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Controlling of Quad-rotor UAV Using PID Controller and Fuzzy Logic Controller

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ABSTRACT: This paper presents the controlling of model of a four rotor vertical take-off and landing (VTOL) unmanned air vehicle known as the quad-rotor aircraft. The paper presents two controlling methods for the flight control of an autonomous quad rotor. The dynamic model of the quad-rotor, which is an under actuated aircraft with fixed four pitch angle rotors, will be described. The controlling of a quad rotor vehicle is not an easy task because of its complex structure. The aim is to develop a control of the vehicle is easy. This paper explains the developments of a PID (proportional integral-derivative) control method and fuzzy logic control method to obtain stability in flying the Quad-rotor flying object. In model there four input forces which are basically the thrust provided by each propeller connected to each rotor with fixed angle. Forward (backward) motion is going to maintain by increasing (decreasing) speed of front (rear) rotor speed while decreasing (increasing) rear (front) rotor speed simultaneously. The aim of this paper is to give enhance performance of quad-rotor.

Keywords: Quad rotor, PID controller, fuzzy logic controller, VTOL, UAV, MATLAB simulink.

I. INTRODUCTION

UAVs, or 'Unmanned Aerial Vehicles,' are defined as Automatic aircraft. This is mostly used to perform intelligence, surveillance, and reconnaissance missions. These Vehicles have several basic advantages over manned systems because of its increased manoeuvrability, reduced cost, reduced radar signatures, longer endurance, and less risk to crews. Such vehicles are to require little human intervention from take-off to landing. Unmanned aerial vehicles (UAVs) are fulfilling many civil and military applications including surveillance, intervention in hostile environments, air pollution monitoring, and area mapping [1].

Unmanned aerial vehicles (UAVs) have a wide area of possible applications. Large outdoor UAVs are use for military and commercial purposes. Indoor flight requires a suitable type of vehicle which requires suitable control. One helicopter-like vehicle with the additional advantage of a simple construction and rotor mechanics is the quad-rotor [2].

Quad rotor aerial robot is an automatic system which is an unmanned VTOL (vertical take-off and landing) helicopter. The main features of this structure are a cross intersection rigid body, cross intersection poles which have been composed of two diagonals of a square. Four rotors has been configured at the four end of the cross intersection. Each rotor is driven by a motor [3].

Unmanned aerial vehicles (UAV) have shown a growing interest thanks to recent technological projections, especially those related to instrument here we are studying the behaviour of the quad rotor. This flying vehicle presents the main advantage of having quite simple dynamic features. the quad rotor is a small vehicle with four propellers placed around a main body.

The main body has power source and control hardware. Here the four rotors are used to controlling the vehicle. The rotational speeds of the four rotors are independent so it's possible to control the pitch, roll and yaw attitude of the vehicle. And its displacement is produced by the total thrust of the four rotors whose direction varies according to the attitude of the quad rotor. The vehicle motion can thus be controlled.

Existing quad-rotor dynamic system is composed of five rigid bodies: four rotors and a crossing body frame. This makes the explanation of several aspects, like gyroscopic effects, very difficult [1].

Quad-rotor consists of four rotors in total, with two pairs of counter-rotating, fixed-pitch blades located at the four corners of the aircraft. Quad-rotors do not require complex mechanical control linkages for rotor actuation, relying instead on fixed pitch rotors and using variation in motor speed for vehicle control. it simplifies both the design and maintenance of the vehicle. The use of four rotors ensures that individual rotors are smaller in diameter than the equivalent main rotor on a helicopter, relative to the airframe size. The individual rotors, therefore, store less kinetic energy during flight [4].

II. MATHEMATICAL MODELLING

A quad rotor is an under actuated aircraft with fixed pitch angle four rotors. Modelling a vehicle such as a quad rotor is not an easy task because of its complex structure.

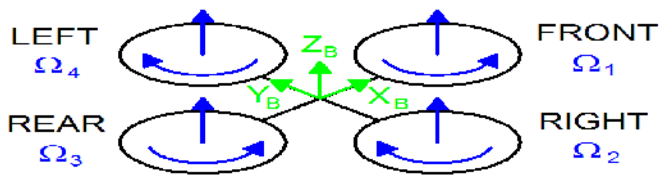

Fig. 1. Quad-rotor motor in hovering.

In a quad rotor there are four rotors with fixed angles which represent four input forces that are basically the thrust generated by each propeller. The collective input (u_1) is the sum of the thrusts of each motor. Pitch movement can be obtained by increasing (reducing) the speed of the rear motor while reducing (increasing) the speed of the front motor. The roll movement can be obtained by increasing (reducing) the speed of the right motor while reducing (increasing) the speed of the left motor. The yaw movement can be obtained by increasing (decreasing) the speed of the front and rear motors together while decreasing (increasing) the speed of the lateral motors together. This should be done while keeping the total thrust constant.
The equations of motion can be written using the force and moment balance.

$$\ddot{X} = U1(Cos\varphi Sin\theta Cos\Psi + Sin\varphi Sin\Psi) - K1\dot{x}/m$$
$$\ddot{y} = U1(Sin\varphi Sin\Psi Cos\Psi - Cos\varphi Cos\Psi) - K2\dot{y}/m$$
$$\ddot{z} = U1(Cos\varphi Cos\Psi) - g - K3\dot{z}/m$$

Where,
x: Forward position in earth axes
y: Lateral position in earth axes
z: Vertical position in earth axes
Ki: The Drag Coefficients for the system.

The center of gravity is assumed to be at the middle of the connecting link.

As the center of gravity moves up (or down) units, then the angular acceleration becomes less sensitive to the forces, therefore stability is increased. Stability can also be increased by tilting the rotor forces towards the center. This will decrease the roll and pitch moments as well as the total vertical thrust.
For convenience, we will define the inputs to be

U1 = (Th1+Th2+Th3+Th4)/m

U2 = l(-Th1-Th2+Th3+Th4)/I1

U3 = l(-Th1+Th2+Th3-Th4)/I2

U4 = C(Th1+Th2+Th3+Th4)/I3

Where,

u1 : Vertical thrust generated by the four rotors

u2 : Pitching moment

u3 : Yawing moment

u4 : Rolling moment

Thi : The thrusts generated by four rotors

Ii : The moments of inertia with respect to the axes

Where This are thrusts generated by four rotors and can be considered as the real control inputs to the system, and C the force to moment scaling factor. And *Ii's* are the moment of inertia with respect to the axes. Therefore the equations of Euler angles become:

$$\ddot{\theta} = u_2 - lk4\dot{\theta}/I1$$

$$\ddot{\Psi} = u_3 - lk5\dot{\Psi}/I2$$

$$\ddot{\varphi} = u_4 - lk5\dot{\varphi}/I3$$

where (*x*, *y*, *z*) are three positions; (θ, φ ,ψ) three Euler angles, representing pitch, roll and yaw respectively; *g* the acceleration of gravity; *l* the half length of the helicopter; *m* the total mass of the helicopter; *Ii's* the moments of inertia with respect to the axes; *Ki*'s the drag coefficients.

III. PID CONTROL DESIGN

In robotics, PID technique represents the basics of control. Even though a lot of different algorithms provide better performance than PID, this last structure is often chosen for the reasons expressed above. The traditional PID structure is composed of the addition of three contributes, as shown in figure and equation [5].

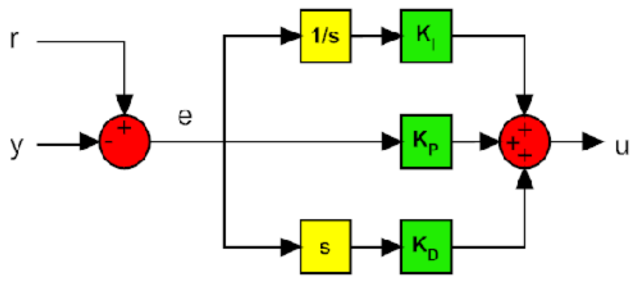

Fig. 2. Traditional PID structure.

The blocks"1/s" and "s" represents the integration and derivation operations.

$$u(t) = KPe(t) + KI\int_0^t e(\tau)\,d\tau + KZ\frac{de(t)}{dt} \quad \ldots (1)$$

Where u is a generic controlled variable, e is the error between the task r and the process output y, K_P is the proportional coefficient, K_I is the integral coefficient and K_D is the derivative coefficient. The first contribute (P) is proportional to the error and define the proportional bandwidth. Inside this interval the output will be proportional to the error while outside the output will be minimum or maximum. The second contribute (I) varies according to the integral of the error. Even though this component increases the overshoot and the settling time, it has a unique propriety: it eliminates the steady state error. The third contribute (D) varies according to the derivate of the error. This component helps to decrease the overshoot and the settling time [5].

IV. FUZZY LOGIC CONTROLLER

Fuzzy Logic Controller (FLC) is based on fuzzy logic controller. And it constitutes a way of converting linguistic control strategy into an automatic by generating a rule base which controls the behavior of the system. Fuzzy control is control method based on fuzzy logic. Fuzzy provides a remarkable simple way to draw definite conclusions from imprecise information.

FLC have some advantages such as simplicity of control, low cost and the possibility to design without knowing the exact mathematical model of the process.

Fuzzy logic incorporates an alternative way of thinking which allows modeling complex systems using higher level of abstraction originating from the knowledge and experience.

Fuzzy logic can be described simply as computing words rather than numbers or control with sentence rather than equations.

A. Structure of Fuzzy Logic

There are some specific components characteristic of a fuzzy controller to support a design procedure here Fig. 3 shows the controller between the preprocessing block and post processing block.

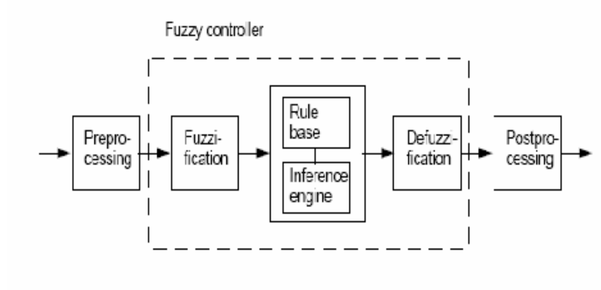

Fig. 3. Structure of fuzzy logic controller.

V. RESULTS AND SIMULATION STUDY

In proposed work we are comparing two control methods to get better stability performance. There are two methods PID controller and Fuzzy logic controller. We can see simulation results by run the GUI window. There are simulation results for every position of quad-rotor i.e X-position, Y-position, Z-position, phi angle, *si* angle and theta angle.

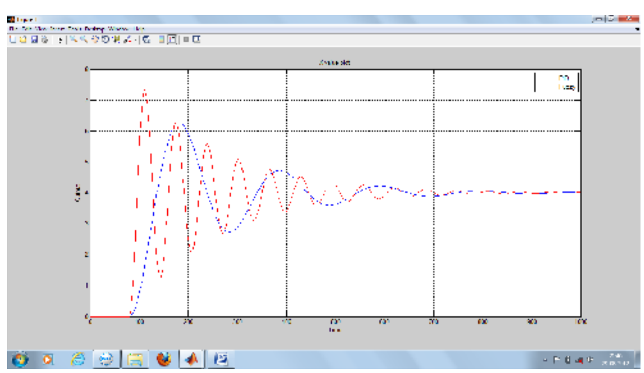

Fig. 4. X-value plot.

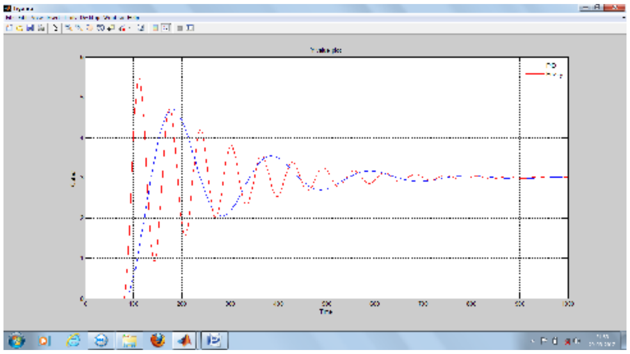

Fig. 5. Y-value plot.

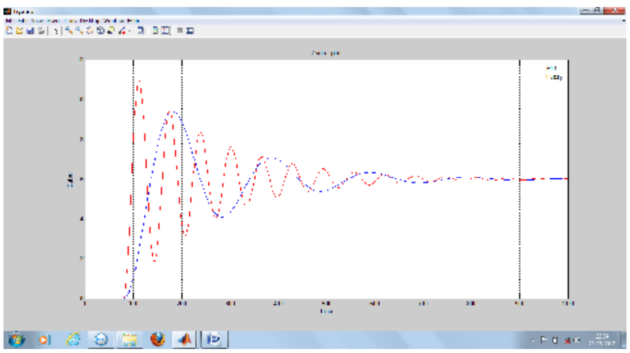

Fig. 6. z-value plot.

Here we can see the plot between time and output. For every position there is value for an initial position and final position in plots there are two graph lines for PID and Fuzzy controller and results shows the graph of Fuzzy controller is taking less time to get stable position as compare to PID. We can get also plots for phi, si and theta angles which are not describes here.

VI. CONCLUSION

This paper represented controlling of quad-rotor by comparing two methods. And results shows system gets better and quickly stable position when fuzzy controller is used and stability is main factor to run any system.

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