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ASEAN CITATION INDEX

Dear Editor of International Journal of the Computer, The Internet and Management

During the 3rd ACI Steering Committee which was held on September 10th, 2015 in Bangkok Thailand, **Asst. Prof. Teerasak Markpin**,ACI Steering Committee from **Thailand**, copied here, submitted the journal entitled **"International Journal of the Computer, The Internet and Management"**, ISSN :**0858-7027** to be included in the ACI database which is the first and the only regional citation index database for ASEAN member. More details regarding the ACI database can be found in the database website (www.asean-cites.org).

We are pleased to inform you that your journal entitled **"International Journal of the Computer, The Internet and Management"**, ISSN : **0858-7027** has been accepted and approved by the ACI Steering Committee on September 10, 2015, to be included in the ACI database.

Congratulations! Currently, there are 159 top quality journals from ASEAN member countries, namely Cambodia, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam indexed in the ACI. The number will increase in the time being.

In the mean time, please wait for our further notices on how to prepare and submit the published articles and related documents for the inclusion in the ACI database system.

Should you have any questions, please do not hesitate to contact us.

Best regards,

Attitude Control of Quadcopter Using Fuzzy PD+I Controller

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***Abstract* - Quadcopter is the nonlinear system that can be controlled by human expert couple with flight control system. This paper utilized the Fuzzy PD+I controller which optimize the stability of the quadcopter can be flying stable in roll and pitch angle minimize to zero degree which reference to the ground. Quadcopter has four motors generated the vertical thrust from their propellers to make it moved. The different of motors' speed result make vary quadcopter's attitude in nonlinear form by Fuzzy PD+I controller design, it can control quadcopter's attitude nicely. This paper compares PID controller result in Control graph that Fuzzy PD+I Controller keep roll angle and pitch angle a little bit better, it may come from parameter tuning in controller spend more time. The testing by tuning in Fuzzy PD+I controller spend less time than tuning in PID controller.**

***Keywords* - Quadcopter, PID Controller, Fuzzy PD+I Controller**

I. INTRODUCTION

The research of quadcopter has been growing fast in the recent years because it can be used for many applications quadcopter control. The first thing consider quadcopter's attitude controller flight stable in the air. The most research used PID controller. The attitude can be controlled by given a varying speed to the four motors where each motor produces different torque and thrust. With the varying speed of four motors quadcopter can move in the different motion of roll, pitch and yaw and electronic speed control equation of four motors as followed in eq. 1 to eq. 4

ESC1_RF = throttle – U_pitch + U_roll – U_yaw ....(1)
ESC2_RR = throttle + U_pitch + U_roll + U_yaw ....(2)
ESC3_LR = throttle + U_pitch – U_roll – U_yaw ....(3)
ESC4_LF = throttle – U_pitch – U_roll + U_yaw ....(4)

by

throttle: manual throttle's stick by outside pilot

U_roll: handling from roll angle balance control system

U_pitch: control from pitch angle balance control system

U_yaw: control from direction angle balance control system

The control system of quadcopter consists of Arduino Uno controller board, 4 units of electronic speed control, 4 units of brushless motor, GY521 (3-Axis Accelerometer / Gyroscope Module) and quadcopter frame. The ready to fly of experimental quadcopter as shown in Fig. 1.

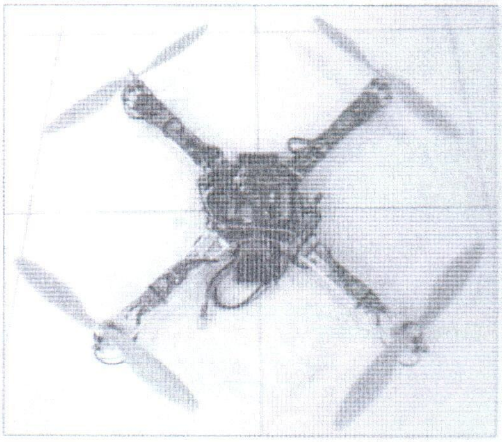

Fig. 1 The Experimental Quadcopter

Quadcopter control is Semi-Automatic type controlling by outside pilot that it will be external loop control of control system which is flight control in direct position. This control system is controlled in roll angle, pitch angle and yaw of quadcopter. Controller part refer to this paper is internal loop control for stabilizing in attitude of quadcopter meanwhile it is no controlling by outside pilot and still keeping attitude at zero degree of roll angle and pitch angle.

II. THEORY

Fuzzy PD+I controller is designed to have two inputs membership function as error and error rate and one output membership function as U_control. Error is defined as roll (n) - roll (desired) for roll angle and pitch (n) – pitch (desired) for pitch angle which are the values from attitude sensor, GY521.

The control system has three close-loop to control the roll angle, pitch angle and yaw angle of quadcopter. The error and error rate of input membership function have three linguistic variables, i.e. Negative, Zero, and Positive. The output of U_control for roll, pitch and yaw have the membership function models which are different from the Trapezoid Fuzzy sets of input membership function, and singleton Fuzzy sets of Negative, Zero and Positive are used for output membership function.

The input and output membership function of Fuzzy sets are shown in Fig. 2 to Fig. 4.

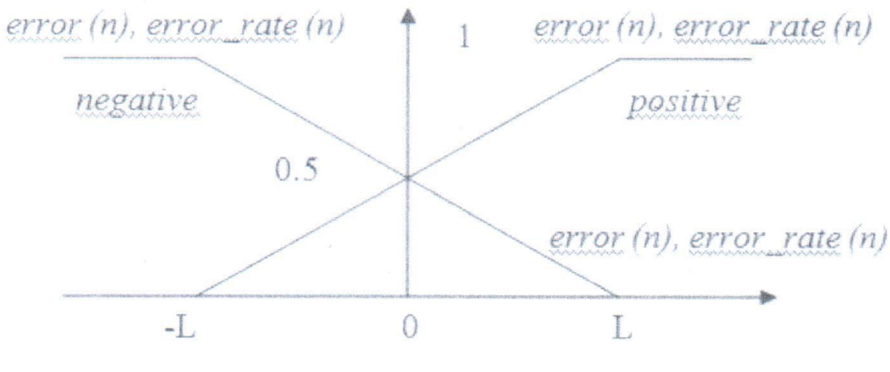

Fig. 2 Input Membership Function of Fuzzy PD

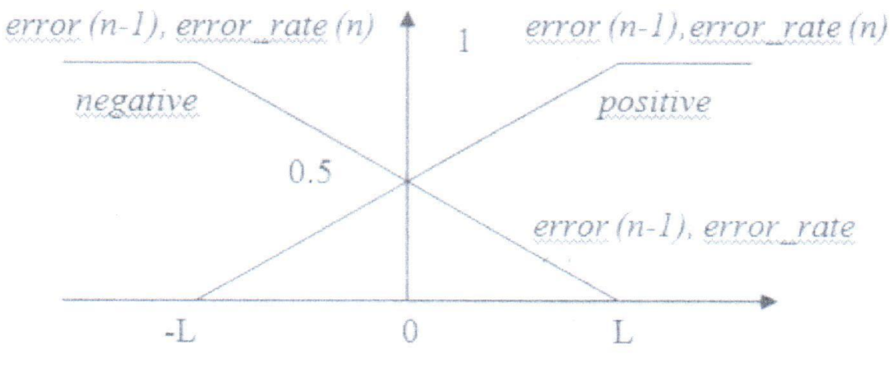

Fig. 3 Input Membership Function of Fuzzy I

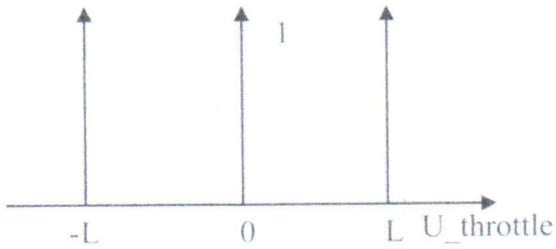

Fig. 4 Output Membership Function of Fuzzy PD and Fuzzy I

The block diagram of Fuzzy PD+I controller is shown in Fig. 5.

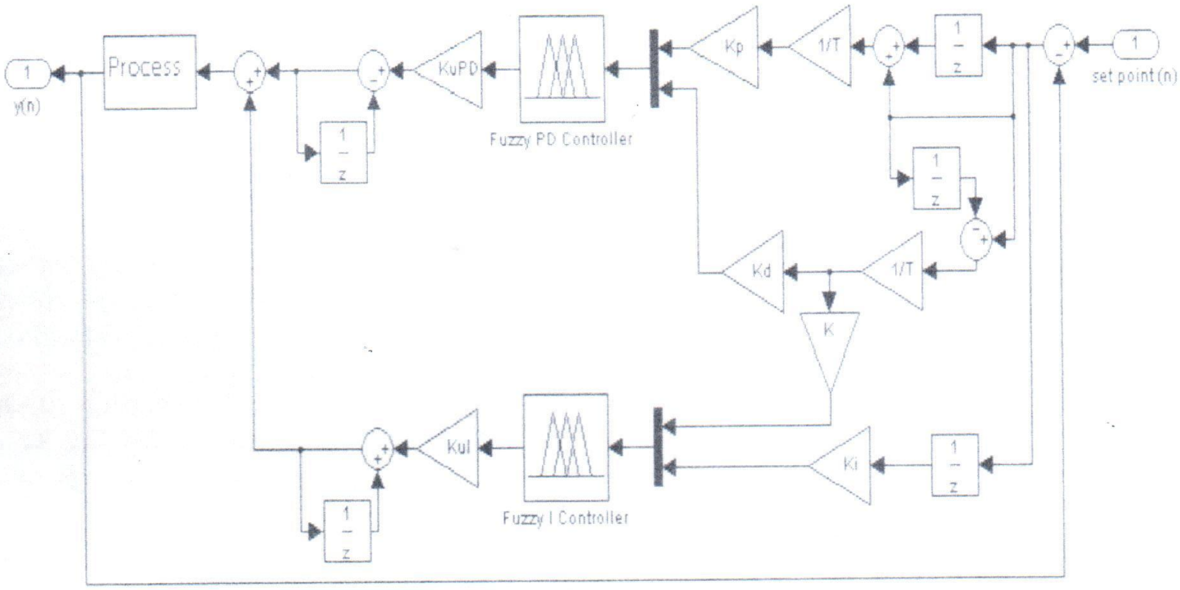

Fig. 5 Block Diagram of Fuzzy PD+I Controller

The next step is to design the Fuzzy rules base for Fuzzy PD and Fuzzy I as shown in table I and table II.

TABLE I
FUZZY PD RULES BASE

Rule base	*Error (n)*	*Error_rate (n)*	Output
R1	P	P	0
R2	P	N	L
R3	N	P	-L
R4	N	N	0

TABLE II
FUZZY I RULES BASE

Rule base	*Error (n-1)*	*Error_rate (n)*	Output
R5	P	P	L
R6	P	N	0
R7	N	P	0
R8	N	N	-L

The defuzzification step of which the Centre of Mass method was used in this research is based on the following eq. (5).

$$\Delta u(nT) = \frac{\sum\{membershipvalue\ of\ input\ x\ corresponding\ output\}}{\sum\{membershipvalue\ of\ input\}} \quad \text{..........(5)}$$

III. EXPERIMENT AND DISCUSSIONS

We built the controller base on Arduino Uno to complete the control unit as the control diagram as in Fig. 6.

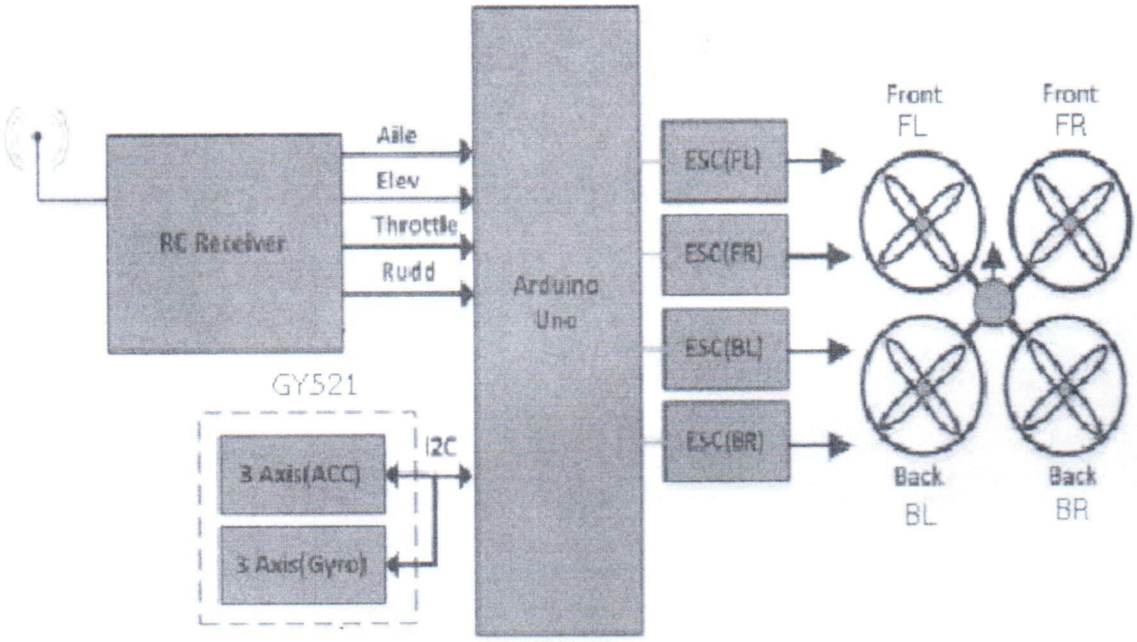

Fig. 6 Control Diagram of Quadcopter

The experiment was setup with 450 mm. size quadcopter as mentioned above after doing many trial and error experiments to get the best performance of quadcopter to fly stable in the air. All parameters of Fuzzy PD+I included inputs and output membership function range values were tested many times until got the system stability as in Fig. 7. and Fig. 8.

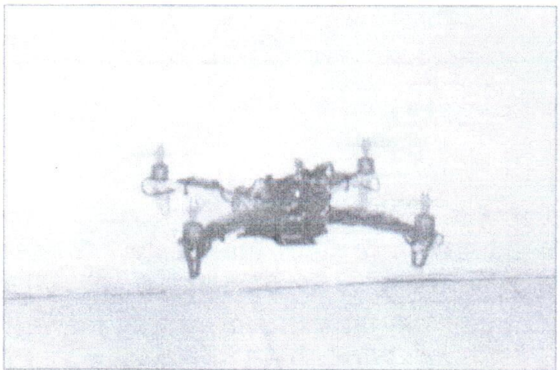

Fig. 7 Quadcopter was Flying Stable in the Lower Air

Fig. 8 Quadcopter was Flying Stable in the Higher Air

The set values control parameters refer to Fig. 4, are:

L = 800, k = 6, ki = 0.1 , kp = 3.5, kd = 0.1

We also setup the attitude control of roll and pitch angle with PID controller and the final control parameters to make the quadcopter can fly stable in the air which the set value control parameters are:

P = 1.3, I = 0.04, D = 15.0

The attitude control is comparison the results of roll and pitch angle between Fuzzy PD+I controller and PID controller can shown in Fig. 6, Fig. 7, and Fig. 8.

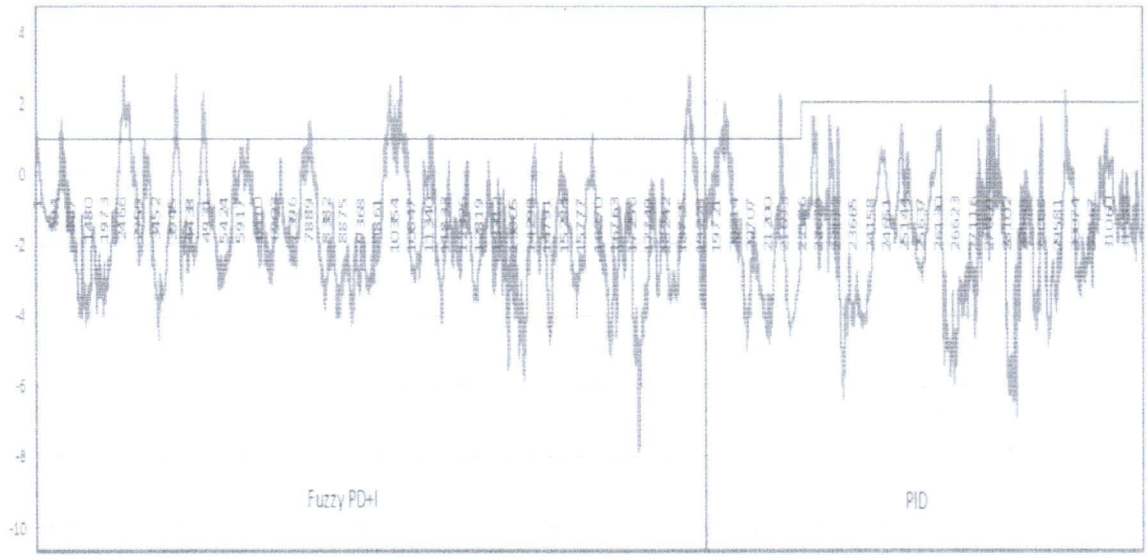

Fig. 9 Attitude Control of Quadcopter's Roll Angle

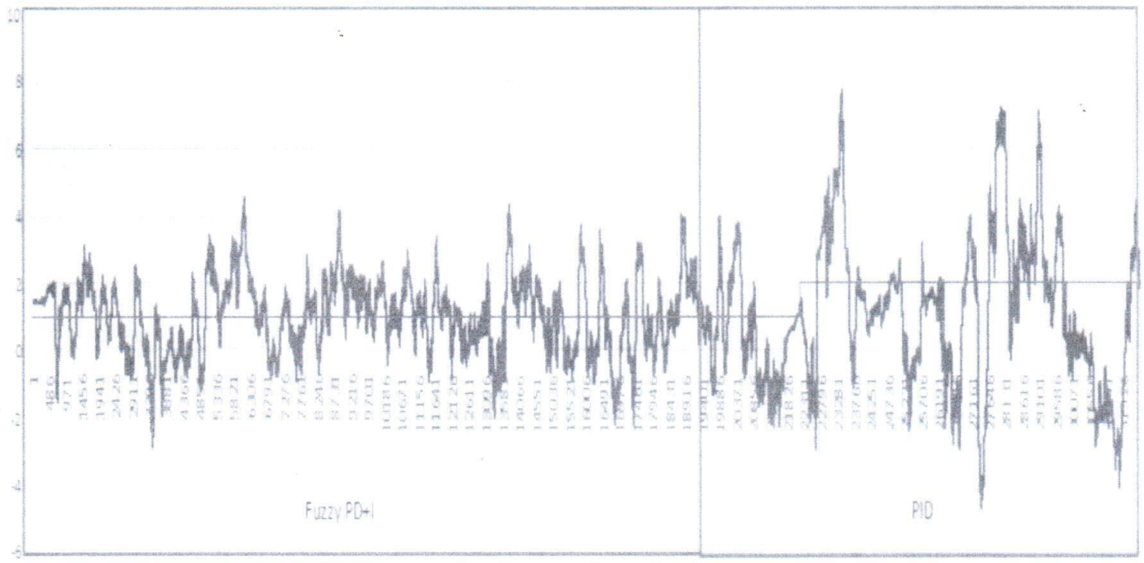

Fig. 10 Attitude Control of Quadcopter's Pitch Angle

IV. CONCLUSIONS

Experiments result for attitude control of roll and pitch angle which make sure the Fuzzy PD+I and PID controller can controllable to make the quadcopter can be flying stable in the air with minimize the error of roll and pitch angle close to zero. The PID parameters were more difficult to tune than the Fuzzy PD+I parameters but the Fuzzy PD+I have more parameters than PID controller. These are more challenge and spend of time to find out the numbers that suitable for each controller. If the numbers were not correct it should be safe the quadcopter from the accident because of unstable flight will be occurred. And the experiment was shown that the Fuzzy PD+I will advantage in PID controller refer to amplitude of fluctuations to be close to zero of Fuzzy PD+I better than the PID controller which Fuzzy PD+I can response to the nonlinear system better than the PID controller.

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(Arranged in the order of citation in the same fashion as the case of Footnotes.)

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