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Autopilot Flight Testing of Unmanned Aerial Vehicle

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Abstract This paper presents the Autopilot Flight Testing of Unmanned Aerial Vehicle (UAV) that we designed the control system to control the flight of an Unmanned Aerial Vehicle that has to fly for an automated mission. After the design and development of the autopilot flight control system, it is imperative to test the flight to verify that the designed control system can operate autonomous flight control for its mission purpose. Furthermore, this research presents a test of autonomous flight with a prototype autopilot flight control system that we use the Fuzzy PD + I controller [1],[2]. The results of this test flight will use a commercially available off-the-shelf remote control aircraft which an autopilot flight control system installed into the aircraft, and then perform a flight test with an expert pilot man. The flight test results after adjusting the control gain, and showed that the aircraft was able to maintain an altitude and can flyable to the desired waypoints very well.

Keywords *Autopilot, Flight testing, Unmanned Aerial Vehicle, UAV.*

I. INTRODUCTION

The autopilot flight control system is a complex control system and it is a nonlinear system that has the characteristic's rapid change of attitude and sensitive response to the control system. In the design of the autopilot flight control system, a Fuzzy PD + I controller was used to control the entire system. The advantages of this Fuzzy PD + I controller have been responsive to non-linear systems as well and results in a relatively rapid change in the control system which depends on the design of the control rules and expertise in fine-tuning of controller parameters. Moreover, the system design engineer must have a good understanding of the system that needs to be controlled as well. In addition to this flight test, the research team used the 0.55 cu in engine trainer remote-control aircraft, an off-the-shelf aircraft that required for flight testing the control of roll, pitch, and heading angles to allow the aircraft to fly to the programmed waypoints. In advance researcher, it needs to record the flight data such as the attitude and altitude of the aircraft according to the needs for future analysis. The flight data of this autopilot flight control system that to be stored in the memory in the form of a mini SD card installed on the aircraft and the flight data is also transmitted to the Ground Control Station in real-time. After completing the flight test, the flight data of the autopilot flight control system was shown in various graphs, control results, and also the response to the control system which is helpful to the researcher to new develop more advanced control systems in the future.

II. AUTOPILOT FLIGHT CONTROL SYSTEM

This autopilot flight control system is designed to control the operation of the servo motor that controls the aileron and elevator of the aircraft can fly stabilize in the air and can fly to the desired waypoints completely. In advance of this autopilot control system must be able to control the direction of movement, heading, and altitude of the aircraft. To control the aileron servo, the input value of this control system is from the fuzzy calculation of the desired roll angle and the roll angle of the aircraft which is related to the control of the aircraft's heading. Whereas the input value of the Heading controller will get the desired roll angle to control the navigation to the desired waypoints. Then we can be written as aileron servo control loop as shown in Fig 1.

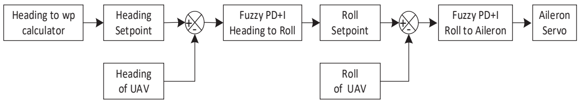

Fig. 1. The control loop of the aileron servo.

As we can see in Fig. 1 the input of the control loop is the desired heading of the aircraft and it is calculated by the Fuzzy PD+I controller to the roll setpoint, and the next Fuzzy PD+I will control the output surface to the aileron servo to meet the roll setpoint to navigate the aircraft to the waypoints direction.

To control the aircraft's altitude, the altitude control system is automatically activated when the pilot man changes the control switch to autopilot mode then the control system keeps the flying to maintain the altitude of the aircraft until the control switch is changed to manual mode and this altitude control will be deactivated. This altitude control system is designed to be controlled to an elevator servo to keep the pitch angle to the setpoint for the aircraft's altitude hold. Then we can be written as elevator servo control loop as shown in Fig. 2.

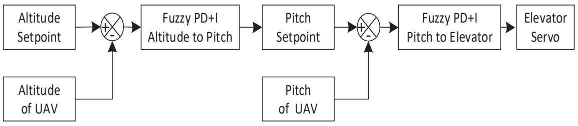

Fig. 2. The control loop of the elevator servo.

And a block diagram showing the hardware interconnection of an autopilot flight control system using an Arduino microcontroller as a processor is shown in Fig. 3 and the Ground Control Station and an pilot man are shown in Fig. 4

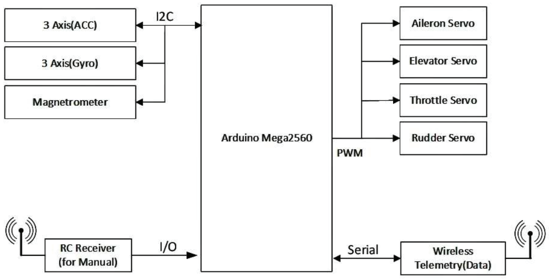

Fig. 3. Block diagram of autopilot flight control system.

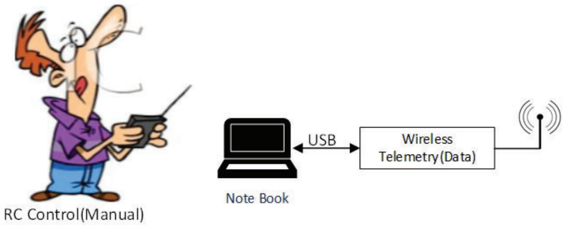

Fig. 4. Ground Control Station and pilot man on the ground site.

III. EXPERIMENTAL RESULTS

In-flight testing, we used a 0.5 cu in engine trainer aircraft for flight testing, and the autopilot control board is installed on the plane. The trainer aircraft and autopilot flight control board installed in the aircraft are shown in Fig. 5 and Fig. 6.

Fig. 5. Trainer aircraft c/w 0.55 cu in engine.

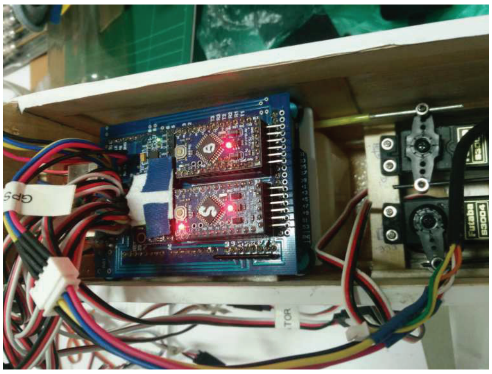

Fig. 6. Autopilot flight control board.

At the beginning of the flight test, we will use an external pilot to take off and the aircraft climbed to the desired altitude then the pilot man was switched to autopilot mode to level flight and hold the altitude. Moreover, we can tune the control gain of the Fuzzy PD + I controller while the test flight was carried out and the control gain of Fuzzy PD + I controller tuning values can be found in Table 1. When the flight test is completed, we downloaded the flight data from the SD card's memory and plotted the various graphs of flight data results as shown in Fig. 7 to Fig. 15.

Table 1. Control gain parameters of Fuzzy PD + I controller

L	K_p	K_i	K_d	K_{uPI}	K_{uD}
800	1.65	0.01	0.85	1	1

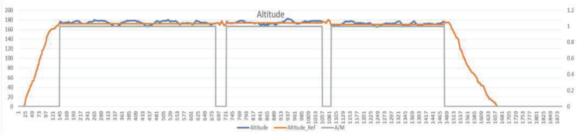

Fig. 7. UAV's altitude control by elevator servo.

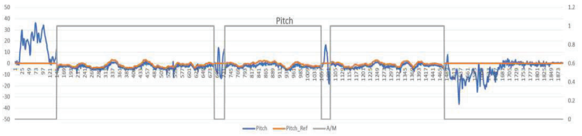

Fig. 8. Pitch angle reference and UAV's pitch angle.

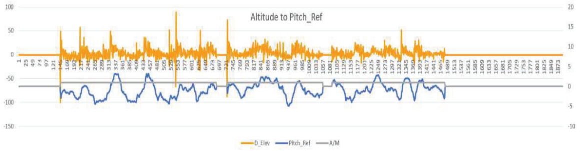

Fig. 9. Pitch angle reference and control output to elevator servo.

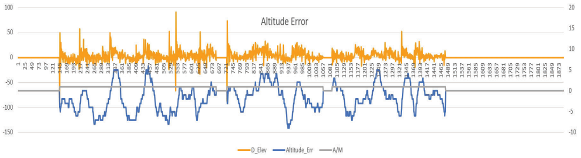

Fig. 10. Altitude's error and control output to elevator servo.

In Fig. 7, it can be seen that the flight to maintain the altitude has an oscillation. This is because two waypoints are approximately 350 meters apart, causing the aircraft to fly in a circular path and bank all the time, making it difficult to maintain a constant altitude. Because when the aircraft flies with the bank angle, the head of the plane will be heading down causing the aircraft to lose altitude, unlike flying in a straight line, it is easy to maintain an altitude. In Fig. 8, the aircraft is controlled to fly at a pitch with the setpoint at all times, but there may be some deviations. Thus, keeping the constant altitude between in-flight there is some oscillate of the altitude as see in Fig. 10.

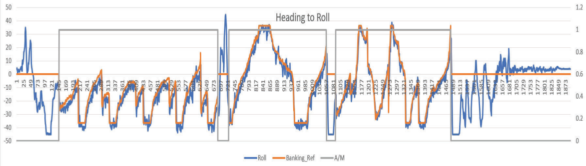

Fig. 11. Roll angle reference and UAV's roll angle.

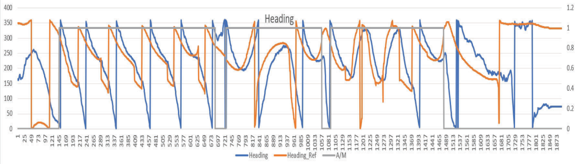

Fig. 12. Heading reference and UAV's heading.

In Fig. 11 and Fig. 12, we can see that the aircraft is controlled by a roll angle to fly in the direction of the desired waypoints, which may be somewhat distorted due to the delay of the aircraft's response time. However, this roll control allows the aircraft to fly to the desired waypoints. And the resulting error of roll angle is likely to be acceptable as see in Fig. 13

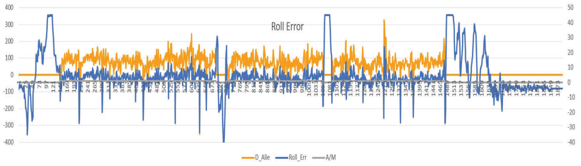

Fig. 13. UAV's roll angle error and control output to aileron servo.

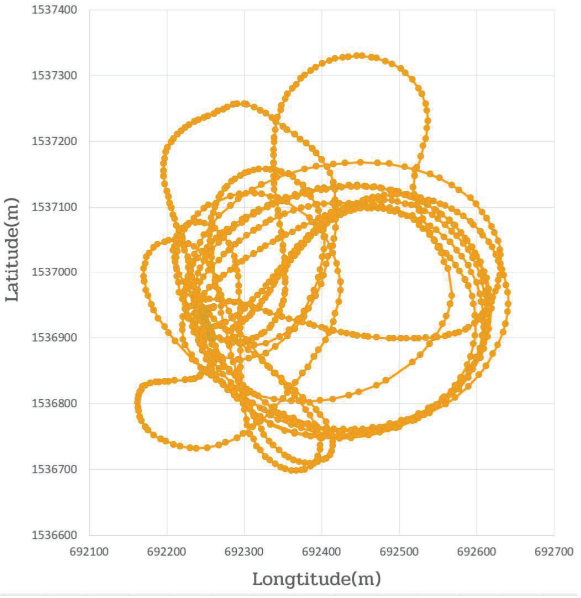

Fig. 14. UAV's trajectory.

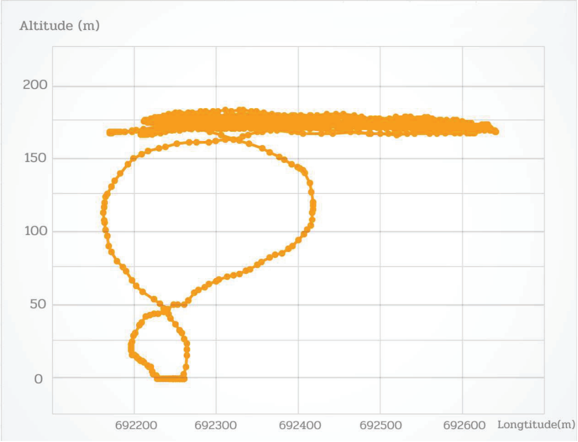

Fig. 15. UAV's altitude.

Fig. 14, shows the flight path of the aircraft to two designated waypoints, which can be seen that the flight path of the moving aircraft is circular. In this way, flying like this has to be flown with bank angles all the time, making it more difficult to maintain a constant altitude than when the plane moves in a straight line and no bank angle occurs while flying. And the altitude control of the graph in Fig. 15 shows that the aircraft can maintain the desired altitude, which may be inconsistent over time. This is because the aircraft has to fly to the waypoints with the bank angle all the time, but if flying to the longer distance waypoints then the aircraft would have been able to maintain its altitude.

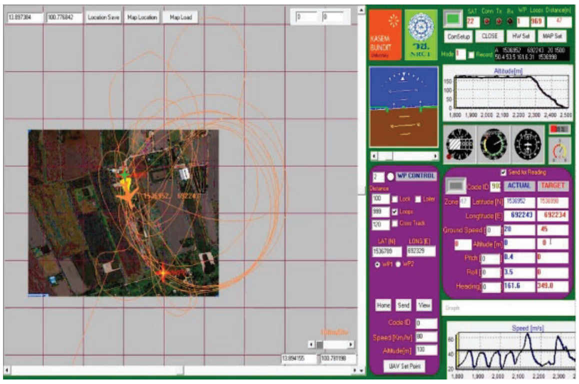

Fig. 16. Ground Control Station software monitoring and control.

In the automatic flight tracking and data control, we can control it via Ground Control Station, which is a software that comes out to receive and send autopilot flight control data to the aircraft to update the commands in the autopilot flight control board which is mounted on the aircraft and Ground Control Station is shown in Fig. 16.

IV. CONCLUSION

The flight test results obtained from flight data recording to control the roll angle and pitch angle to control the flight direction and the altitude which response to the desired roll angle and pitch angle, we can show that the roll angle error corresponds to the plane heading. This control demonstrates that the control can be able to navigate the aircraft in a specified direction to the desired waypoints and hold the altitude with a pitch error of approximately +/- 3 degrees and a roll angle error of approximately +/- 5 degrees. The altitude error is approximately +/- 10 meters, and the aircraft can be able to fly completely to the desired waypoints and keep its altitude as we can be seen from Fig. 14 and Fig. 15. This flight test with the autopilot flight control, Fuzzy PD + I controller can control the autonomous flight may require fine-tuning of control gain parameters for even more control. In this research, we do not analyze the system stability due to we unknown the aircraft's mathematic model and it is difficult to identify the mathematic model. Furthermore, the fuzzy logic control system is not required to know the exact mathematic model of the system but requires an expert system engineer to design the fuzzy control rules and must have the knowledge to control the system to achieve the desired purpose and the fuzzy logic control system is also suitable for non-linear systems that require sophisticated control and fast response.

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