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Effect of Path Planning on Flying Measured Characteristics for Quadcopter Using APM2.6 Controller

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***Abstract*----The effect of path planning for quadcopter flying robot on flying measured characteristics velocity and flying angles (Roll, Pitch and Yaw) have been investigated. Ardupilot Mega2.6 autopilot system controller is used; this controller has the ability to run many multi-rotor or Unmanned Aerial Vehicle (UAV) capable of Performing GPS missions with waypoints. The controller works with software called Mission Planner, this software is open with Google map to implement and record the estimated path for the quadcopter. Through the mission planner software the velocity of flying robot can be set between the waypoints. Three different types of path planning have been studied. Comparisons between the estimated velocities calculated from Mission Planner and the actual velocity have been conducted. The actual flying angles reading (Roll, Pitch and Yaw) have been recorded and compared with estimated angles for all three tests. The Robot shows more stability after each flying test also the velocity of the robot after each test became more close to the set velocity in mission planner for the robot, this relate to the rebalancing of the robot after each test.**

***Keywords*------ Quadcopter, APM2.6 Controller, Autopilot system, Path planning, Velocity, Flying angles.**

I. INTRODUCTION

Quadcopter have recently withdrawn the attention of many researchers interesting on topics such as control systems, wireless communications, path planning and image processing [1, 2]. A quadcopter is one of UAV vehicles which utilize four motors with propellers for lifting and movements. By adjusting the relative velocities of these rotors; and hence the Roll, Pitch and Yaw angles; the requires motion can be generated.

This structure is useful in several applications, especially for surveillance, imaging, navigation and mapping [3]. In such missions, the microdrone must supply certain area coverage and determine events at interested waypoints [4]. Therefore, path planning considered a crucial issue in quadcopter implementation. Path planning technique target to get accurate trajectories that navigate a microdrone from its current position to a required location in different circumstances [5].

However, trajectory planning issues has been studied in several ways. An algorithm based on Dubins theory to find the shortest path in UAV has been described in [6]. L. Wei and *et. al.* [7] presents an adaptive path planner for (UAVs) to adapt a real-time path search procedure to variations and fluctuations of UAVs'performance. Article [8], introduces easy method for generating candidate minimum time paths from initial point and final point. The vehicle was modeled as a particle that travels in the horizontal plane at a constant velocity with respect to ambient flow. The vehicle may turn in either direction. A description of a motion planning algorithm for a quadrotor helicopter flying autonomously without GPS, has been given in [9]. The Belief Roadmap (BRM) algorithm was used to plan vehicle trajectories that incorporate sensing. Soft computing techniques used in quadrotor control, modeling, object following and collision avoidance has been studied in [10]. Fuzzy logic techniques were used in position and altitude control systems for UAVs.

The advent of quadrotor controllers led to more practical, precise and portable path planning methods [5]. ArduPilot-Mega (APM 2.6) is a complete autopilot system that can turn any RC control vehicle into fully autonomous [11]. The purpose of this work is to investigate the accuracy of path planning measurements, velocity & flying angles, when APM 2.6 controller drives the quadcopter.

II. CONTROL SYSTEM

The electronic parts of the quadcopter consist of control board, brushless Electronic Speed Controller (ESC) and GPS module. The control Board is APM2.6. The motors of the robot connect to the output ports of the controller. And the Receiver channels connect to the input ports of the controller. The ESC will connect from one side to the motors and the other side is to the APM2.6. the software used is mission planner, an open source program available on the net [11].. The PID gain of the APM2.6 is set by default for each Roll, Pitch, Yaw and Throttle. The y can be changed by mission planner in Configuration, pid tuning. The PID consists of Proportional, Integral and Derivative. The Proportional gain coefficients make the quadcopter more sensitive and reactive to angular change. The integral gain coefficient increase precision of angular position. The derivative gain coefficients allow the quadcopter to estimated attitude more quickly [12].

III. EXPERIMENTAL WORK

The complete quadcopter robot is shown in Fig. 1.

Fig. 1 Complete quadcopter robot system

Three tests were made to the quadcopter at the University of Baghdad, Al-Khwarizmi Engineering College. The errors calculated between the actual velocity and the estimated velocity that set in the mission planner program.

If the APM is connect for the first time to the computer, it`ll need to calibrate the Accelerometer. Simple procedure in **Initial Setup** Section, Mandatory hardware Accel Calibration. The APM2.6 controller must move as the instruction that appeared. The APM2.6 need to put on flat surface, in order to achieve that a weighbridge was used.

Fig. 2 Controller movement for Accel calibration

IV. RESULT AND DISCUSSION

Three tests were made for the Quadcopter at University of Baghdad, Al-Khwarizmi Engineering College. The Paths of the three tests is shown in Fig. 3,4 and 5. Path one area lies between location (44.371943, 33.270768) and (44.375397, 33.270862).

Fig. 3 Path of test one

Path two area lies between location (44.372712, 33.270768) and (44.373321, 33.70500).

Fig. 4 Path of test two

Path three area locations lies between (44.372638, 33.271422) and (44.3742211, 33.270727). The location unit is in Decimal degrees, this mean each point represent the Longitude and Latitude.

Fig. 5 Path of test three

The actual velocity of the robot was calculated by knowiing the time the robot move each waypoint and the next waypoint, the distance between each waypoint is known from the mossion planner .

And by applying the velocity law

$$velocity = \frac{Distance}{Time} \qquad (1)$$

[13]

And the Error percentage law is as follows

$$\%Error = \frac{|Actual\ value - Exact\ value|}{Exact\ value} * 100 \qquad (2)$$

[14]

Table I, II and III shows the velocity error at each test.

Table I Actual velocity and Error for test one

Waypoints	Distance(m)	Time(s)	Velocity(m\s)	%Error
1	52.1	13	4.0076	4.5
2	47.5	11.73	4.049	3.5
3	52.7	13.1	4.0229	4.2

Table II Actual velocity and Error for test two

Waypoints	Distance(m)	Time(s)	Velocity(m\s)	%Error
1	14.5	3.5	4.14	1.428
2	9	2.2	4.09	2.59
3	10.5	2.56	4.1	2.39

Table III Actual velocity and Error of test three

Waypoints	Distance(m)	Time(s)	Velocity(m\s)	%Error
1	17.7	4.3	4.116	1.99
2	60.2	14.5	4.15	1.19
3	3.3	0.8	4.125	1.78

The tables readings shows good performance of the robot since the error was reduced 4% to 1.19% and this was due to several reasons one of them is that After each test the distributed load(the position of the component of the robot) was changed in order to see how close to the estimated flight velocity and actual velocity can be reached.

Fig. 6, 7, and 8 shows the data flight readings of each test that stored in the controller and downloaded from it by the Mission planner software. The data was taken at almost each second and they numbered in mission planner. The readings represent Roll, Pitch and Yaw angle readings respectively. The Blue curves represent the estimated readings and the Pink curves represent actual readings. The x-axis represents the data number and the y-axis represents the angles value in Centi-degrees.

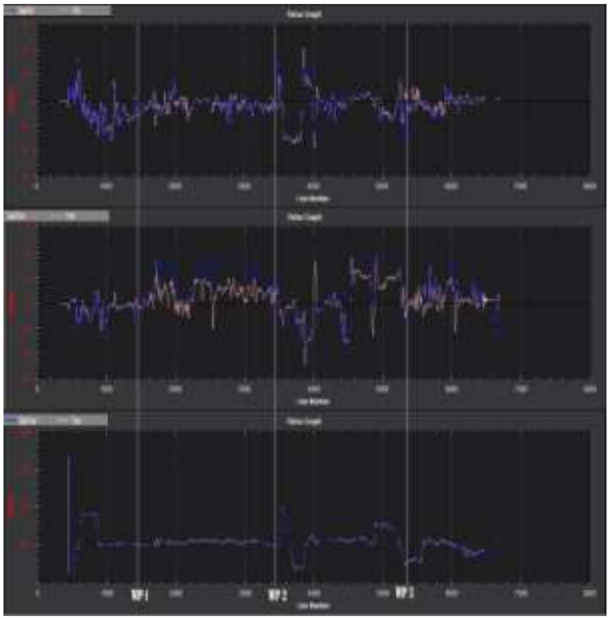

Fig. 6 Roll, Pitch and Yaw angles readings of test one

Path one as showed in Fig. 3 has turning with Acute Obtuse angles. The figure shows very little difference between Actual and estimated reading in Roll and Yaw angle. The notice difference is in Pitch angle, as shown in the figure after waypoint one the pitch angle begin the difference since the quadcopter turn its path in Acute angle after it reach waypoint one and another turn in Acute angle after it reach turn waypoint two. As mentioned earlier the rotation about pitch axis represents the movement forward and backward, so the turn-over will have big effect on pitch angle. The reading of actual Roll angles are above the estimated readings, also the actual reading of Pitch angles is under the estimated readings, while the Yaw angle is almost the same.

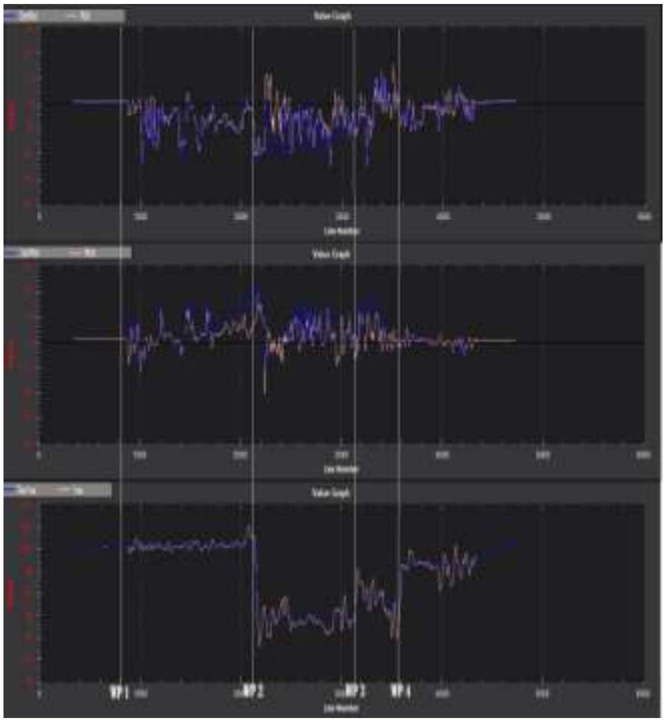

Fig. 7 Roll, Pitch and Yaw angles readings of test two.

In test two, difference between the actual and the estimated readings is less than test one, this because that the robot in this test is more stable than the first test. The Yaw angle is oscillating above and under the estimated reading. The weather in this test was little windy, this can have some effect on the flight. Roll angle actual reading is above the estimated readings and the pitch angle actual readings are under the estimated readings.

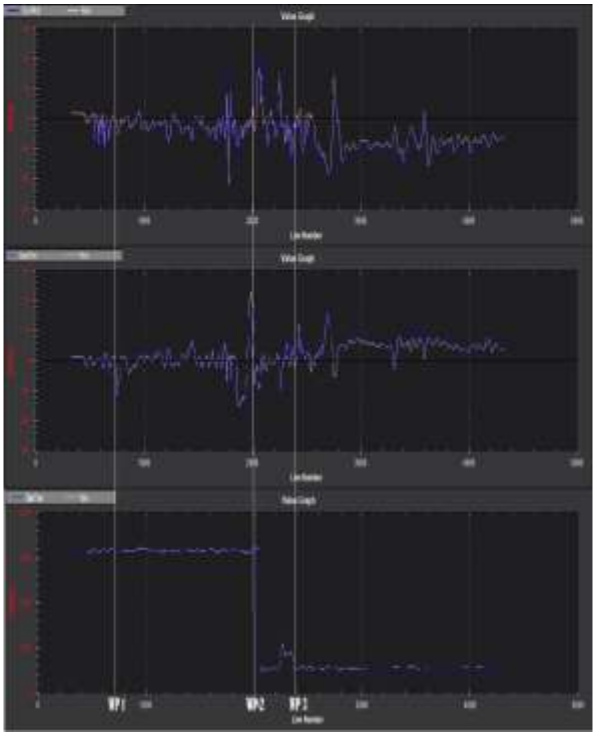

Fig. 8 Roll, Pitch and Yaw angles readings of test one.

This test as shown in Fig. 5 is a straight line but the direction is change in 180 degree from waypoint two to waypoint three. The readings of the angles are better than the first two tests. The pitch angle difference is very little compared to previous tests. The quadcopter is more stable. The distance between the waypoint two and three is short (around three meters). The error between the actual and estimated readings in Yaw angle is almost zero. Pitch angle actual readings is under the desires readings except for a small part before waypoint two. At the same small part the Roll angle actual readings is under the estimated readings while on other parts is above the actual readings

V. CONCLUSIONS

- The Robot shows more stability after each test
- The velocity of the robot after each test became closer to the set velocity in mission planner for the robot, this relate to the rebalancing of the robot after each test.
- The Error in Roll angle is very little and became closer to the estimated reading after each test.
- The difference of actual and estimated readings of Pitch angle decreases after each test, since the direction is changed in different angles in the first two tests and in test three the path was straight line.
- Yaw angle readings doesn`t affected by changing the direction because Yaw represent the rotation about z-axis.
- The change in flight direction with 180 degree has less effect on Pitch angle than other degrees.

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