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Development of Dynamic Modeling and Fuzzy Logic System by Classical and Modern Strategies for the Control of Quadcopter

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Abstract

Quadcopters or Drones have multiple applications for different purpose such as investigation, assessment, exploration, rescue and decreasing the human strength in an adverse situation. Unmanned air vehicles (UAV) is designed with four propellers to resolve the issue of constancy however it will make the drone further more complex for the dynamic modelling and for the control system. In this research, smart controller is intended to regulate the attitude of drone. Simulation ideal model and fuzzy logic control approach is formulated to implement for four elementary motions i.e. roll, pitch, yaw, and height of our drone for the application of earth-quake. The key objective of this research paper is to develop the anticipated output as compare to the desired input.

Keywords: Quadrotor; Earth-quake; Dynamic Modeling; Fuzzy Logic Control.

1. Introduction

As the rate of technological advancement is increasing with time, robotics is an emerging technology that is established to support society to achieve plenty of jobs, a job that requires extraordinary alertness, great threat, a task that requires an enormous power, or any monotonous tasks [1].

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Moreover, the advance technology of robotics is able to reach on that threaten areas where it's very difficult to reach or are hazardous for Protecting workers. Robotics is the stunning, stupendous and advance technology and techniques that is being established for human safety [2]. Hovering robots or drones, whether they compile in the form of quadrotor, multirotor and helicopter with numerous categories [3]. Flying robot can be used for different locations that is hardly accessible by human such as to observe and visualize the traffic queue, inspection and monitoring. spy robots specially use to inspect natural catastrophe and land and forest fire, searching media for Search and Rescue (SAR) mission and to investigate the fault during the building renovations in structural engineering field [4]. In recent times many researchers developing quadrotor robot, particularly associated to hardware development and the modelling regarding the performance and constancy of the quadrotor machines by employing a optical instrument to capture still and moving images that is connected to the quadrotor whose job is to perform as GPS navigation system designed for a specific purpose that has a potential to travel automatically [5].To produce lift, the rotors have to spin at a certain speed to produce enough thrust. The quantity of thrust will determine the altitude and speed at which the Quadrotor rises [6]. However, researchers are design and developing multipurpose quadrotor that is able to change its position by means of visual flight controller [7]. This special purpose quadrotor can visualize and investigate the state of its surrounding and then find the suitable path and direction based on the motion detector automatically [8]. The objective of this research paper presents altered classical and modern control approaches for the control of our proposed drone. Simulations outcome and evaluation of all control methods are accessible at the end of this research paper.

2. Dynamic Modeling of Quadcopter

Quadcopters glides with the support of four rotors as shown in figure 1. For the vertical flight two rotors which are on opposite sides rotates in the same direction to keep stabilize on the x-axis. The other two opposite rotors rotate in the similar direction for steadiness on the y-axis.

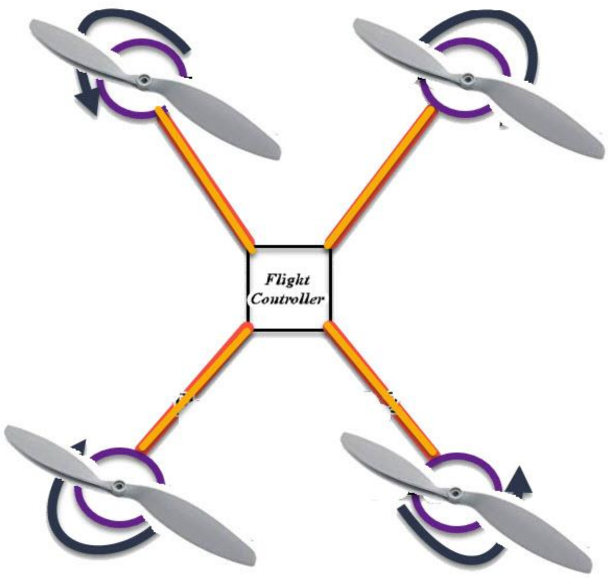

Figure 1: Systematic diagram of quadcopter

Design technique of quadrotor system contains different kinds of sensors, actuators, frame, Landing gears, propeller, brushless motors, relevant hardware components, Electronic speed controller (ESC), Flight Controller (FC), Batteries and camera. In this design and configuration of the quadrotor, all features that can affect the stability and performance of the quadrotor will be optimized. Hardware scheme comprises of some fragments as shown in Figure 1:

- Mechanical scheme of quadrotor robot.
- Electronic system design.

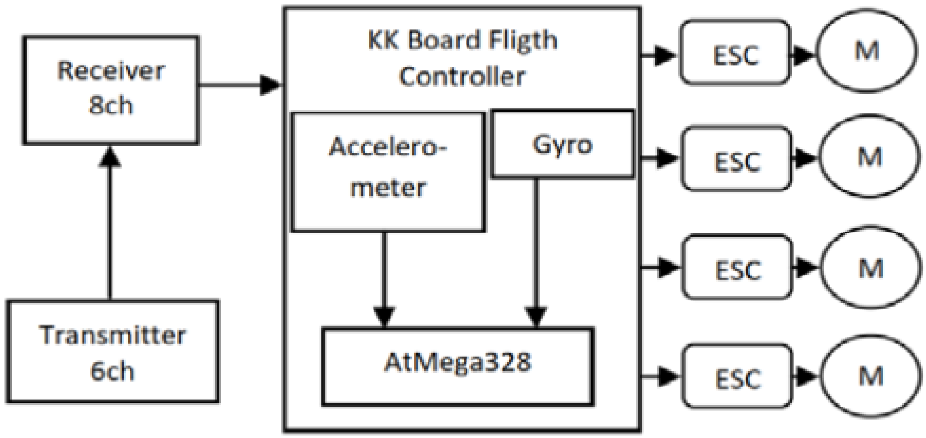

Figure 2: Block Diagram Electronic Systems Quadcopter.

Figure 2 illustrates that the remote control (RC) provides directive signal to quadrotor vehicle, then the optical device mounted on the quadrotor will transfer data and the other useful instructions in the form of videos and audios to receiving device. Quadcopter is a six degree of freedom air-vehicle, we will consider six variables (x, y, z, Ø, θ and φ) are particularly used to express its orientation in space. Ø, θ, and φ are well known variables recognized as Euler's angles. Particulars of individually variable are as follows. x and y are particularly used to characterize the position of drone in space and z use to characterizes the altitude of the drone. ϕ used to represent the roll angle about the horizontal axes (x-axis). θ is defined as pitch angle about the (vertical axes) y-axis. φ use to characterize the yaw angle about the third coordinate axes i.e. (z-axis). In our research, we are also using Newton-Euler formalism to develop the dynamics of the drone. The Assembly of proposed quadrotor is firm rigid and balanced. The following equation of motion is presented in this research paper.

$$\ddot{x} = \frac{U_1(cos\phi\ \sin\theta\ \ \cos\varphi + \sin\phi\ \sin\varphi)}{m} \tag{1}$$

$$\ddot{y} = \frac{U_1(cos\phi\ \sin\theta\ \ \cos\varphi + \sin\phi\ \sin\varphi)}{m} \tag{2}$$

$$\ddot{z} = \frac{U_1(cos\phi\ \cos\theta) - \mathrm{gm}}{m} \tag{3}$$

$$\dot{\phi} = \varphi\theta\left\{\frac{I_{yy}-I_{zz}}{I_{xx}}\right\} - \left\{\frac{J}{I_{xx}}\right\}\theta\Omega + \frac{U_2}{I_{xx}} \tag{4}$$

$$\dot{\theta} = \varphi\phi\left\{\frac{I_{zz}-I_{xx}}{I_{yy}}\right\} - \left\{\frac{J}{I_{xx}}\right\}\phi\Omega + \frac{U_3}{I_{yy}} \tag{5}$$

$$\dot{\varphi} = \theta\phi\left\{\frac{I_{xx}-I_{yy}}{I_{zz}}\right\} - \frac{U_4}{I_{zz}} \tag{6}$$

In equations (1), (2) and (3) m is the mass of quadcopter while I_{xx}, I_{yy} and I_{zz} in equations (4), (5) and (6) are the inertia matrix., J express here as the angular momentum and Ω is the propeller speed. U1, U2, U3, and U4 are the inputs.

$$U_1 = (\Omega_1^2 + \Omega_2^2 + \Omega_3^2 + \Omega_4^2)b \tag{7}$$

$$U_2 = (-\Omega_2^2 + \Omega_4^2)lb \tag{8}$$

$$U_3 = (-\Omega_1^2 + \Omega_3^2)lb \tag{9}$$

$$U_4 = (-\Omega_1^2 + \Omega_2^2 - \Omega_3^2 + \Omega_4^2)d \tag{10}$$

$$\Omega = (-\Omega_1^2 + \Omega_2^2 - \Omega_3^2 + \Omega_4^2) \tag{11}$$

In equation (7), (8) and (9) b and l express the lift and drag respectively and in equation (10) d describe the distance between rotor midpoint and quadcopter center and Ω_1, Ω_2, Ω_3 and $\Omega_4$are front, right, back and left propeller's velocity.

3. Fuzzy Control System (FCS)

Fuzzy control system (FCS) is divided into five main parts. First section we have to define the inputs variables, secondly the fuzzification, change all inputs into fuzzy inputs and in third part we have to define the fuzzy rules which is the most important part of fuzzy control system. Fourth part is defuzzification, it is a method that transforms a fuzzy set into a crisp number. Defuzzification is an extremely significant fragment in the scheme of a fuzzy control system (FCS), meanwhile it will regulate the action taken by the system. Fifth and last section is determining output variables. A fuzzy control system (FCS) is illustrated in the figure below.

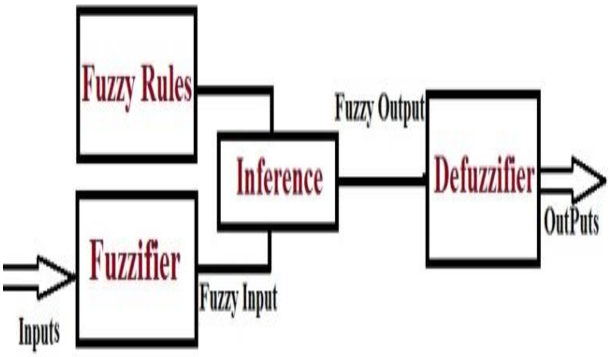

Figure 2: Fuzzy Control Systems (FCS)

By investigation and vigilant consideration subsequent fuzzy rules are illustrated for all four controllers.

Table 1: Fuzzy Rules

Error w.r.t Time	HO = Highly Opposite	O = Opposite	N = Null	E= Efficient	HE=Highly Efficient
O = Opposite	ED=Extremely Descend	D = Descend	D= Descend	H=Hovering	LU=Lift Up
N = Null	ED=Extremely Descend	D = Descend	H=Hovering	LU=Lift Up	ELU=Extremely Lift Up
E = Efficient	D = Descend	H=Hovering	LU=Lift Up	ELU=Extremely Lift Up	ELU=Extremely Lift Up

Trapezoid and Gaussian membership functions are used for control of the quadcopter. The range is defined for the error input membership function derivative of error input function are from [-2, 2] and however output membership function is in the range of [-15, 15]. Here are the inputs and outputs of the membership functions defined for individual controller.

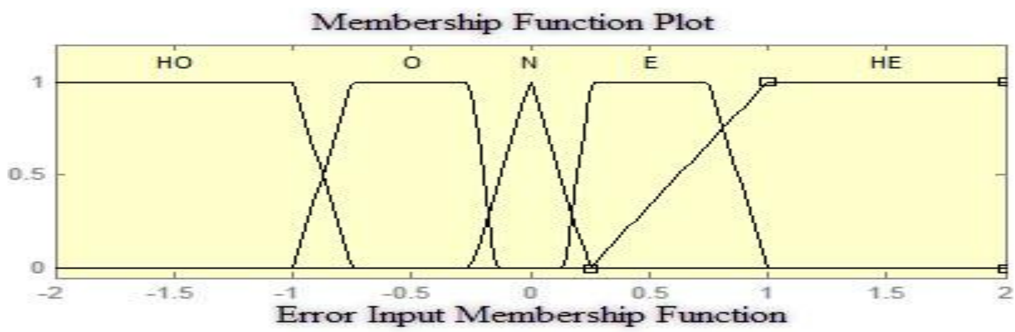

Figure 3: Error Input Membership Function

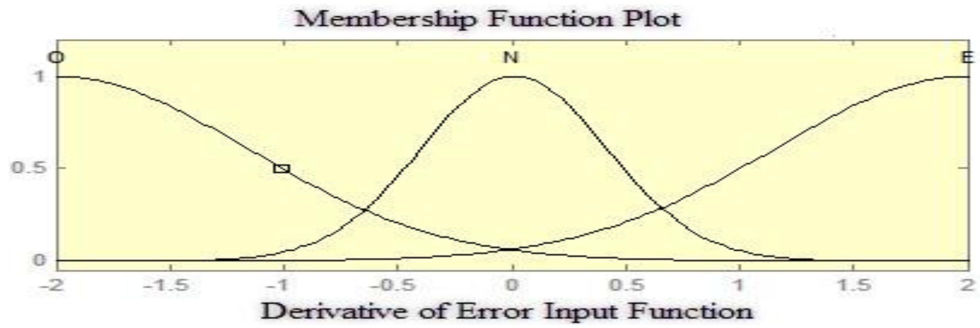

Figure 4: Derivative of Error Membership Function

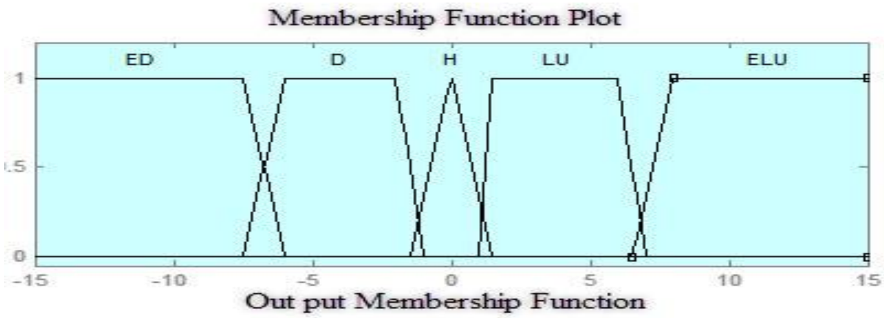

Figure 5: Output Membership Function

Figure (6) and (7) shows the MATLAB simulation results of proposed system. MATLAB rule viewer and Fuzzy rules surface can be perceived in the figure below.

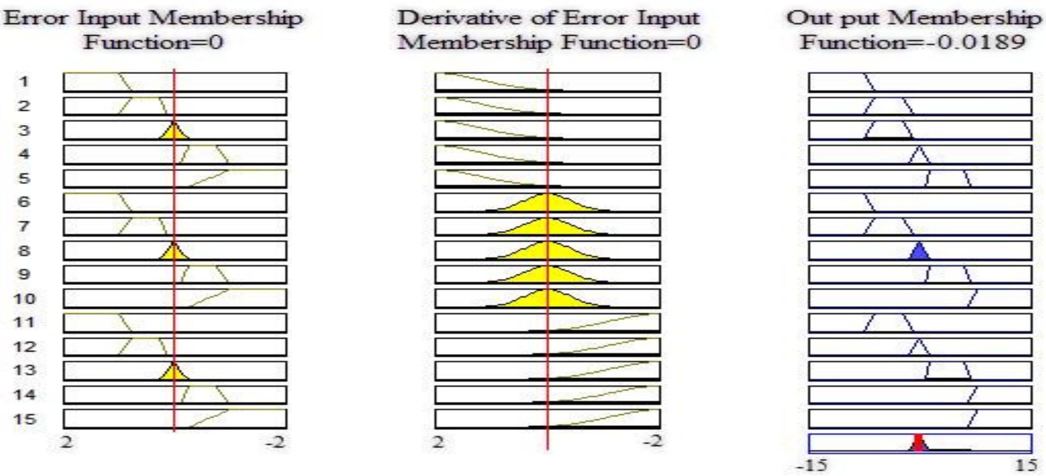

Figure 6: MATLAB rule viewer and simulation results for the quadcopter control fuzzy logic system.

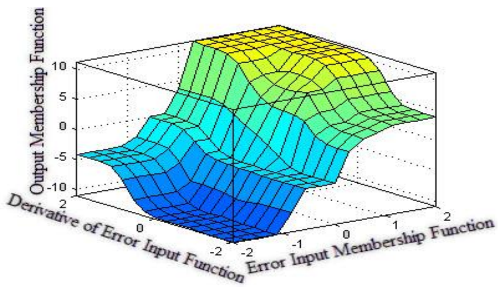

Figure 7: Fuzzy Rules Surface.

4. Conclusion

A nonlinear typical mathematical model and improvement of quadcopter mechanism by means of fuzzy logic algorithms is introduced and execution of the classical model is constructed by Mat-lab. This mechanism used to steady the quadcopter when it takes-off, lands, and hover. The errorof this controller is that it cannot steady the angular accelerations of the roll, pitch and yaw when hovering. Additional research can be made by expending the identical controller scheme and implement it on hardware.

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