

# Comparison of PID and Fuzzy Controller for Position Control of AR.Drone

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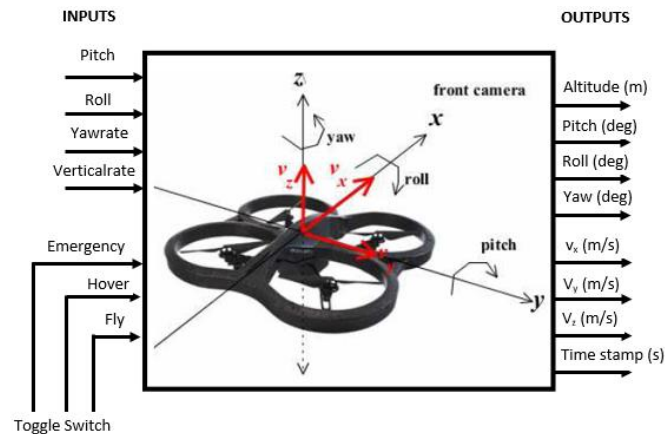
**Abstract.** This paper describes the implementation of the PID Controller to control the position of the AR.Drone in the x-y-z. This position control scheme uses three PID controllers to maintain the position of x, y and z using the signal control pitch, roll and vertical rate. PID Controller implemented on AR.Drone 2.0 and then tested in an indoor space. The performance of the controller will be compared with Fuzzy Logic Controller schemes that have been implemented previously. The results show that the PID Controller generate a response with rise time less than 3 seconds at the x and y position with around 25% overshoot. The result for z position give better result without overshoot. The comparison between fuzzy logic and PID Controller indicates that the results of the PID controller is better although there is overshoot.

## 1. Introduction

Currently, the AR.Drone is widely used by researchers for its research platform. AR.Drone was chosen because it is relatively inexpensive but has onboard controller and internal software. AR.Drone body constructs from frame which made of carbon pipe with 4 brushless motors complete with propellers and the main body is made of plastics fiber in which there are onboard electronics and Lithium-Polymer (Li-Po) battery. User can access controller via Wi-Fi communication. The onboard controller consists of motherboard and navigation board. On the motherboard, there are the processor, front camera, bottom camera, and Wi-Fi chips. On the navigation board there is a microcontroller board that use as an interface to the sensors. AR.Drone equipped with accelerometer, gyroscope and ultrasonic altimeter [1].

AR.Drone maneuver can be controlled using 4 control signals (values between -1 and 1): pitch (positive values for backward, negative values for forward), roll (positive values for move to right, negative values for move to left), yawrate (positive values for the movement pivot clockwise, negative values for the movement pivot counterclockwise) and vertical rate (positive values for vertical rate to up, negative values for vertical rate to down). Moreover, there are 3 toggle switches for fly, hover and emergency command. Navigation data can be accessed from the AR.Drone includes the actual pitch, forward speed, actual roll, sideward speed, actual yaw, vertical speed, altitude, and time stamp. Using this data we can estimate the x,y,z position of the drone. Figure 1 show the inputs and outputs of the AR.Drone system.





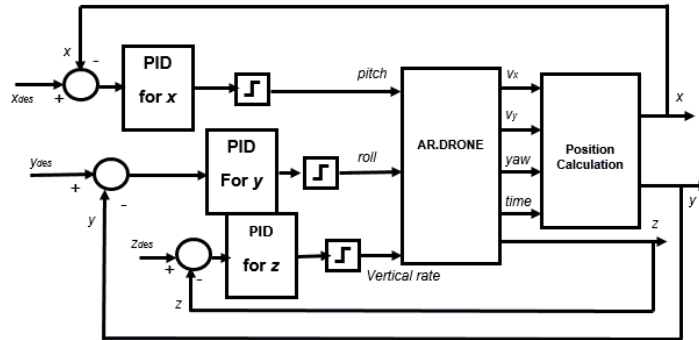
**Figure 1.** AR.Drone Inputs – Outputs.

Many studies have described a variety of development and application using the AR.Drone. Michael [2] created LabVIEW Toolkits consisting of Main VI, Video VI, NavData VI, and Additional Supporting VI to control the AR.Drone. This software has the ability to transmit control commands and keep the communication channel running, read UDP packets that contain video frame sent from the AR.Drone, sends UDP packets that contain sensor's navigation data output to the IP address of the computer and estimate x, y, z position of the navigation data. Krajnik [3] formulated four AR.Drone structure models which has input output relations: setpoint pitch - actual pitch - forward speed; setpoint roll - actual roll - sideward speed, setpoint yaw rate - actual yaw rate - yaw, and setpoint vertical rate - actual rate vertical - altitude. Agung [4] calculated model of roll, pitch, yaw rate and critical rate with a step response test on the AR.Drone 1.0. Sarah [5] identified the model parameters of the internal and dynamic model of AR.Drone using second order system approach. Some control scheme are designed and implemented the the model obtained. The control schemes are waypoint navigation controller, leader-follower behavior, trajectory-following behavior. Agung [6] designed a fuzzy scheme trajectory tracking control for applications in x-y coordinates. This fuzzy scheme has two inputs that distance, angle and has two outputs, namely pitch, yawrate. Fuzzy control scheme tested on straight and curved trajectory. Veronica [7] implemented fuzzy logic control for waypoint navigation applications. This fuzzy scheme uses three fuzzy logic to control pitch, roll and vertical rate respectively with each input in the form of desired position and the actual position. Three scenarios were designed and implemented for the waypoint problem. The test results indicate that the fuzzy scheme can be used for waypoint applications. Veronica [8] implemented position control of ar.drone by using two fuzzy control. The first fuzzy used to control pitch and yawrate simultaneously with the input of distance and angle, while the fuzzy second is used to control the vertical rate using the input of desired and actual position z.

This paper reports the development of the PID controller scheme to control the position of the AR.Drone in the x-y-z. The result then compares with fuzzy control schemes that have been implemented in [8].

## 2. PID Controller Design

The design of PID Controller that will be implemented in this study is shown in figure 2. It can be seen that each position x, y and z of the drone will be controlled by individual PID. Input of each PID is error x, error y and error z, and the output is pitch, roll and vertical rate respectively. In this paper, PID controller design procedure is as follows:



**Figure 2.** Block diagram of control system.

- Understanding the dynamics of the system AR.Drone. To understand the dynamics of the system, do the step response test on the system pitch, roll and vertical rate of AR.Drone by giving a value ranging from -1 up to 1. Navigation data such as actual pitch, forward speed, x, actual roll, sideward speed, y, vertical rate, and z are recorded and analyzed.
- From the data obtained, considering the limitations of indoor space there should be restrictions on the control signals. Pitch in the range of -0.115 to 0.115, roll in range of -0.125 to 0.125
- Formulate each subsystem PID controller, figure 3, into a computer program. For easy programming and implementation, the PID equation converted as follow.

$$PID = K_P e(t) + K_I \int e(t) + K_D \frac{de(t)}{dt} \quad (1)$$

$$PID = K_P * error + (K_I * integral * dt) + (K_D * \frac{derr}{dt}) \quad (2)$$

where:

$K_P$  : Proportional Constant

$K_I$  : Integral Constant

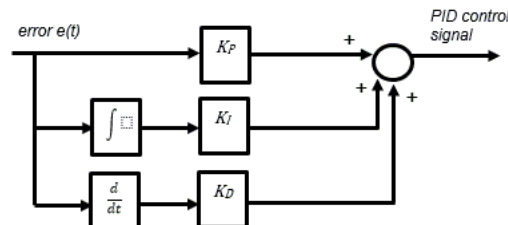
$K_D$  : Derivative Constant

$error = desired\ point - actual\ point$

$integral = integral_{previous} + error$

$derr = error - error_{previous}$

$dt$  : execution time



**Figure 3.** Block diagram of PID.

- Realize the system into computer program, block diagram and front panel.
- By trial and error, tune the PID parameter until obtain the best response. The obtained parameter is tabulated in table 1.

**Table 1.** PID Parameters.

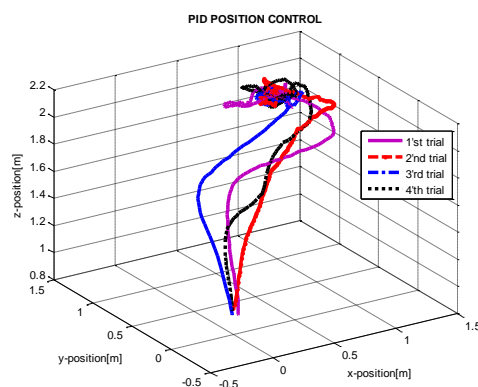
Parameters	Values		
	PID for pitch	PID for roll	PID for vertical rate
Kp	1.6	1.6	1
Ki	0.005	0.005	1
Kd	0.5	0.5	2

### 3. Results and Analysis

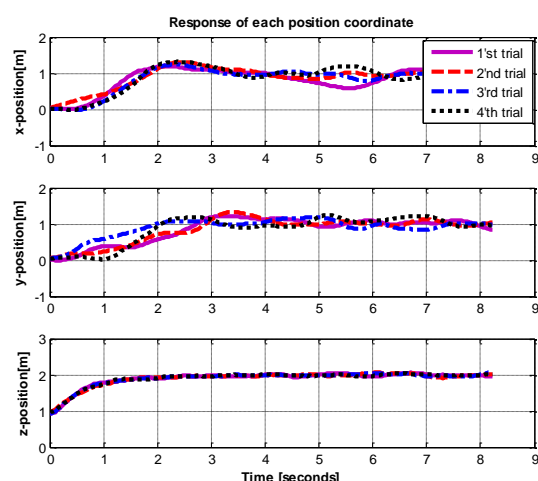
PID controller is implemented on the AR.Drone 2.0 and flown at indoor laboratory. The testing process is conducted as follows:

- From the front panel, specify the setpoint position  $x$ ,  $y$  and  $z$ , which are trying to reach by the AR.Drone.
- With the push button on the front panel, AR.Drone fly hover as high as 1 m. The hover position is considered as the initial coordinat (0,0,0).
- Then switch OFF hover in front panel, AR.Drone will fly autonomous with PID Controller designed to the setpoint. During flew the flight data is recorded.
- When it reaches the intended position, indicated hover fly, AR.Drone is landed.

The results of four time testing at the set point (1,1,1) are shown in figure 4 and figure 5. Figure 4 are 3-D representation, while figure 5 is 2-D representation of the AR.Drone response.



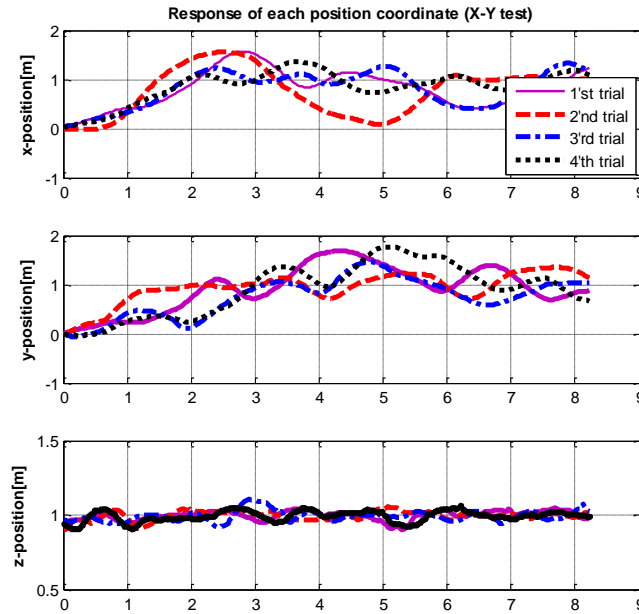
**Figure 4.** Experiment result of PID Position Control in 3-D.



**Figure 5.** Experimental results of PID Position Control in 2-D.

From the test results, figure 5, it appears that the AR.Drone can reach the desired position with a rise time of about 2 seconds, has about 25% overshoot and settling time of about 4 seconds. From 3-D graphics, figure 4, it appears that the AR.Drone experienced oscillations around the setpoint.

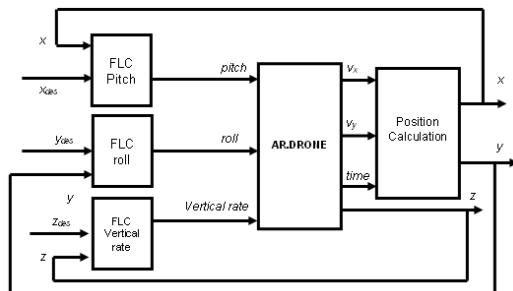
Tests were also done on the set point (1,1,0) to see the response AR.Drone in flight the x-y plane. The results of four time testing are shown in figure 8.



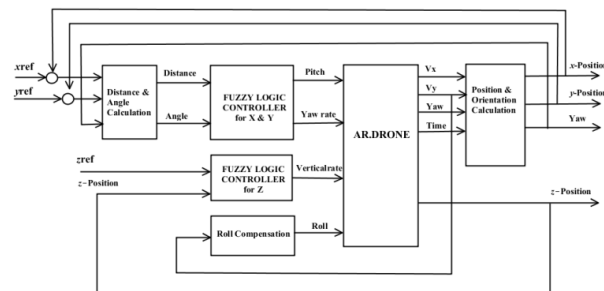
**Figure 6.** Experimental results of PID Position Control in 2-D.

#### 4. Comparison with Fuzzy Control Scheme

Results PID position control is compared with the Fuzzy position control implemented by Veronica [8], where the fuzzy scheme is shown in figure 7 and figure 8:



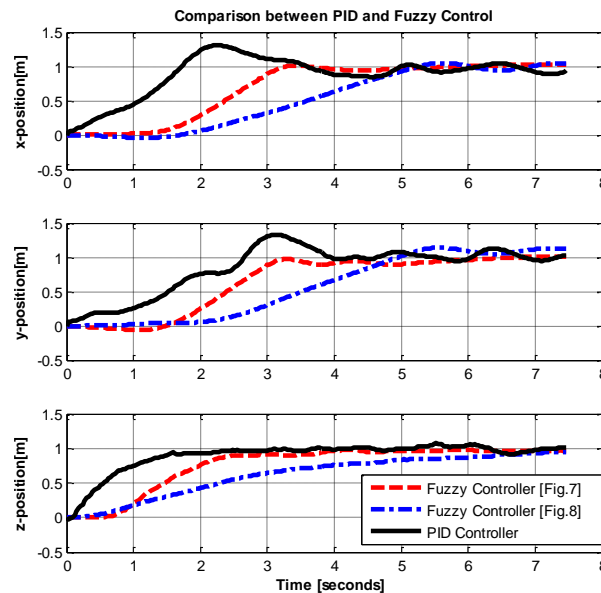
**Figure 7.** First fuzzy scheme implemented on [8].



**Figure 8.** Second fuzzy scheme implemented on [8].

Similar to the PID Controller scheme, scheme in figure 7, uses three pieces of FLC controller to control pitch, roll and vertical rate simultaneously. Each fuzzy input is the desired position and the actual position. While scheme in figure 8 uses only two pieces of fuzzy control for pitch and yawrate simultaneously and fuzzy logic for the vertical rate.

The results of the comparison PID response with two fuzzy schemes that has been done is shown in figure 9. It is noticeable that the PID controller generates a better response both in the x, y and z, but has a slightly higher overshoot



**Figure 9.** Comparison of two control schemes.

## 5. Conclusion

To control position of  $x$ ,  $y$ ,  $z$  of the AR.Drone can be realized with three PID controller to manipulate the pitch, roll and vertical rate. The implementation results show that PID controlled system gives response with a rise time of about 2 seconds, 25% overshoot and settling time of about 4 seconds. The results of the comparison between PID controlled system and fuzzy controlled system, the PID controlled system gives better result in this experiment.

## References

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