It looks like a regular helicopter it may freeze. They have various advantages such as vertical. Takeoff, freezing and so on. Quadcopter is actually two pairs of screws for takeoff and movement. Two pairs are set so that one pair is clockwise (CW) and the other counterclockwise (CCW) direction. Quadcopter is equipped with different sensors. The aim of this work is to create a motion control system of quadcopter.

The aim of this article is to present a general model simulation of a controlled quadcopter and the study of basic mathematical Quadcopter model and the latest developments in this area. The goal of this study is to analyze the main mathematical model of multi-copter dynamics and UAV design with the function of self-stabilization. Problem in control multi-copter consists in the fact that there are only four control inputs (i.e., rotation, pitch, yaw and traction), and it has 6-DOF (degree of freedom). but in this article, we use three inputs and a 3-DOF system.

This article presents the study of differential equations quadcopter dynamics, which are obtained both from Newton-Euler equations and Euler-Lagrange equations.

Quadcopter stabilization is achieved by simple PID control method. How to gain the interest of a wide circle of researchers, different researchers work on different mathematical models to control and stabilize the quadcopter. Other Researchers have developed various models based on Euler Calculation of angles and Newton's laws, while others used the wording of the Langragians. These methods require evaluation, parameters and lacks good stability behavior due to linearized equation inside the model.

There are various control methods, including LQR controller, PID controllers, back step-by-step control and non-linear controllers with embedded saturation. The basic structure of the quadcopter is shown in Figure 1.

The position of the quadcopter is determined in the inertial coordinate system x, y, z and ξ. The angular position is determined in an inertial system with three Euler angles η. The pitch angle θ decides around the y-axis from rotation of

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quadcopter. Roll angle φ decides x-axis rotation and the yaw angle ψ z-axis rotation. The vector q represents the linear and angular position vectors.

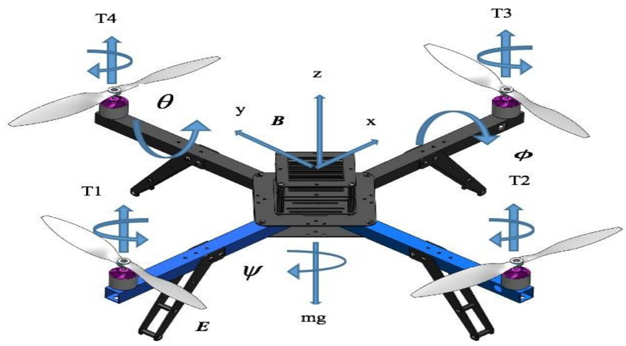

Fig. 1. Basic structure of the quadcopter (Source -internet).

$$\xi=\begin{bmatrix}x\\y\\z\end{bmatrix},\eta=\begin{bmatrix}\emptyset\\\theta\\\psi\end{bmatrix},q=\begin{bmatrix}\xi\\\eta\end{bmatrix}$$

To stabilize the quadcopter, a PID controller is used. PID controller has a simple structure and controller the implementation is simple. The general form of the PID controller is

$$e(t) = x_d(t) - x(t),$$

$$u(t) = K_p\, e(t) + K_i \int_0^t e(t)dt + K_d \frac{de(t)}{dt}$$

In which u (t) = control unit, e (t) = the difference between the desired state x_d (t) and the present state x(t) and K_p , $K_i$and K_d are equal parameters for proportional, integral and derivatives PID controller elements.

Quadcopter is vertical takeoff and landing drone with 4 rotors. Many researchers have developed the technique using simple control and it can perform simple maneuvers quite easily one. There is simplified dynamic equation for the outer loop position tracking, if there is no wind, then we recorded yaw with yaw controller. We checked it indoors. Consequently, we ignore yaw because there is no wind to disturb Quadcopter. Consequently, for this condition, without any disturbances that we use the baseline controller described in, in Drawing. 2 For our purpose, we must stabilize the quadcopter desired height using the height adjuster. In a previous work, many researchers are working on the design of a height regulator.

II. Our Propose Design

A. Equation of motion

For our purpose, we must stabilize the quadcopter desired height using the height adjuster. Our drone is really modeled in two dimensions, it has z and y planes, it will move only in this plane with an angle φ, is the angle of heel. u1 is equal to the force from the screws and u2 is equal to the moment, the mass (m)is 0.2 kg, and the moment of inertia (IXX) is 0.1 units.

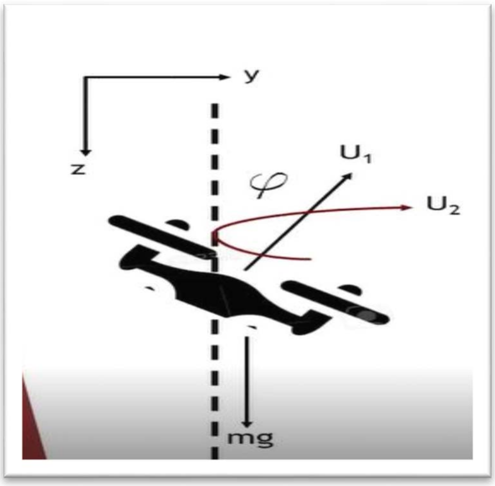

Fig. 2. Kinematic diagram of a quadcopter.

$$\ddot{z} = g - \frac{u_1}{m}\cos(\varphi) \quad (1)$$

$$\ddot{y} = \frac{u_1}{m}\sin(\varphi) \quad (2)$$

$$\ddot{\varphi} = \frac{u_2}{Ixx} \quad (3)$$

B. Llinearization

Since the system is nonlinear because we have sine function and cosine functions for phi also u1 is coupled for both y and z reachable from a linearization.

Designing a controller for a 2d quadcopter in Simulink our drone really modeled in two dimensions as shown here we have our z and y plane ,it will only be moving in that plane with an angle of phi which is the roll u1= the force from the propellers and u2 = the moment, mass equals 0.2 kg and the moment of inertia equals 0.1 units

The system is linearized around the hover point, where the properties are u2=0, y=y0, z=z0.u1=mg, phi=0.The reason u1=mg is because z; and y; are=0.

The system is linearized around the whole point because that'll be the most stable point. So, at this hover point we have a number of properties u2 equals zero because we have no moment since the roll angle must be zero. When we set the z double dot to zero it starts moving up and down .So u1 must be mg with that being said we can then perform a small angle approximation the phi is zero we can add delta phi to that and we add delta values to the y , z , u1 and u2 as well. When we plug these values into our equals, we get z double dot equals g minus u1 over m, phi double dot stays the same and y double dot equals sin g/phi. The reason why the sine and the cosine disappear because cosine of a small angle z equal to 1 and sine of a small angle z equal to just the angle itself.

$$\ddot{z} = g - \frac{u_1}{m}\cdot\cos(\phi)$$

$$\ddot{y} = \frac{u_1}{m}\cdot\sin(\phi)$$

$$\ddot{\phi} = \frac{u_2}{Ixx}$$

- $\ddot{z} = g - \frac{u_1}{m}\cdot\cos\Delta\phi \rightarrow g - \frac{u_1}{m}$
- $\ddot{\phi} = \frac{u_2}{Ixx}$, stays the same
- $\ddot{y} = \frac{mg}{m}\cdot\sin\Delta\phi \rightarrow g\phi$, small

Fig. 3. Formation for linearization.

C. Building control design

We will be designing a controller for the system since this is a system in which we have lower a smaller number of control variables than the degree of freedom as shown here. It is possible to develop a controller for a system because it is a system with fewer control variables than the degree of freedom, both the 3-DOF system (y, z, φ) and the two control variables u1 and u2. It is necessary to design a cascade controller for the second function since from u2 you can get phi and from phi you can also get y.

Input of controller u1 $\longrightarrow \ddot{z} \longrightarrow z' \longrightarrow$ z, loop

Input of controller u1 $\longrightarrow \ddot{\varphi} \longrightarrow \varphi' \longrightarrow \varphi$, loop

$\longrightarrow \ddot{y} \longrightarrow y' \longrightarrow$ y, loop,cascaded

Fig. 4. Cascaded looping for building controller design.

D. Trajectory of the quadcopter(input)

For our path, we can use the figure 8, the drone will start at 0.0 and move on the figure 8 and return to 0.0, we T will have about 10 to 20 seconds and we will have the z function f as 5 sines T and Y as 0.5 sin (o. 5 t).

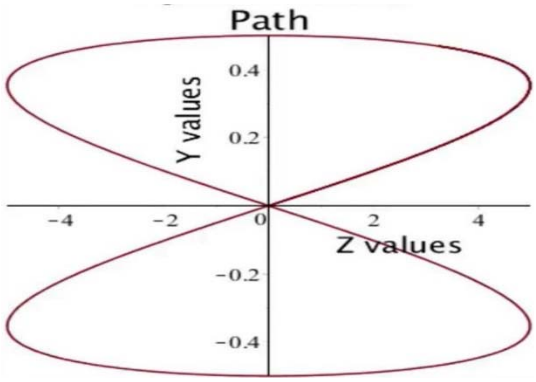

Fig. 5. Trajectory path of quadcopter.

E. Simulation of the dynamics of the quadrocopter

With the help of MATLAB (and Simulink) software package, we will simulate a nonlinear model of a quadcopter using PID controllers.

The first thing will be starting with z double dot function and inputs u1, u2 and we can set whole subsystem in Simulink. Our plant is done and we will get our controller.

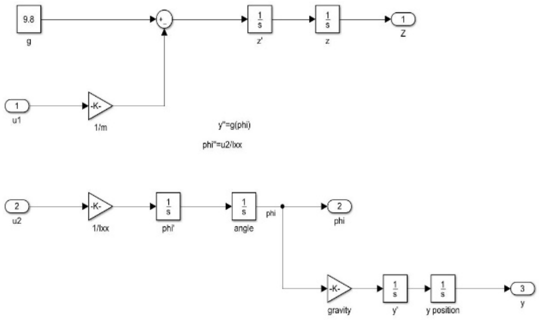

Fig. 6. Block diagram for equation of motion.

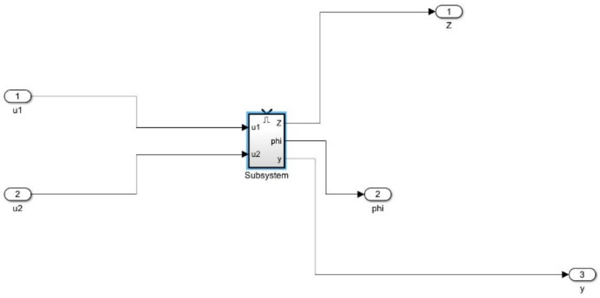

Fig. 7. Subsystem to design controller.

Its only going to be a PD controller no integral action because the function itself is quite linear so set K_p and K_d values and K_i is zero everywhere. For the phi loop and y loop, we can value K_p and K_d. But the values of K_p and K_d much higher in phi loop because inner loop dynamics which must be more faster than the outer loop. This is a fundamental concept of a cascaded controller because inner dynamics must adjust much quicker with respect to the outer dynamics. The phi value is jumping very high up and down, so we can stabilize this by using saturation block drag it in to set the limit 0.8 which is about 85 to 90 degrees. So, after connecting saturation block, we can obtain phi values in stabilize condition.

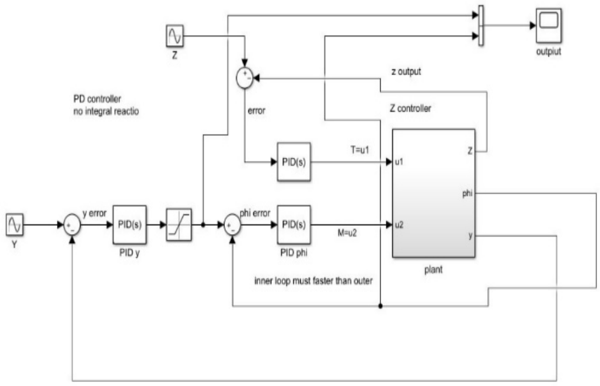

Fig. 8. Simulink-a model of a nonlinear quadcopter model.

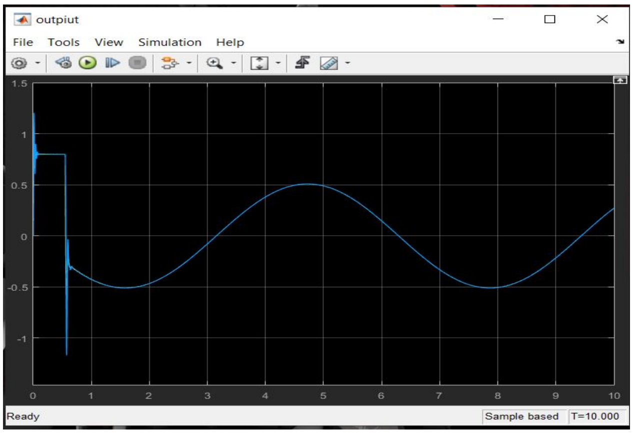

Fig. 9. In Simulink implemented Quad control flight path.

III. CONCLUSION

The mathematical model of the quadcopter was transformed to simplify the operation and with the help of the PID controller, a control system was obtained that allows the quadcopter to occupy the desired position, orientation and stability. Thus, this article is a simulation of a quadcopter using a simple 2D cascaded PID controller moving in two dimensions y and z.

IV. ADVANTAGE

The advantage of the four rotary unmanned aerial vehicles is the simplicity of design and flight flexibility, which makes it easier to approach the targets compared to traditional helicopters; More importantly, the quadcopter in many areas of high, sophisticated, sharp technologies, such as: aerodynamics, automatic control, autonomous navigation, sensor technology and so on; Currently, sensor technology and computer technology continue to evolve, quadcopters for these areas have also provided a comprehensive research platform. Thus, both scientific research and the integrated use of quadcopter aircraft research are of great scientific importance.

V. FUTRUE WORK

Various research reports show that research and design of quadcopter are currently undergoing rapid development, their research content and applications are more extensive, in all areas you can see their shadow:

1. Aircraft can be used to enter the biochemical restricted area for tasks, real-time monitoring of forests, meadows and agricultural land, and other environmental environments; Search for victims of disasters, harmful sources of pollution; It can also be used for firing civil aviation. In addition, in accordance with various carrying sensors, but also in the field of motion control, space research and field adventures and other aspects play an important role;
2. Low altitude research. The aircraft can perform the coordination task at a distance of several meters to several hundred meters of air, especially in areas where the terrain or personnel cannot reach, and can accurately transmit the detected information;
3. Military raid. Aircraft can be used as offensive weapons used to destroy enemy radar and other electronic equipment, but also to carry weapons for assault;
4. Communication relay. Aircraft can be used to detect and maintain communication lines, which saves labor resources;
5. Signal interference. The aircraft can also be used to intervene in the working area of enemy communications equipment;
6. In addition, in scientific research, the design and development of a quadcopter includes a number of disciplines of high, sophisticated, acute technology, including a number of complex scientific problems, such as aero-dynamics, MEMS technology, power, image Processing and communication technologies and much more.

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