International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

Vol. 31 No. 1 February 2022, pp. 215-222

# *Fuzzy Logic and PID Control of Quadrotor Translational Motion*

ANDRIAMANALINA Ando Nirina[1], RANDRIAMITANTSOA Andry Auguste[2], RANDRIAMITANTSOA Paul Auguste[3]

[123] Doctoral School in Science and Technology of Engineering and Innovation (ED – STII)

[123] Research Laboratory in Telecommunication, Automation, Signal and Images

[123] University of Antananarivo, BP 1500, Antananarivo 101 - Madagascar.



**Abstract—This research paper is about fuzzy logic and PID control of quadrotor. The goal is to control the position, time response of quadrotor by choosing proportional, integral and derivative coefficient of PID controller with fuzzy logic and all parameters for reliable performance. With Simulink simulation of translational motion by step input, ramp input and personalized input, we can see that, fuzzy logic controller with PID is performant.**

**Keywords—Error; Precision; Fuzzy; Control; PID**

## I. INTRODUCTION

For any system, precision, time response and stability are defaults proprieties. Thus, the output must follow the input and time response should be as fast as possible. For quadrotor, the motion is controlled by varying each of four motor speeds to obtain a desired effect that causes movement. Translational motion and rotational motion of quadrotor must be controlled for reliable performance. Here, Fuzzy logic and PID are used to control translational motion of quadrotor [1].

## II. EQUATION MOTION OF QUADRIROTOR

With, Newton-Euler model, we can have translation and rotatioal motion equation of quadrotor. For rotational motion, to illustrate respectively yaw motion, pitch motion and roll motion, three angles namely $\psi$, $\theta$ and $\varphi$ are used [2].

These angles are expressed by:

$$-\pi < \psi < \pi \tag{1}$$

$$-\frac{\pi}{2} < \theta < \frac{\pi}{2} \tag{2}$$

$$-\pi/2 < \varphi < \pi/2 \tag{3}$$

### 2.1. Translation motion equation

The translation motion equations along OX, OY and OZ axes are expressed by [2]:

$$\ddot{x} = [\sin(\psi)\sin(\varphi) + \cos(\psi)\sin(\theta)\cos(\varphi)\ ]F/m \tag{4}$$

$$\ddot{y} = [\sin(\psi)\sin(\theta)cos(\varphi) - \cos(\psi)\sin(\varphi)]F/m \quad (5)$$

$$\ddot{z} = -g + \cos(\varphi)cos(\theta)F/m \quad (6)$$

Where g and m are, the gravity and the weight of the drone.

### 2.2. Rotational motion equation

For rotational motion equation, the acceleration according to the angles of rotation is expressed by :

$$\begin{pmatrix} \ddot{\psi} \\ \ddot{\theta} \\ \ddot{\varphi} \end{pmatrix} = \begin{bmatrix} lb(\omega_4^2 - \omega_2^2)/I_X \\ lb(\omega_3^2 - \omega_1^2)/I_Y \\ d(\omega_1^2 - \omega_2^2 + \omega_3^2 - \omega_4^2)/I_Z \end{bmatrix} \quad (7)$$

Where $I_X$, $I_Y$ and $I_Z$ represent respectively inertia moment of OX, OY and OZ.

## III. Control Design System

When the output system does not follow input, a close loop mechanism of system is used to control output by error measurement [3].

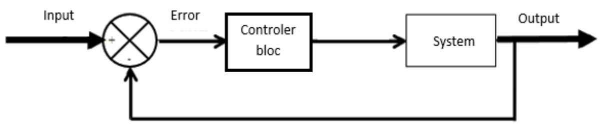


Fig. 1. Close loop

The corrector introduced is used to correct the output of the system. PID is a classical control method for Proportional (P) Integral (I) and Derivative (D), control action. In this paper, the goal is to minimize the error between the actual system output and the desired by choose PID coefficient with fuzzy logic controller.

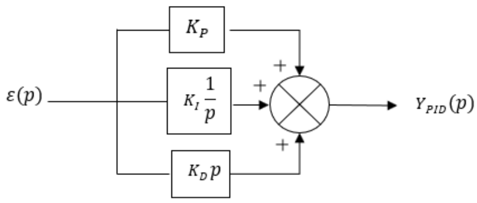


Fig. 2. PID system

Where Ɛ is the error, $Y_{PID}$ the output of PID controller.

$$y_{PID}(t) = K_p\varepsilon(t) + K_i\int_0^t \varepsilon(\tau)d\tau + K_d\frac{d\varepsilon(t)}{dt} \quad (8)$$

## IV. Logic Controller of Quadrirotor

Fuzzy logic is a mathematical theory, based on degree of truth, defined as a many-valued logic form which may have truth values of variables in any real number between true and false .Fuzzy logic process is based in three stages: fuzzification, inference and defuzzification [4] [5].

With (3), (4) and (5), fuzzy logic controller of quadrotor is describe by Fig. 3. and Fig. 4..

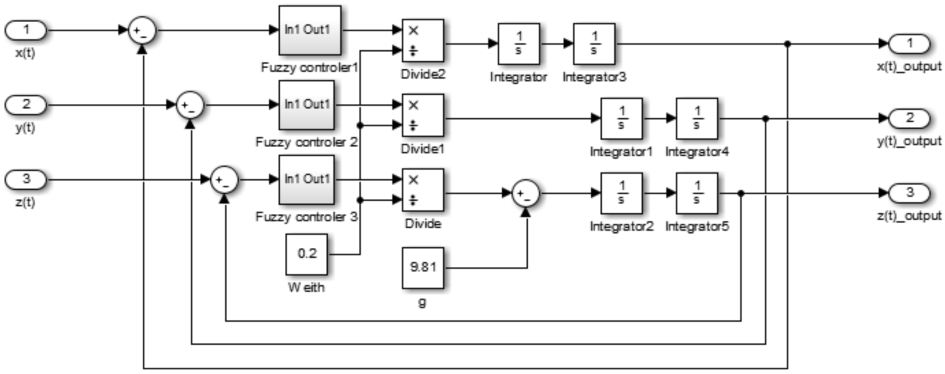


Fig. 3. Translation motion block with Fuzzy controller block

Fuzzy controller 1, Fuzzy controller 2 and Fuzzy controller 3 on Fig -3 are respectively motion controller for x translation, y translation and z translation is. These are described by a Fuzzy controller block in Fig. 4.

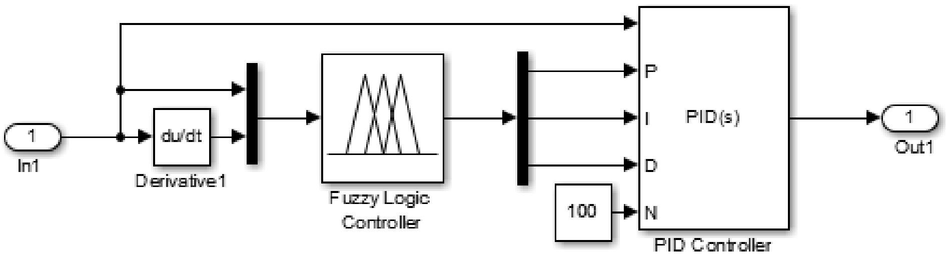


Fig. 4. Fuzzy controller block

### 4.1. Fuzzification

Here, inputs of fuzzy controller are the error and derivate of error or “dError”. Outputs are PID coefficient, so we have three output sets: Proportional output or “outputP”, Integral output or “outputI” and derivate output or “outputD”.

During fuzzification process, we suppose that :

- Error is between [-1; 1] and can take three possible values, less, near or greater than zero. Three input sets of Fuzzy controller are ELZ or Error is Less than Zero, ENZ or Error Near Zero and EGZ or Err or is Greater than Zero.

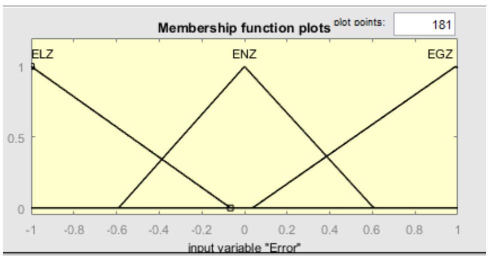


Fig. 5. Fuzzy partition of input error

- Derivate of error or dError is between [-1; 1] and like error value, can take three possible values, less, near or greater than zero. Three input sets are DLZ or Derivate is Less than Zero, DNZ or Derivate Near Zero and DGZ or Derivate is Greater than Zero.

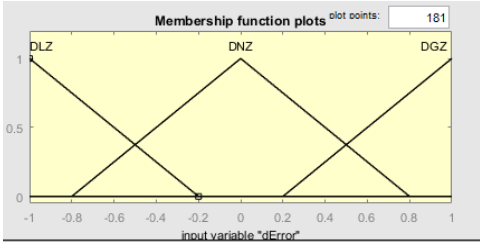


Fig. 6: Fuzzy partition of input derivate error

- Output, for proportional coefficient or “outpuP”, is between [9 ; 12] and can take three possible values, when error is less, near or greater than zero. Three output sets are OELZ or Output when Error is Less than Zero, OENZ or Output when Error is Near Zero and OEGZ  or Output when Error is Greater than Zero.

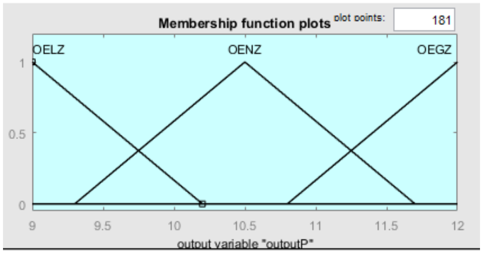


Fig. 7. Fuzzy partition of output Proportional coefficient

- Output, for integral coefficient, is between [9;11] and can take three possible values, when error is less, near or greater than zero. Three output sets like proportional coefficient are OELZ or Output when Error is Less than Zero, OENZ or Output when Error is Near Zero and OEGZ or Output when Error is Greater than Zero.

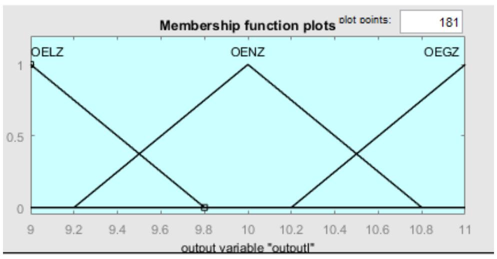


Fig. 8. Fuzzy partition of output Integral coefficient

- Output of Derivate is between [1;3] and like error value, can take three possible values as, less, near or greater than zero. Three output sets like proportional an integral coefficient are OELZ or Output when Error is Less than Zero, OENZ or Output when Error is Near Zero and OEGZ or Output when Error is Greater than Zero.

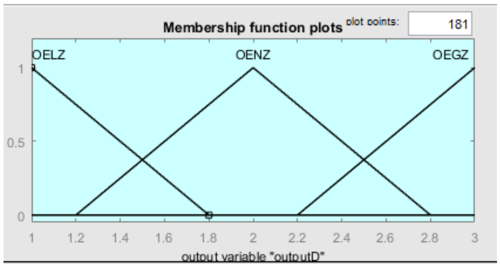


Fig. 9. Fuzzy partition of output of derivative output coefficient

### 4.2. Fuzzy inference

Rules used are:

- If (Error is ELZ) and (dError is DLZ) Then (OutpuP is OELZ) and (OutpuI is OELZ) and (OutpuD is OELZ)
- If (Error is EGZ) and (dError is DNZ) Then (OutpuP is OELZ) and (OutpuI is OEGZ) and (OutpuD is OELZ)
- If (Error is EGZ) and (dError is DLZ) Then (OutpuI  is OENZ) and (OutpuD is OENZ) and (OutpuD is OELZ)

### 4.3. Defuzzification

The input for the defuzzification process is a fuzzy set and the output is a single number [5].

## V. Translation Motion Control Process

To appreciate, performance of fuzzy logic controller, during simulation, step, ramp and sinusoidal input are used.

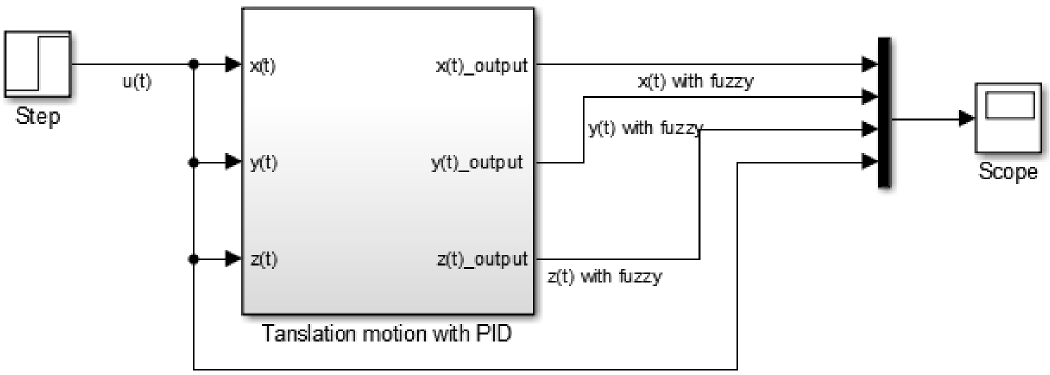


Fig. 10. Simulink model of translation motion control

All inputs, for position, speed, and personalized control of motor, inputs are defined by:

$$x(t) = u(t) \tag{9}$$

$$x(t) = r(t) \tag{10}$$

$$x(t) = \sin(2\pi 0{,}2t) \tag{12}$$

Where x(t) is the input, u(t) is unit step signal and r(t) is ramp signal.

## VI. RESULTS

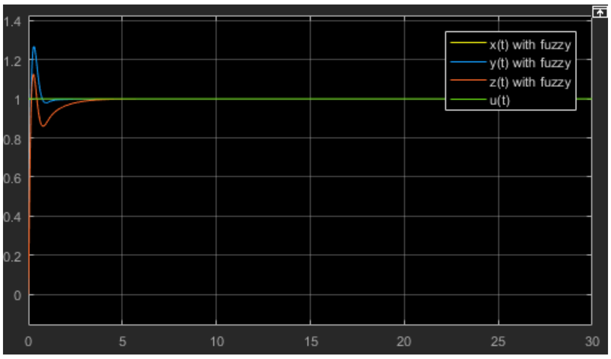


Fig. 11. Response for step input

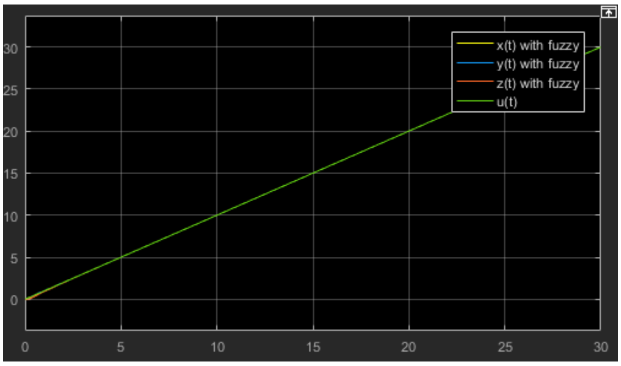


Fig. 12. Response for ramp input

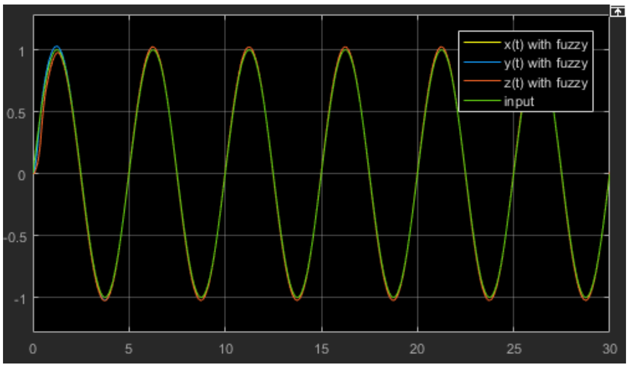


Fig. 13. Response for sinusoidal input

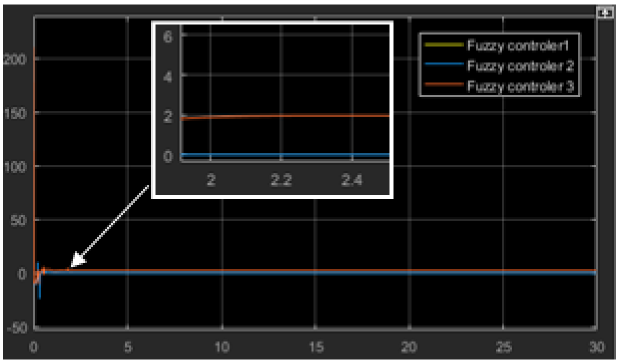


Fig. 14. Output of fuzzy controller with step input

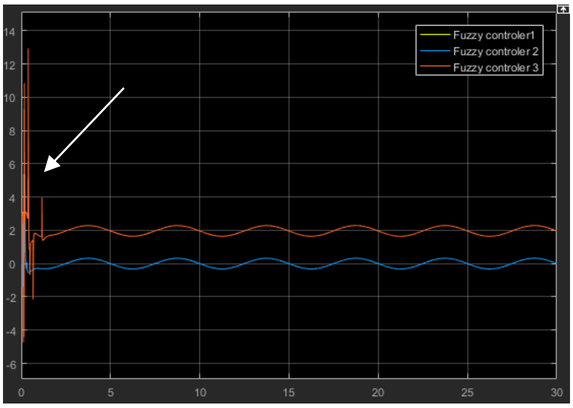


Fig. 15. Output of fuzzy controller with sinusoidal input

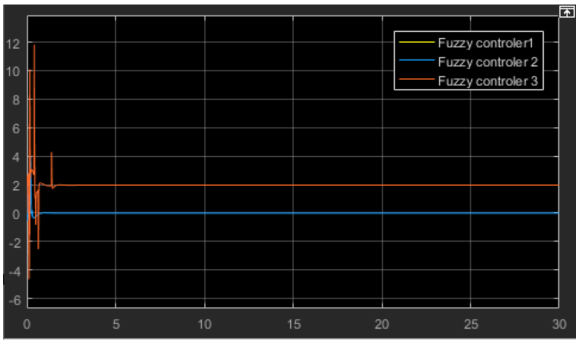


Fig. 16. Output of fuzzy controller with ramp input

- From Fig. 11, Fig. 12 and Fig. 13, with fuzzy logic controller, all outputs follow inputs.
- From Fig. 14, Fig. 15 and Fig. 16, the output of the fuzzy controller 1 and 2 are the same but zero for fuzzy controller 3.
- For all inputs, the level difference between the output of fuzzy controller 1 and the output of fuzzy controller 3 is always equal to two.

## VII. Conclusion

For, Fuzzy logic the efficiency also depends on the number of fuzzy sets used at the input and output level. Fuzzy controller parameters like input and output range value depend on the system property. For PID, the proportional coefficient, the integral coefficient and the derivation coefficient also depend on the propriety of the system. Control of a translation motion quadrotor, with a combination of Fuzzy controller and PID is performant.

## REFERENCES

[1] C. Graham, F. Stefan, E. Mario, “Control Design System”, Prentice Hall, 2001.

[2] A. N. Andriamanalina, A.A. Randriamitantsoa, P. A. Randriamitantsoa, “Mathematical modelling of quadrotor“, IJARIIE, v8-I1, 2022.

[3] C. Chen, “Analogic and Digital Control Design System” Saunders College Publishing, 2006.

[4] M. Hichem, “Intelligent control for a drone by self-tunable fuzzy inference system,” Conference Systems, Signals and Devices (SSD), 2009.

[5] F. Dernoncourt, “Introduction to fuzzy logic”, MIT, 2013.