Design of SelfBalancing Pitch Control in FixedWing Unmanned Aerial Vehiclewith Fuzzy Logic Controller

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Design of Self Balancing Pitch Control in Fixed Wing Unmanned Aerial Vehicle with Fuzzy Logic Controller

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I. INTRODUCTION

After the invention of an airplane by the Wright Brothers, flying vehicle has been adapting a concept of control to help Pilot's jobs. Currently, the design of a flying vehicle focus on the automatic control system to monitor and control all subsystems in a flying vehicle. Development of an automated control system has an important role in the development of the civil and military aviation [1] - [3].

Further development of the telecommunications and aerospace technology combine the information about a particular location with a state-level high cruising through the air with unmanned flying vehicle called the Unmanned Aerial Vehicle (UAV).

One important element in controlling the stability of Fixed Wing UAV is controlling the pitch angle (pitching). Pitching is a nodding or moving up and down the nose of the plane. Pitching moves in the longitudinal axis to determine wether the UAV will be taking off or landing.

To maintain the stability of the pitch, UAV requires some sensors that can generate data of angle compared to provided set-point angle. Data Motion Processing Unit 6050 sensor can be used to design an automated system based on the reference position of the object [4]. This sensor is a combination of two sensors, the accelerometer and gyroscope. Based on previous conducted research in the Department of Electrical Engineering S-1 and reference journals, the data output from the accelerometer and gyroscope sensor can be used to convert the coordinates of an object into an Earth Axis Coordinates Systems [5] - [11]. Information of pitch angle position is used to determine deflection elevator servo motor to maintain a flat condition UAV to earth axis coordinates system.

Many techniques have been developed to control a dynamic system using feedback control such as PID control, LQ control, and MPC. But only few techniques can be implemented in real flights applications. The main reason not to implement advanced optimal control techniques is due to the difficulties to understand intuitively and in the world of aviation security is a top priority so that controls methods that are less credible intuition are not implemented in a real flying vehicle [1]. Fuzzy control methods can be used to provide the data set-point and maintain output stability UAV subsystems of the reference signal at the desired set-point [1], [12] - [18].

This paper presents an implementation of fuzzy method to control the pitch angle of a fixed wing UAV to maintain the balance or flat condition automatically (self-balancing).

II. METHODOLOGHY

A. Hardware Design

In this research two prototypes of UAV are developed for different testing purposes. The implemented control method is tested using a mechanical design as shown in *Fig. 1*. While the fly is tested using mechanical design as shown in *Fig. 2*. Mechanical design is useful for simulating and checking of all the actuators against possible disturbances that occur before tested in actual flight conditions. *Fig. 3* shows the block design of hardware systems of the Self Balancing system Pitch Control in Unmanned Aerial Vehicle.

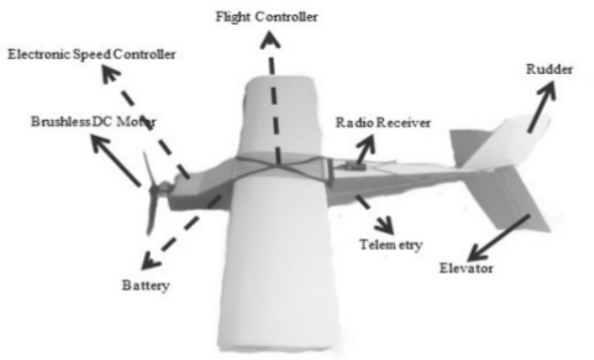

Fig. 1. Mechanical design for testing the fuzzy controller

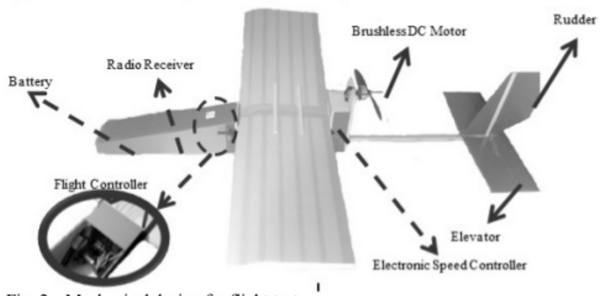

Fig. 2. Mechanical design for flight test

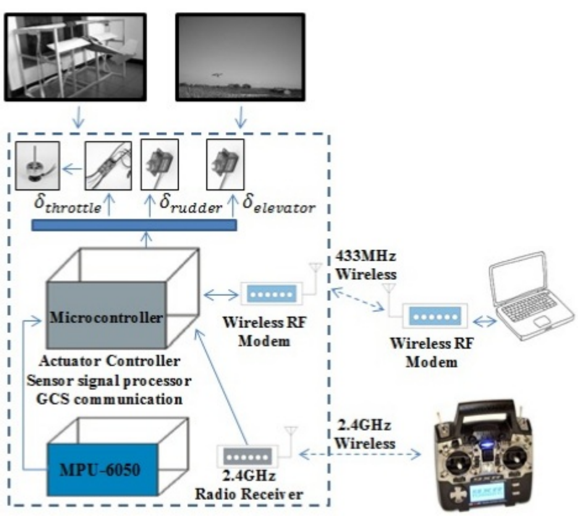

Fig. 3. Design of hardware systems on UAV FLC system testing

B. Main Program Design

The design of the main software program is broadly aimed at regulating the whole system work such as setting data acquisition sensors, radio transmitter signal reading process, settings the controller and actuator settings in UAV systems. The main program flow diagram is shown in *Fig. 4*.

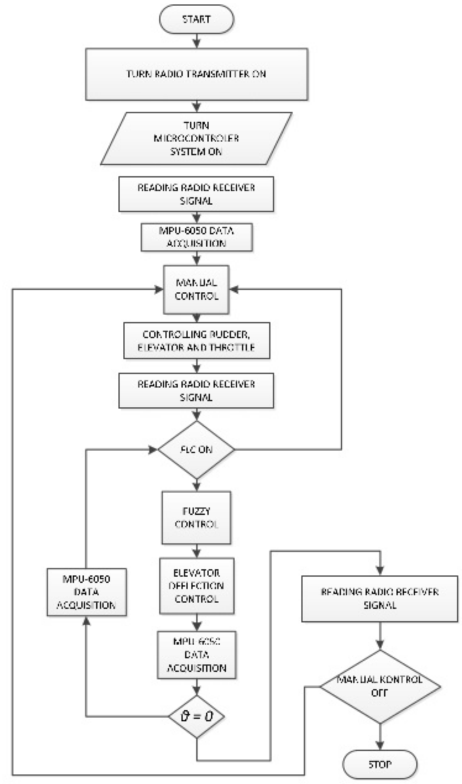

Fig. 4. The main program flow diagram

C. Fuzzy Controller Design

In study of Self Balancing Pitch Control on Unmanned Aerial Vehicle controller using fuzzy logic. The membership function of the fuzzy controller obtained from the position sensor data that have previously been tested on some degree of slope. The membership function as a parameter for determining the angle of deflection of the elevator servo actuator. In general, controller block diagram is shown in *Fig.*

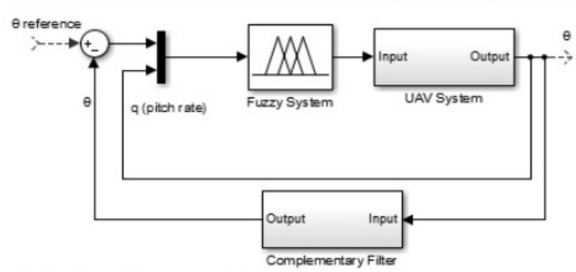

Fig. 5. The main system controller block diagram

Fig. 5 shows the overall closed-loop system for FLC to control the pitch angle of the UAV that designed in this research. Input to the fuzzy controller is the pitch angle of the complementary filter output and the output rate of the pitch angular velocity sensor Motion Processing Unit 6050, while the output is a change in the control signal to adjust elevator servo deflection.

Fuzzification process is a process of mapping the input and output of crisp variables into linguistic variables. There are no standard rules in selecting the membership functions of fuzzy sets, but the use of membership functions of fuzzy sets should represent the characteristics required by the system. Inputs that are used in fuzzy controller obtained from pitch angle complementary filter output and pitch angular velocity (pitch rate) sensor output the gyroscope. The design of fuzzy set membership functions for pitch angle complementary filter output shown in Fig. 7 and set membership to pitch angular velocity (pitch rate) of the gyroscope sensor is shown in *Fig. 6*.

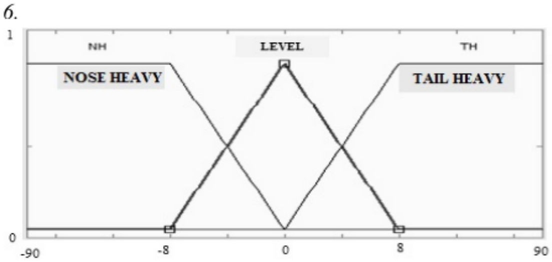

Fig. 6. Fuzzy sets for pitch rate (q)

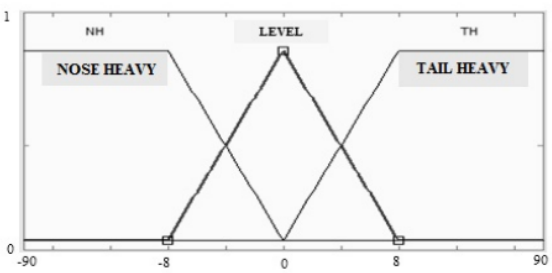

Fig. 7. Fuzzy sets for complementary filter pitch angle (θ)

The design of the rule base can be seen in *Table I*. The values and parameters used in the design of fuzzy rule base obtained using trial and error method and based on intuition gained through experience and experiments in flying an Unmanned Aerial Vehicle.

TABLE I. RULE BASE FOR UAV SELF BALANCING PITCH SYSTEM

q \ θ	NH	Level	TH
NH	10	90	170
Level	10	90	170
TH	10	90	170

Defuzzification is the process of changing the value in the form of fuzzy sets membership functions for become form of crisp values (actual value). Fuzzy data processing become the crisp data required for UAV actuator system due to the system only recognizes the crisp value for the controlling process. Defuzzification method used is the weighted average method. This method is used for computing the weighting corresponding to the elevator deflection angle that weighting variables in the form of constants [19].

III. IMPLEMENTATION AND RESULT

Overall testing system includes hardware and software testing. Hardware testing includes the analysis of the output data radio signal receiver for controlling the servo motor and ESC and IMU position sensor testing of MPU-6050. Software testing includes testing of the open-loop control and fuzzy control methods with giving disturbance to the UAV pitch angle.

Testing the signal for servo motor control and signal input for the Electronic Speed Controller were conducted by comparing the output value of 50 data sensor readings result from changes joystick on radio transmitter for each channel with the output PWM signal as input for servo motors and Electronic Speed Controller. Stick movement on radio transmitter is used as a reference for controlling the opening deflection of the rudder and elevator servo motors as well as for setting the rotation speed Brushless DC Motor.

The output signal from the radio receiver in the form of a signal with a low period for 20 ms and a high signal period between 1 milliseconds to 2 milliseconds read using a timer on the microcontroller ATmega128. The maximum range is designed on the controller can read high signal period of up to 3 milliseconds it aims for reading output signal radio receiver more accurately. The output value of the high signal reading period is represented by a range of values between 0 and 750. Furthermore, the output value of the radio receiver converted by equation 1 and 2 for be represented back in a a scale from 0 to 180 degrees. Response graphs taken during testing of the UAV system shown in *Fig. 8*.

$$\text{out} = (\text{value}_{\text{channel}} - \text{value\_min\_rx\_outsgn})/1.427 \quad (1)$$

$$\text{motorservo1} = (\text{out}/2.9) + 63 \quad (2)$$

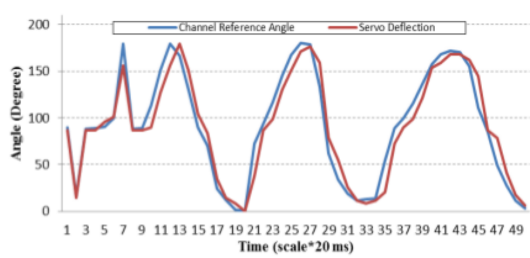

Fig. 8. Graph response actuator input signal and the reference signal from the radio receiver.

Open-loop control testing proved that if the system is affected by disturbances, the system can not maintain a flat condition of zero degree of on a longitudinal axis. This condition is shown in *Fig. 9*. The system contained on the tail causing interference tail heavy conditions so that the system can not maintain a balanced condition of the flat to the longitudinal axis. Based on the test results obtained by 55 098 percent RMSE values.

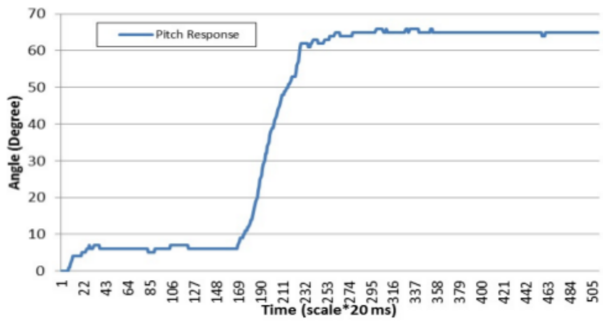

Fig. 9. Graph response open-loop control UAV system.

In the testing process fuzzy logic controllers showed that this method can be used for maintain the balance conditions of a flat on pitch angle of 0 degree. The testing process conducted by maintaining the throttle signal value in certain circumstances to get the best response from the controller. Based on the test results shown improvement of system performance due to the addition of fuzzy logic controller. This is evidenced by the improvement RMSE values with fuzzy logic controller that the results can be reached 9.1421 percent. RMSE values UAV systems with fuzzy logic controller after testing its value better than using open-loop control RMSE value is 55 098 percent. Graph Response system with fuzzy logic controller is shown in Figure 10.

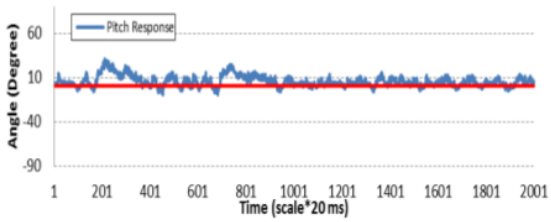

Fig. 10. Graph response UAV system with fuzzy logic controller.

Some test scenarios were also developed in the design of Fuzzy Logic Controller for Self Balancing Pitch System on Unmanned Aerial Vehicle. The first test scenario by giving disturbance to UAV systems resulting pitch angle of is more positive than the set-point value which is 0 degree pitch angle. Other test scenario that is by giving disturbance to the UAV system resulting pitch angle of set-point value is more negative than the pitch angle of is 0 degrees. Based on the test results in 1001 sampling random data, on the first scenario RMSE values of the system amounted is 8.4507 percent and the results obtained in the second test scenarios get RMSE values of 9.0085 percent. *Figure 11* and *Figure 12* shows the Fuzzy Logic Controller attempted to conditioning UAV System in accordance with the references given is 0 degrees on the pitch angle of the Earth Axis Coordinate System.

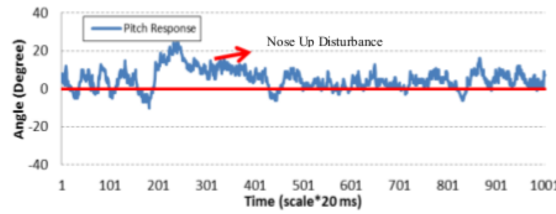

Fig. 11. Graph response first scenario Fuzzy Logic Controller test.

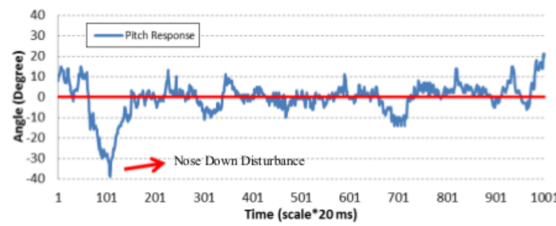

Fig. 12. Graph response second scenario Fuzzy Logic Controller test.

IV. CONCLUSION

Based on the testing shows that the methods used to control UAV system manually by a reference signal from a radio transmitter can work in real-time condition. The addition of fuzzy logic controller can improve the performance of the UAV system. Performance improvement seen with the changes RMSE values by using fuzzy logic controller of 9.1421 percent which is better value than the value of RMSE only uses Open-Loop Control of 55 098 percent. In the testing process there are several obstacles including the effect of vibration which can affect the input Fuzzy Logic Controller System so that the controller does not work to maintain the balance of the UAV flat conditions at an angle of 0 degrees. For further development required an algorithm to reduce the effects of vibration that occurs in UAV systems and for full autonomous control application needs to be developed control based on the reference coordinates of the GPS or azimuth angle as well as the addition of air-speed sensors to improve response of the UAV full autonomous control system.

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