Comparison of Two Fuzzy Logic Controller Schemes for Position Control of AR.Drone

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Abstract — **This paper explains the AR.Drone position control scheme using Fuzzy Logic Controller (FLC) in a 3 dimensional coordinate. This control scheme uses two FLC block, for X-Y position and Z position. The inputs of FLC block for X-Y position are distance and angle, while the output is pitch and yaw rate. Z-position will be controlled by another FLC block, which has two inputs, namely setpoint of z and real position of z, while the output is vertical rate. To compensate the sideward speed of the drone, roll compensation is used. The implementation results show that the AR.Drone can achieve the desired position with settling time for x, y position approximately 6 seconds, while z position around 10 seconds. Response x has the oscillation of approximately 5% around the set point. The implementation result are also compared with other fuzzy control for the same setpoint position**

Keywords—AR.Drone position control; fuzzy logic control;roll compensation; pitch compensation

I. Introduction

AR.Drone is one of Parrot's quadrotors which is widely used as a research platform in some universities in the world nowadays. AR.Drone is preferred because it is reasonably priced and has additional sensors, as well as included onboard controller and internal software. At first, AR.Drone was made as a toy which can be played using applications that can be downloaded from Google Play for Android devices or AppStore for iOS devices, namely AR.FreeFlight 2.0 and AR.Race 2. The launching of Software Development Kit (SDK) enables users to access the internal controller of AR.Drone through Wi-Fi communication, so they can maneuver said AR.Drone using various control algorithm made beforehand.

AR.Drone is constructed of the x-form frame, which is made of carbon fiber pipe tip. Of which ends' are brushless motors complete with propellers. In its middle frame the main body is made of plastic fiber in which there is onboard electronics, 2 cameras (front and bottom) and Lithium-Polymer (Li-Po) battery. In the onboard electronics there are 2 board, namely motherboard and navigation board. On the motherboard are the processor, Wi-Fi chips, front and bottom camera. While navigation board is equipped with a microcontroller board that act as interface to the sensor. The sensors used are accelerometer, gyroscope and ultrasonic altimeter [1].

In this research, the type of the AR.Drone used is type AR.Drone 2.0 Elite Edition, Fig.1 [1]. The AR.Drone has 4 inrunner brushless motors 14.5W 28,500 RPM. The motherboard equipped with 32-bit ARM Cortex A8 1GHz processor with 800MHz DSP TMS320DMC64x video, 1GB DDR2 RAM at 200MHz, 60 FPS QVGA vertical ground speed cameras for measurement, USB 2.0 high speed for extensions, Wi-Fi chips, HD Camera 720p 30 fps. While navigation board has 3-axis gyroscopes 2000°/second precision, three axis accelerometers +/- 50 mg precision, three-axis magnetometers 6° precision , Pressure +/- 10 Pa precision sensors, ultrasound sensors for measurement of ground altitude. And the internal software used is Linux 2.6.32 [2].

With the Wi-Fi communication, the user is able to access drone internal controller drone from a computer in a ground station. The user can maneuver the AR.Drone's flight by providing a range of value -1 to 1 on pitch, roll, yaw rate and vertical rate. Pitch is used to move backward (+) and forward (-), roll used to move to the right (+) and left (-), yaw rate used for the movement pivot clockwise (+) and pivot counterclockwise (-) while vertical rate to up (+)and down (-).

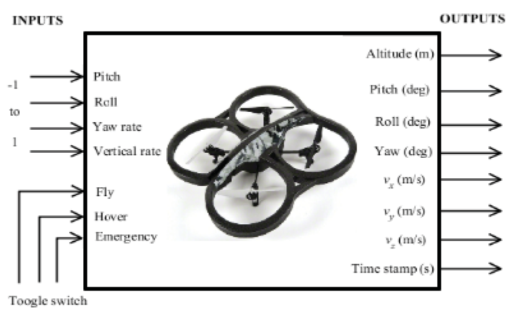

Fig. 1. AR.Drone Inputs – Outputs

There are many research conducted using AR.Drone as its platform. Some of them are described here. Michael [3] created software to control AR.Drone using LabVIEW. Some subVI made, there are Main VI, Video VI, NavData VI, Supporting VI and Additional VI. Main VI is used to transmit control command and keep the communication channel running. Video VI is used to read UDP that contain video frame packets sent from the AR.Drone, turn it into an image or pixel clusters. NavData VI sends UDP packets to the nav data output who ordered AR.Drone to send sensor's data to IP address of the computer. While one additional VI made is State VI is used to estimate x,y,z position of the nav data. Krajnik, Vonasek, Fiser, Faig [4] indicates that the AR.Drone can be used as a platform for research and education. They show how to identify AR.Drone model parameters by experiments and some algorithm for autonomous navigation. Some of them are position scheme, hovering over an object, visual based navigation and some experiment for mobile localization system and autonomous surveillance. Sun Yue [5] conducted the experiment to get AR.Drone model parameters. Then they designed position control using local controller scheme, global controller and filter. The local controller scheme uses PID controller to control the pitch, roll, yaw and height of the drone while the filter used to filter the noise of sensor. The global controller also uses PID controller to control x and y position of the drone from a Kinect® sensor. Agung, Veronica, Gabriel [6] design and implement fuzzy logic controller for trajectory tracking of an AR.Drone in 2-dimension x-y. Fuzzy is implemented using 2 inputs, namely distance and angle while the output is pitch and yaw rate. Control system has been successfully tested in straight trajectory, upright and curved trajectory. Sarah [7] conducted experiment to identify the model parameter of the internal model AR.Drone and AR.Drone dynamic models. Further to the model gained some control scheme are designed and implemented, which include waypoint navigation controller, trajectory-following behavior, leader-follower behavior and so forth. Agung, Veronica, Thomas [8] design and implement 3 fuzzy logic control scheme for waypoint navigation. The inputs of third fuzzy control scheme are x_{ref} and x, y_{ref} and y, z_{ref} and z. Whereas the output are pitch, roll and vertical rate. This control scheme will be use as a comparator in this paper.

In this paper, the author will develop the control scheme in [6] that can be used to control 3-dimensional position *x-y-z*, implement the fuzzy logic controller then compares it with other fuzzy control scheme has been implemented in [8].

II. Fuzzy Logic Controller Design

Control architecture used in this paper is a development of the control scheme, which was used in [6], is shown in Fig.2. Two blocks of Fuzzy Logic Controller (FLC) are used to control AR.Drone position. The first FLC block (existing controller) used to control X and Y position of the AR.Drone, while the second FLC block (additional) is responsible to the altitude (Z-position) of the AR.Drone. To compensate the sideward shift, roll compensation is used. Explanation of each FLC block will be explained in the next paragraph.

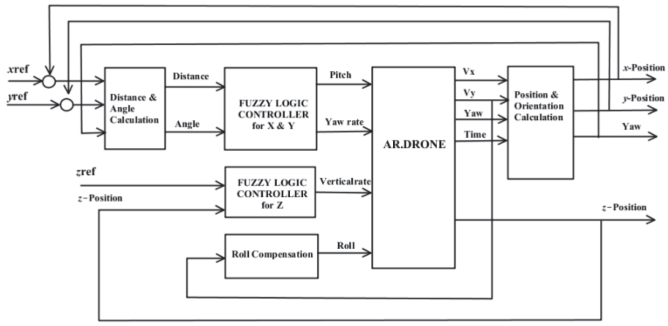

Fig. 2. Block diagram of control system

FLC block for X-Y position has two inputs, namely distance (r) and angle (α), each of which comprises 5 membership functions. The algorithm in [6] used to calculate distance and angle. Each of the outputs, which are pitch and yaw rate, also consists of 5 membership functions. More detail about fuzzy design is shown in Fig.3.

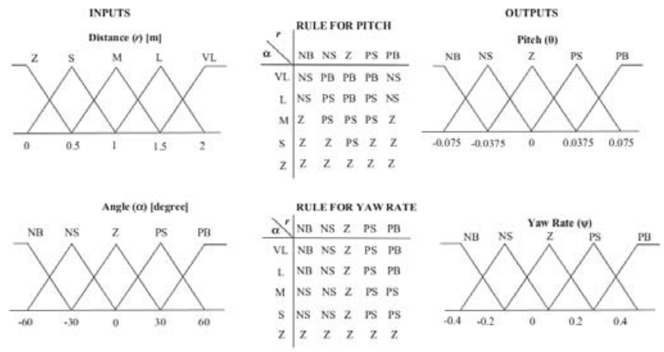

Fig. 3. Block diagram of FLC for x-y position

FLC block for the Z position has two inputs, namely setpoint of Z, z_{ref} and Z current position, each of which consist of 5 membership functions. And the output is vertical rate which also consist of 5 membership functions. More detail about fuzzy design is shown in Fig.4. This block is FLC block to control Z position used in [8]. More detail about fuzzy design is shown in Fig.4.

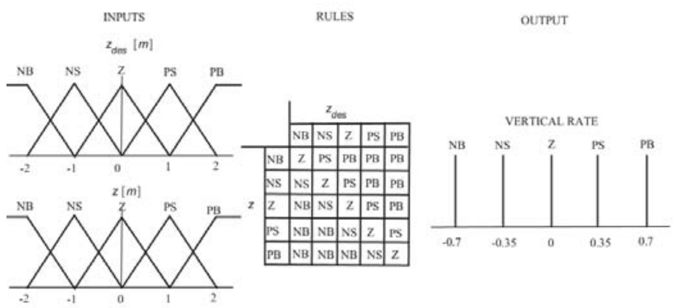

Fig. 4. Block diagram of FLC for z position

For experimentation and testing are used LabVIEW software. Some subVI are designed to represent each block in control scheme Fig.2.

III. RESULT AND ANALYSIS

The control scheme implemented on AR.Drone was tested indoor. The test procedure is as follow.

- The first step is to determine the desired setpoint position.
- Next, AR.Drone flown manually, by toggle, switched ON 'Fly' and set in 'Hover' mode. In this mode AR.Drone will hover at 1 metre height. This position is used as the initial position and is considered as coordinate (0,0,0).
- By switching OFF 'Hover' mode, AR.Drone will switch from manual mode to autonomous mode. AR.Drone will fly autonomously to the desired position.
- During flight AR.Drone position are recorded and saved in a file.
- Once the desired position is reached, indicate by flying like 'Hover' mode, AR.Drone landed back to the floor by toggle switch OFF 'Fly'. Data recording is stopped and testing is completed.

The test carried out repeatedly for several different positions. In this paper are shown the result of testing at position coordinate (1,1,1). The origin is the point when AR.Drone flown 'Hover' mode. Fig.5 shows the test result represented in each position with 3 times trial.

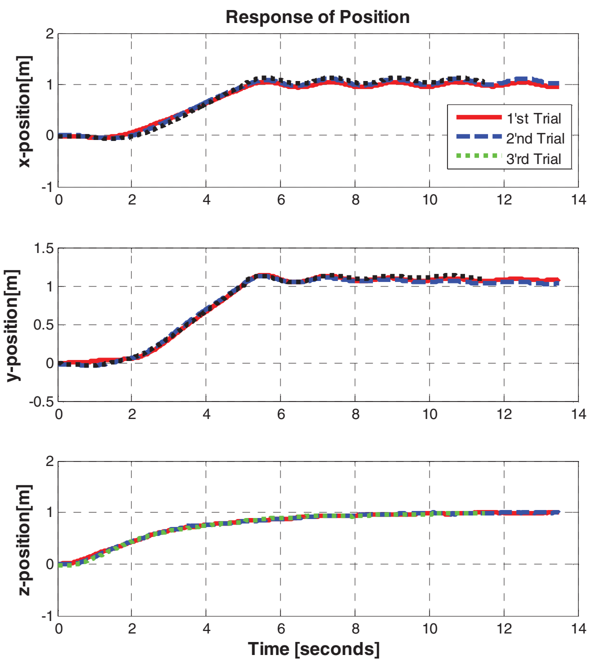

Fig. 5. Response of each position

It is shown that x and y response have similarities performance of about 5 second rise time, 5.5 second peak time and 6 second settling time. However, y position response has greater maximum overshoot than x position response, which is 11% and 5%. The x position tends to oscillation within the range of 5% of the setpoint. Response of z position tends to be slower about 10 second and without any overshoot.

In this paper the control signal output of 2 FLC blocks, which are used: pitch, yaw rate and vertical rate, are shown in Fig.6.

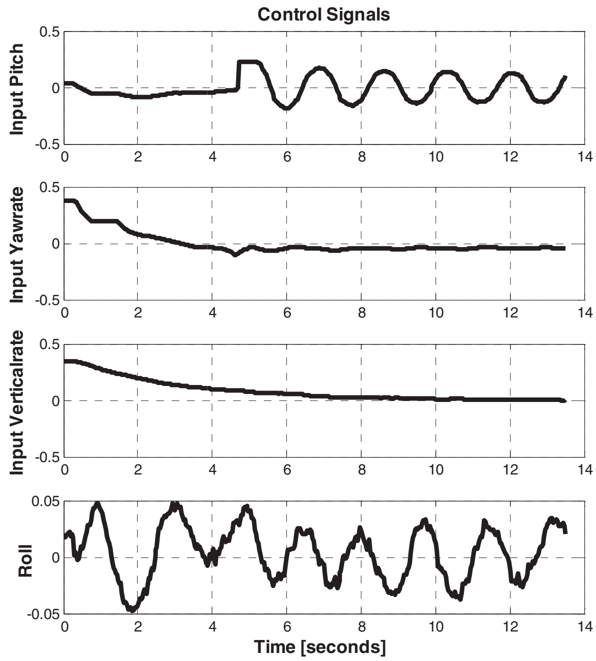

Fig. 6. Control Signals

As seen at the beginning, the input pitch response is relatively constant. But, at the time it reaches set point, it undergoes oscillation along with another oscillation as the response in x position. The same relative response shown in yaw rate input and vertical rate input toward the value 0.

IV. COMPARISON WITH ANOTHER FUZZY CONTROL SCHEME

Furthermore, the response of control scheme developed in this paper, as seen in Fig.2, will be compared with a control scheme that has been implemented in [8]. The control scheme is shown in Fig.7.

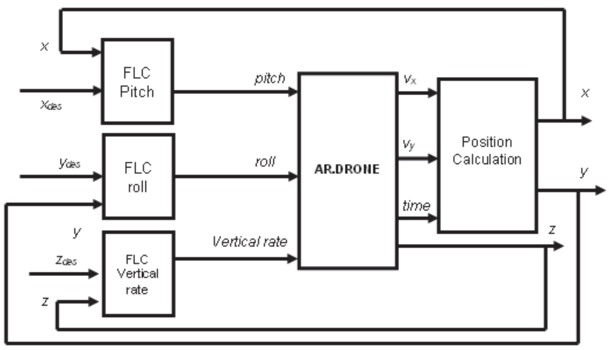

Fig. 7. Fuzzy Scheme implemented on [8]

On this scheme, all 3 fuzzy control scheme have inputs x_{ref} and x, y_{ref} and y, z_{ref} and z. Whereas as its output, consecutively, are pitch, roll and vertical rate.

The comparison between the two control schemes is shown in Fig.8 for each position.

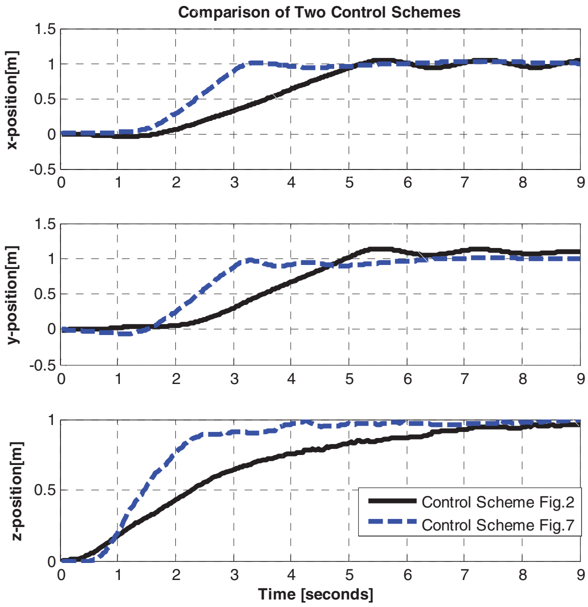

Fig. 8. Comparation of two control schemes

It appears that both fuzzy control schemes can be used to control the position. Nevertheless, control scheme Fig.7 has shown to have better performance, both in transient and steady state response. So as to control the AR.Drone position fuzzy scheme as shown in Fig.7 is recommended.

V. CONCLUSION

The test results shown that fuzzy logic controller scheme that is designed with the inputs distance, angle, z_{ref}, and z can be used to control AR.Drone position on x,y,z, coordinates. However, there are still weaknesses in x position response which still produce oscillation. Addition compensator for pitch might fix this flaw. In general, system has a fast settling time for x,y position, which is about 6 seconds and 10 seconds for z position. The comparison shows the control scheme in Fig.7 produces better response than the scheme of Fig.2.

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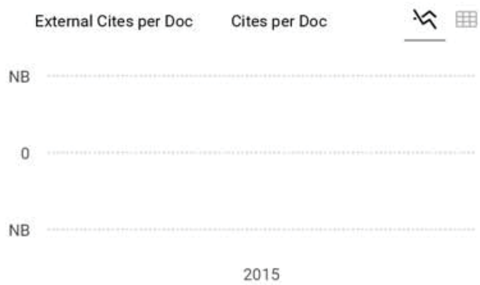

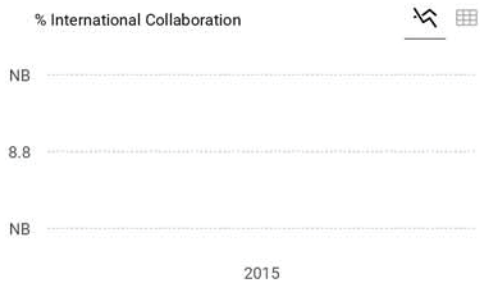

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