System Control Holding Position on Quadcopter Using GPS with Waypoint

Trisno Widhianto [1], Anton Yudhana [2,*]
[1, 2] Department of Electrical Engineering, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
Email: [1] Trisno1500022006@webmail.uad.ac.id, [2] eyudhana@ee.uad.ac.id
*Corresponding Author

***Abstract*— This study designs an autonomous quadcopter system that can work in outdoor areas using a waypoint and quadcopter system so that it can fly without being controlled to complete a given mission with accuracy that has a low offside value. The tests carried out were divided into 3 tests using 3 different missions using Post Hold flight mode and a height of 5 m, on each mission there were 3 waypoints with each waypoint distance of 10 m which later on each waypoint would perform a Holding Position. at each waypoint point and see the error value generated based on the waypoint point by calculating the Latitude and Longitude values between the vehicle and the waypoint point so as to get the error value between the vehicle and the waypoint point and then make a comparison with measurements using a measuring instrument at each waypoint point in carrying out missions.**

Keywords*— quadcopter; holding Position waypoint; GPS; pixhawk.

I. Introduction

Research that is currently developing is regarding auto pilots or even unmanned aircraft [1][2]. This can be seen from the many studies regarding quadcopter movement control [3][4]. Quadcopter is a type of UAV that is driven by 4 rotors [5][6][7]. Control of the system is achieved by varying the speed of each motor to shape the movement of the quadcopter [8][9][10]. Quadcopters have the ability to take off and land vertically, Quadcopters can be flown manually by pilots using remotes, but often Quadcopters experience instability in carrying out flights. Unmanned aircraft research has been put forward for various purposes, one of which is to test photo-taking aircraft or videos, carrying out high-risk missions and others [11][12][13][14]. A quadcopter is a type of unmanned aerial vehicle or UAV (Unmanned Aerial Vehicle) which has four propellers and four brushless motors as actuators [15][16][17][18][19].

The use of UAVs is currently needed both in the military and civilian fields [20][21]. Examples of this use are searching for disaster victims in extreme conditions [22], remote sensing such as monitoring systems and is useful as a mapping and monitoring tool in an area [23][24]. The problem that is often encountered in operating this quadcopter is the problem of stability which cannot only be done by using the gyroscope sensor [25][26][27][28]. An alternative to implementing the degree of inclination of the robot is to be able to use the accelerometer sensor to detect the tilt angle (pitch, roll, yaw) so that the robot can move properly and is able to maintain its own stability (self balancing) [29][30]. The aim of this study is to design an autonomous quadcopter system that can work in outdoor areas using a waypoint system and a quadcopter so that it can fly without being controlled to complete a given mission with accuracy that has a low offside value [31][32].

II. Research Methods

This research was conducted to find out how the holding position of a drone-type UAV vehicle works and to see the reactions arising from the holding position when carrying out flight missions, so that the vehicle was calibrated and tested several times, starting from vehicle electricity, calibrating various sensors on the vehicle, several vehicle construction components as well as sensor value readings.

A. Design System

To simplify the design, the circuit is separated based on its function. The following is a block circuit diagram for the controller in Fig. 1.

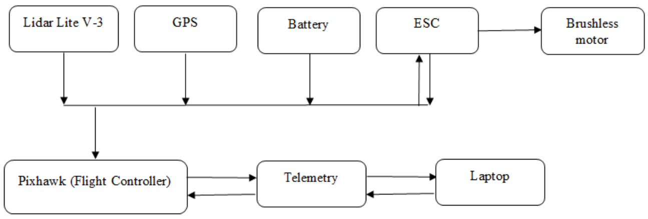

Fig. 1. System circuit block diagram

Needed some theories and materials are needed for research. The theories used in making the final project is using the Waypoint feature on the quadcopter to set the desired path on the quadcopter and for the materials used in the final project such as carbon frames, pixhawk flight control and those used as controls to run the quadcopter using mission planner software and remote control to anticipate program errors.

B. Methods

In this method section there is a system design to determine the coordinate values of the quadcopter. The method in the form of a system flow chart (Flowchart) is shown in Fig. 2.

This system flow diagram shows the process of collecting data by carrying out the initial process of initializing the connected Quadcopter via telemetry which is connected to the flight controller, then accessing data on the Quadcopter, reading the home coordinate values and determining 3 waypoints, after that carrying out the command process to carry out the mission on mission planner, then the flight controller will send the results of the Quadcopter coordinates which will be displayed on the GCS (Ground Control System) computer.

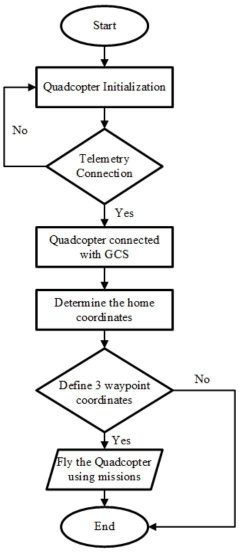

Fig. 2. System flow chart

a) Determine the difference value of latitude

This process is a process for determining the difference in latitude that will be used to calculate the error value on the GPS, using equation (1) which is denoted by $\Delta\varphi$.

$$\Delta\varphi = -(Posisi\ Hold) - (-eror\ posisi) \quad (1)$$

b) Determine the value of the difference from longitude

This process is a process for determining the value of the difference from longitude which will be used to calculate the error value on the GPS, using equation (2) which is denoted by $\Delta\varphi$.

$$\Delta\varphi = -(Posisi\ Hold) - (-eror\ posisi) \quad (2)$$

III. Result and Discussion

This research was conducted to find out how the holding position of a UAV vehicle with a drone type works and to see the reaction caused by the holding position when carrying out a flight mission, so that several calibrations and testing of the vehicle were carried out, starting from the electrical vehicle, calibrating various sensors on the rides, some of the building components of the rides as well as sensor values readings. In this study the data collection process was carried out in the Moyudan Village field, the tests were carried out using a UAV with a Quadcopter type (4 motor drive). The tests carried out are divided into 3 tests using 3 different missions using the Post Hold flight mode and a height of 5m, each mission has 3 waypoints with each waypoint distance of 10m which later on each waypoint will carry out a Holding Position at each waypoint and see the error value generated based on the waypoint by calculating the Latitude and Longitude values between the ride and the waypoint so that you get the error value between the ride and the waypoint then make comparisons with measurements using a meter gauge at each waypoint in carrying out the mission.

A. Hardware System Testing Results

The results of testing the hardware system aim to find out the results of the data retrieval test needed in research which aims to make it easier to process or process data, the stages of testing carried out include testing the vehicle data supply, GPS sensors used as sensors to determine vehicle coordination points, Lidar sensors Lite-V3 is used as a sensor for measuring altitude, holding position testing for mission 1, holding position testing for mission 2, holding position testing for mission 3.

B. Power Supply Testing

In testing the power supply voltage carried out on the Quadcopter using a Multimeter as a measuring tool, by providing a voltage input from the battery of 16.8 volts. When the Pixhawk (Flight Controller) is turned on with the LED on the Pixhawk flashing quickly, then use an analog multimeter to measure the voltage on the Power Module connected to the Pixhawk. The negative probe on the multimeter is connected to ground on the Power Module and the positive probe is connected to the positive on the Power Module. Fig. 3 below is a picture of the Quadcopter power supply measurement test.

Fig. 3. Power supply measurement

After measuring the power supply on the Quadcopter using an analog multimeter in Fig. 3, the results are obtained in Table 1.

TABLE I. Power Supply Measurement Results

No	Input	Output	Description
1	16,8 V	5 V	Normal

From Table 1, can be seen that the input voltage received from the battery is 16.8 v and the output voltage is 5 v, this is directly proportional to the expected results of the output voltage of 5 v which is generated because the Quadcopter is not yet of flight mode, so for the time being the Pixhawk (Flight Controller) only requires a voltage of 5 v to activate a series of components on the Quadcopter. If the condition of the Quadcopter is in flight mode, the resulting output voltage will increase even greater because the driving components on the Quadcopter require a greater voltage to be able to carry out the flight process, the input voltage which is initially 16.8 v will decrease as the voltage increases the resulting output will cause the capacity of the battery power supply that is used to be drained at the maximum limit.

C. GPS Sensor Testing

The GPS sensor test carried out aims to carry out the GPS calibration process on Pixhawk, which is useful for increasing the value of the accuracy of a GPS when used, this is very necessary in carrying out a UAV flight which will later become a reference value for the coordination point of a vehicle so that it can move according to what is desired, the calibration process is carried out by means of the vehicle being left on a flat surface, after that the vehicle is tilted 90° to the right, the vehicle is returned to its original position then the vehicle is tilted again 90° to the left, then the vehicle is returned in its original position and the nose of the vehicle is tilted upwards by 90°, the vehicle is returned to its original position with the nose of the vehicle tilted downwards by 90°, after that it is returned to its original position then the vehicle is reversed by 90°, then return it to its original position then do go back the steps until the vehicle gives a signal in the form of a sound (beep) indicating that calibration is complete. Fig. 4 shows the GPS calibration process.

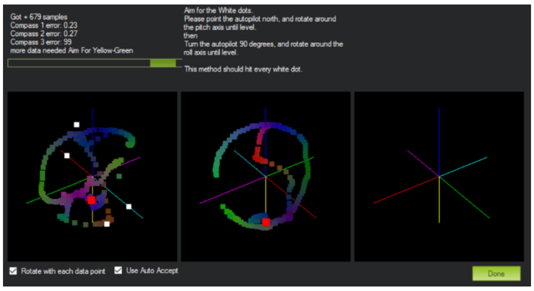

Fig. 4. GPS calibration process

After carrying out the calibration process on the GPS, the vehicle will send the GPS value that was used before the flight as an offsets value. For the results of the calibration can be seen in Table 2.

TABLE II. VALUE OF GPS CALIBRATION RESULTS

No	Offsets X	Offsets Y	Offsets Z
1	-110	-96	40

D. Testing Holding Position at Waypoint 1

This stage is the stage for carrying out the flight process with the Waypoint which is divided into 3 points that form like a triangular angle at each waypoint with a distance of 10 m, the flight is carried out at the first waypoint which is 10 m from the Home point with a height of 5 m, the flight was carried out using the Autonomus mode, the test was carried out 6 times, which aims to see the holding position error caused by the flight process being carried out, the results of the holding position error will be measured again using a meter which will become a reference value to calculate the Latitude and Longitude values of the waypoint stage based on the layout on the earth's surface. The results of this testing stage are shown in Table III.

TABLE III. WAYPOINT SYSTEM TESTING 1

Try to-	Wp point	Distance (m)	Wind Speed (m/s)	Height (m)
1	1	10	1.54	5
2	1	10	2.00	5
3	1	10	1.20	5
4	1	10	2.45	5
5	1	10	2.78	5
6	1	10	1.10	5

After conducting flight testing for waypoint 1, flights were carried out using Autonomus mode with a flight height of 5 m and with a distance of waypoint 1 points of 10 m, flight testing was carried out 6 times, after carrying out flight tests, the error value was obtained Holding Position which can be seen in Table IV.

TABLE IV. ERROR HOLDING POSITION WAYPOINT 1

No	Position	Hold Position	Error Hold Position
1	Altitude	5m	5m
	Latitude	-7.8566167	-7.8566184
	Longitude	110.3518765	110.3518758
2	Altitude	5m	5m
	Latitude	-7.8566167	-7.8566163
	Longitude	110.3518765	110.3518771
3	Altitude	5m	5m
	Latitude	-7.8566167	-7.8566151
	Longitude	110.3518765	110.3518783
4	Altitude	5m	5m
	Latitude	-7.8566167	-7.8566165
	Longitude	110.3518765	110.3518764
5	Altitude	5m	5m
	Latitude	-7.8566167	-7.8566172
	Longitude	110.3518765	110.3518770
6	Altitude	5m	5m
	Latitude	-7.8566167	-7.8566148
	Longitude	110.3518765	110.3518791

As can be seen in Table IV above, the result values from flight testing were carried out for waypoint 1, the table above explains the waypoint point values and the point values of the rides so as to produce the resulting error difference values derived from the values of Latitude and Longtitude from the waypoint point and ride point, to find out the value of the difference in the resulting error can be calculated using equation (1) and equation (2). Then the calculation results are shown in Table V.

Latitude difference for experiment 1

$$\Delta\varphi = -7.8566184 - (-7.8566167) = -0.0000017$$

Latitude difference for experiment 2

$$\Delta\varphi = -7.8566163 - (-7.8566167) = -0.0000004$$

Latitude difference for experiment 3

$$\Delta\varphi = -7.8566151 - (-7.8566167) = -0.0000016$$

Latitude difference for experiment 4

$$\Delta\varphi = -7.8566165 - (-7.8566167) = -0.0000001$$

Latitude difference for experiment 5

$$\Delta\varphi = -7.8566172 - (-7.8566167) = 0.0000005$$

Latitude difference for experiment 6

$$\Delta\varphi = -7.8566148 - (-7.8566167) = -0.0000019$$

TABLE V. DIFFERENCE IN LATITUDE WAYPOINT VALUE 1

No	Error Latitude
1	-0.0000017
2	-0.0000004
3	-0.0000016
4	-0.0000002
5	0.0000005
6	-0.0000019

After performing the calculation to determine the Latitude error value from waypoint 1 and the vehicle point, the next step is to measure the Longitude error value of the vehicle point to waypoint 1 using equation (2) so that it can be seen in the calculation below and this results are shown in Table VI.

Longitude difference for experiment 1

$$\Delta\varphi = 110.3518758 - 110.3518765 = 0.0000007$$

Longitude difference for experiment 2

$$\Delta\varphi = 110.3518771 - 110.3518765 = -0.0000006$$

Longitude difference for experiment 3

$$\Delta\varphi = 110.3518783 - 110.3518765 = 0.0000018$$

Longitude difference for experiment 4

$$\Delta\varphi = 110.3518764 - 110.3518765 = -0.0000002$$

Longitude difference for experiment 5

$$\Delta\varphi = 110.3518770 - 110.3518765 = -0.0000005$$

Longitude difference for experiment 6

$$\Delta\varphi = 110.3518791 - 110.3518765 = 0.0000026$$

TABLE VI. DIFFERENCE IN LONGITUDE WAYPOINT VALUE 1

No	Error Longitude
1	0.0000007
2	-0.0000006
3	0.0000018
4	-0.0000002
5	-0.0000005
6	0.0000026

After calculating the Latitude and Longitude values for flights at waypoint 1, the next step is to measure the vehicle error value from waypoint 1, namely by using a meter measuring instrument, which can be seen in Table VII.

TABLE VII. MEASUREMENT RESULTS USING A METER

No	Meter (Cm)	Intersection Line (Cm)
1	164	20.4657
2	24	8.02733
3	80	26.8092
4	121	2.48917
5	188	7.87144
6	34	35.8475

In Table VII above, it can be seen the results of measurements using a meter with a measuring unit of centimeters (cm) with a measuring intersection between the vehicle latitude value and a ruler having different intersection lines based on the latitude value caused by the vehicle.

E. Testing Holding Position at Waypoint 2

This stage is the stage for carrying out the flight process with the Waypoint which is divided into 3 points that form like a triangular angle at each waypoint point with a distance of 10 m, the flight is carried out at the second waypoint point which is 10 m from the Waypoint 1 point with a height of 5 m, the flight was carried out using the Autonomous mode, the test was carried out 6 times, which aims to see the holding position error caused by the flight process being carried out, the results of the holding position error will be measured again using a meter which will be the value reference to calculate the Latitude and Longitude values of the waypoint stage based on the layout on the earth's surface. The following is the result of waypoint 2 system testing shown in Table VIII.

After conducting flight testing for waypoint 2, flights were carried out using Autonomus mode with a flight height of 5 m and with a distance of 10 m for waypoint 2 points, flight testing was carried out 6 times, after carrying out flight tests, the error value was obtained. Holding Position which can be seen in Table IX.

TABLE VIII. WAYPOINT SYSTEM TESTING 2

Try to-	Wp point	Distance (m)	Wind Speed (m/s)	Height (m)
1	2	10	1.54	5
2	2	10	2.00	5
3	2	10	1.20	5
4	2	10	2.45	5
5	2	10	2.78	5
6	2	10	1.10	5

TABLE IX. ERROR HOLDING POSITION WAYPOINT 2

No	Position	Hold Position	Error Hold Position
1	Altitude	5m	5m
	Latitude	-7.8566487	-7.8566509
	Longitude	110.3518311	110.3518305
2	Altitude	5m	5m
	Latitude	-7.8566487	-7.8566496
	Longitude	110.3518311	110.3518315
3	Altitude	5m	5m
	Latitude	-7.8566487	-7.8566489
	Longitude	110.3518311	110.3518319
4	Altitude	5m	5m
	Latitude	-7.8566487	-7.8566489
	Longitude	110.3518311	110.3518299
5	Altitude	5m	5m
	Latitude	-7.8566487	-7.8566435
	Longitude	110.3518311	110.3518381
6	Altitude	5m	5m
	Latitude	-7.8566487	-7.8566473
	Longitude	110.3518311	110.3518315

It can be seen in Table IX above that the result values of flight testing were carried out for waypoint 2, the table above explains the waypoint point values and the point values of the rides as to produce the resulting error difference values derived from the values of the Latitude and Longitude of the waypoint point and ride point, to find out the value of the difference in the resulting error can be calculated using equation (1) and equation (2). Then the calculation results are shown in Table X.

Latitude difference for experiment 1

$$\Delta\varphi = -7.8566509 - (-7.8566487) = 0.0000022$$

Latitude difference for experiment 2

$$\Delta\varphi = -7.8566496 - (-7.8566487) = 0.0000009$$

Latitude difference for experiment 3

$$\Delta\varphi = -7.8566489 - (-7.8566487) = 0.0000002$$

Latitude difference for experiment 4

$$\Delta\varphi = -7.8566489 - (-7.8566487) = 0.0000002$$

Latitude difference for experiment 5

$$\Delta\varphi = -7.8566435 - (-7.8566487) = -0.0000052$$

Latitude difference for experiment 6

$$\Delta\varphi = -7.8566473 - (-7.8566487) = -0.0000014$$

TABLE X. DIFFERENCE WAYPOINT VALUE 2

No	Error Latitude
1	0.0000022
2	0.0000009
3	0.0000002
4	0.0000002
5	-0.0000052
6	-0.0000014

After performing the calculations to determine the Latitude error value from waypoint 2 and the vehicle point, the next step is to measure the Longitude error value of the vehicle point to waypoint 2 using equation (2) so that it can be seen in the calculation below. Then the calculation results are shown in Table XI.

Longitude difference for experiment 1
$$\Delta\varphi = 110.3518305 - 110.3518311 = 0.0000006$$
Longitude difference for experiment 2
$$\Delta\varphi = 110.3518315 - 110.3518311 = -0.0000004$$
Longitude difference for experiment 3
$$\Delta\varphi = 110.3518319 - 110.3518311 = -0.0000008$$
Longitude difference for experiment 4
$$\Delta\varphi = 110.3518299 - 110.3518311 = 0.0000012$$
Longitude difference for experiment 5
$$\Delta\varphi = 110.3518381 - 110.3518311 = -0.0000007$$
Longitude difference for experiment 6
$$\Delta\varphi = 110.3518315 - 110.3518311 = -0.0000004$$

TABLE XI. DIFFERENCE IN LONGITUDE WAYPOINT VALUE 2

No	Error Longitude
1	0.0000006
2	-0.0000004
3	-0.0000008
4	0.0000012
5	0.0000007
6	-0.0000004

After calculating the Latitude and Longitude values for flights at waypoint 2, the next step is to measure the vehicle's error value from waypoint 2, namely by using a meter measuring instrument, which can be seen in Table XII.

TABLE XII. MEASUREMENT RESULTS USING A METER

No	Meter (Cm)	Intersection Line (Cm)
1	74	25.3846
2	144	10.9637
3	30	9.1796
4	64	13.5425
5	76	97.0712
6	28	16.2083

In Table XII above it can be seen the results of measurements using a meter with a measuring unit of centimeters (cm) with a measuring intersection between the vehicle latitude value and a ruler having different intersection lines based on the latitude value caused by the vehicle.

F. Testing Holding Position at Waypoint 3

This stage is the stage for carrying out the flight process with the Waypoint which is divided into 3 points that form like a triangular corner at each waypoint point with a distance of 10 m, the flight is carried out at the third waypoint point which is 10 m from the Waypoint 2 point with a height of 5 m, the flight was carried out using the Autonomous mode, the test was carried out 6 times, which aims to see the holding position error caused by the flight process being carried out, the results of the holding position error will be measured again using a meter which will be the value reference to calculate the Latitude and Longitude values of the waypoint stage based on the layout on the earth's surface. The following is the result of waypoint 2 system testing shown in Table XIII.

After conducting flight testing for waypoint 3, flights were carried out using Autonomous mode with a flight height of 5 m and with distance of waypoint 3 points of 10 m, flight testing was carried out 6 times, after carrying out flight tests, the error value was obtained. Holding Position which can be seen in Table XIV.

TABLE XIII. WAYPOINT SYSTEM TESTING 3

Try to-	Wp point	Distance (m)	Wind Speed (m/s)	Height (m)
1	3	10	1.54	5
2	3	10	2.00	5
3	3	10	1.20	5
4	3	10	2.45	5
5	3	10	2.78	5
6	3	10	1.10	5

TABLE XIV. ERROR HOLDING POSITION WAYPOINT 3

No	Position	Hold Position	Error Hold Position
1	Altitude	5m	5m
	Latitude	-7.8566616	-7.8566622
	Longitude	110.3517249	110.3517243
2	Altitude	5m	5m
	Latitude	-7.8566616	-7.8566619
	Longitude	110.3517249	110.3517252
3	Altitude	5m	5m
	Latitude	-7.8566616	-7.8566622
	Longitude	110.3517249	110.3517199
4	Altitude	5m	5m
	Latitude	-7.8566616	-7.8566629
	Longitude	110.3517249	110.3517229
5	Altitude	5m	5m
	Latitude	-7.8566616	-7.8566616
	Longitude	110.3517249	110.3517236
6	Altitude	5m	5m
	Latitude	-7.8566616	-7.8566636
	Longitude	110.3517249	110.3517346

It can be seen in Table XIV above that the result values of flight testing were carried out for waypoint 3, the table above explains the waypoint point values and the point values of the rides as to produce the resulting error difference values derived from the values of the Latitude and Longitude of the waypoint point and ride point, to find out the value of the difference in the resulting error can be calculated using equation (1) and equation (2). Then the calculation results are shown in Table XV.

Latitude difference for experiment 1
$$\Delta\varphi = -7.8566622 - (-7.8566616) = 0.0000006$$
Latitude difference for experiment 2
$$\Delta\varphi = -7.8566619 - (-7.8566616) = 0.0000003$$
Latitude difference for experiment 3
$$\Delta\varphi = -7.8566622 - (-7.8566616) = 0.0000006$$
Latitude difference for experiment 4
$$\Delta\varphi = -7.8566629 - (-7.8566616) = 0.0000013$$
Latitude difference for experiment 5
$$\Delta\varphi = -7.8566616 - (-7.8566616) = 0.0000000$$
Latitude difference for experiment 6
$$\Delta\varphi = -7.8566636 - (-7.8566616) = 0.000002$$

TABLE XV. DIFFERENCE IN LONGITUDE WAYPOINT VALUE 3

No	Error Latitude
1	0.0000006
2	0.0000003
3	0.0000006
4	0.0000013
5	0.0000000
6	0.000002

After performing calculations to determine the Latitude error value from waypoint 3 and the vehicle point, the next step is to measure the Longitude error value of the vehicle point to waypoint 3 using equation (2) so that it can be seen in the calculation below. Then the calculation results are shown in Table XVI.

Longitude difference for experiment 1

$$\Delta\varphi = 110.3517243 - 110.3517249 = 0.0000006$$

Longitude difference for experiment 2

$$\Delta\varphi = 110.3517252 - 110.3517249 = -0.0000003$$

Longitude difference for experiment 3

$$\Delta\varphi = 110.3517199 - 110.3517249 = 0.000005$$

Longitude difference for experiment 4

$$\Delta\varphi = 110.3517229 - 110.3517249 = 0.000002$$

Longitude difference for experiment 5

$$\Delta\varphi = 110.3517236 - 110.3517249 = 0.0000013$$

Longitude difference for experiment 6

$$\Delta\varphi = 110.3517346 - 110.3517249 = -0.0000097$$

TABLE XVI. DIFFERENCE IN LONGITUDE WAYPOINT VALUE 3

No	Error Longitude
1	0.0000006
2	-0.0000003
3	0.000005
4	0.000002
5	0.0000013
6	-0.0000097

After calculating the Latitude and Longitude values for flights at waypoint 3, the next step is to measure the vehicle error value from waypoint 3, namely by using a meter measuring instrument, which can be seen in Table XVII.

TABLE XVII. MEASUREMENT RESULTS USING A METER

No	Meter (Cm)	Intersection Line (Cm)
1	73	9,44573
2	70	4,72287
3	72	56,0588
4	108	26,5537
5	34	14,4715
6	112	110,2508

From Table XVII above it can be seen that the results of measurements using a meter with a measuring unit of centimeters (cm) with a measuring intersection between the vehicle latitude value and a ruler have different intersection lines based on the latitude value caused by the vehicle.

IV. CONCLUSION

After conducting research and discussion, it has succeeded in building a Holding Position Control System on a Quadcopter Using GPS with Waypoints. After carrying out several stages of testing, it can be concluded that the first, the results of the Quadcopter flight trials using the waypoint method, the Quadcopter can carry out missions using 3 waypoint points with many experiments. Then the second waypoint 1 with a flight altitude of 5 m and a distance from home to waypoint 1 is 10 m. By conducting 6 flights of experiments, the results with the best accuracy when compared with measurements using a meter are 35.8475. The third is waypoint 2 with a flight altitude of 5 m and the distance from home to waypoint 2 is 10 m. By conducting 6 flights of experiments, the results with the best accuracy when compared with measurements using a meter are 16.2083. At waypoint 3 with a flight altitude of 5 m and the distance from home to waypoint 3 is 10 m, by conducting 6 flights of experiments, the results with the best accuracy when compared with measurements using a meter are 110.2508. External factors that cause the Quadcopter's level of accuracy to not be good are the strong wind when the Quadcopter flies, so that when the Quadcopter lands and when the Quadcopter locks the coordinates the difference in value is large. The internal factor that causes the Quadcopter's accuracy level is not good, namely when the pre-flight calibration is not correct, causing the Quadcopter's accuracy level to be not good.

ACKNOWLEDGMENTS

Thanks to all who were involved in this research. I hope this research can be useful and useful for many people and hopefully in the future it can be further developed, because this research is far from perfect.

REFERENCES

[1] L. Davies, R. C. Bolam, Y. Vagapov and A. Anuchin, "Review of Unmanned Aircraft System Technologies to Enable Beyond Visual Line of Sight (BVLOS) Operations," *2018 X International Conference on Electrical Power Drive Systems (ICEPDS)*, pp. 1-6, 2018, https://doi.org/10.1109/ICEPDS.2018.8571665.

[2] L. Wang *et al.*,"Applications and prospects of agricultural unmanned aerial vehicle obstacle avoidance technology in China," *Sensors*, vol. 19, no. 3, p. 642, 2019, https://doi.org/10.3390/s19030642.

[3] J. Yoon and J. Doh, "Optimal PID control for hovering stabilization of quadcopter using long short term memory," *Advanced Engineering Informatics*, vol. 53, p. 101679, 2022, https://doi.org/10.1016/j.aei.2022.101679.

[4] C. Budaciu, N. Botezatu, M. Kloetzer and A. Burlacu, "On the Evaluation of the Crazyflie Modular Quadcopter System," *2019 24th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA)*, pp. 1189-1195, 2019, https://doi.org/10.1109/ETFA.2019.8869202.

[5] P. Sanjana and M. Prathilothamai, "Drone Design for First Aid Kit Delivery in Emergency Situation," *2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS)*, pp. 215-220, 2020, https://doi.org/10.1109/ICACCS48705.2020.9074487.

[6] M. Tkáč and P. Mésároš, "Utilizing drone technology in the civil engineering," *Selected Scientific Papers-Journal of Civil Engineering*, vol. 14, no. 1, pp. 27-37, 2019, https://doi.org/10.1515/sspjce-2019-0003.

[7] P. K. Reddy Maddikunta *et al.*, "Unmanned Aerial Vehicles in Smart Agriculture: Applications, Requirements, and Challenges," in *IEEE Sensors Journal*, vol. 21, no. 16, pp. 17608-17619, 2021, https://doi.org/10.1109/JSEN.2021.3049471.

[8] R. Kumar, A. M. Deshpande, J. Z. Wells and M. Kumar, "Flight Control of Sliding Arm Quadcopter with Dynamic Structural Parameters," *2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pp. 1358-1363, 2020, https://doi.org/10.1109/IROS45743.2020.9340694.

[9] R. Kumar, J. Z. Wells, D. Jhawar, K. Ranjan and M. Kumar, "Prototype Development and Flight Controller Implementation of the Sliding-Arm Quadcopter," *IFAC-PapersOnLine*, vol. 55, no. 37, pp. 542-547, 2022, https://doi.org/10.1016/j.ifacol.2022.11.239.

[10] I. S. Leal, C. Abeykoon and Y. S. Perera, "Design, Simulation, Analysis and Optimization of PID and Fuzzy Based Control Systems for a Quadcopter," *Electronics*, vol. 10, no. 18, p. 2218, 2021, https://doi.org/10.3390/electronics10182218.

[11] K. Lu, J. Xie, Y. Wan and S. Fu, "Toward UAV-Based Airborne Computing," in *IEEE Wireless Communications*, vol. 26, no. 6, pp. 172-179, 2019, https://doi.org/10.1109/MWC.2019.1900025.

[12] M. Alwateer, S. W. Loke and A. M. Zuchowicz, "Drone services: issues in drones for location-based services from human-drone interaction to information processing," *Journal of Location Based*

Services, vol. 13, no. 2, pp. 94-127, 2019, https://doi.org/10.1080/17489725.2018.1564845.

[13] C. Paz, E. Suárez, C. Gil and C. Baker, "CFD analysis of the aerodynamic effects on the stability of the flight of a quadcopter UAV in the proximity of walls and ground," *Journal of Wind Engineering and Industrial Aerodynamics*, vol. 206, p. 104378, 2020, https://doi.org/10.1016/j.jweia.2020.104378.

[14] S. Kunze and A. Weinberger, "Concept for a Geo-Awareness-System for Civilian Unmanned Aerial Systems," *2021 31st International Conference Radioelektronika (RADIOELEKTRONIKA)*, pp. 1-6, 2021, https://doi.org/10.1109/RADIOELEKTRONIKA52220.2021.9420196

[15] S. Darvishpoor, J. Roshanian, A. Raissi and M. Hassanalian, "Configurations, flight mechanisms, and applications of unmanned aerial systems: A review," *Progress in Aerospace Sciences*, vol. 121, p. 100694, 2020, https://doi.org/10.1016/j.paerosci.2020.100694.

[16] M. Schiestl *et al*., "Development of a High Power Density Drive System for Unmanned Aerial Vehicles," in *IEEE Transactions on Power Electronics*, vol. 36, no. 3, pp. 3159-3171, 2021, https://doi.org/10.1109/TPEL.2020.3013899.

[17] M. S. Chehadeh and I. Boiko, "Design of rules for in-flight non-parametric tuning of PID controllers for unmanned aerial vehicles," *Journal of the Franklin Institute*, vol. 356, no. 1, pp. 474-491, 2019, https://doi.org/10.1016/j.jfranklin.2018.10.015.

[18] D. Invernizzi, M. Giurato, P. Gattazzo and M. Lovera, "Comparison of Control Methods for Trajectory Tracking in Fully Actuated Unmanned Aerial Vehicles," in *IEEE Transactions on Control Systems Technology*, vol. 29, no. 3, pp. 1147-1160, 2021, https://doi.org/10.1109/TCST.2020.2992389.

[19] Z. F. Pan, L. An and C.Y. Wen, "Recent advances in fuel cells based propulsion systems for unmanned aerial vehicles," *Applied Energy*, vol. 240, pp. 473-485, 2019, https://doi.org/10.1016/j.apenergy.2019.02.079.

[20] P. K. Selvam, G. Raja, V. Rajagopal, K. Dev and S. Knorr, "Collision-free Path Planning for UAVs using Efficient Artificial Potential Field Algorithm," *2021 IEEE 93rd Vehicular Technology Conference (VTC2021-Spring)*, pp. 1-5, 2021, https://doi.org/10.1109/VTC2021-Spring51267.2021.9448937.

[21] J. Tang, S. Lao and Y. Wan, "Systematic Review of Collision-Avoidance Approaches for Unmanned Aerial Vehicles," in *IEEE Systems Journal*, vol. 16, no. 3, pp. 4356-4367, 2022, https://doi.org/10.1109/JSYST.2021.3101283.

[22] H. Hildmann and E. Kovacs, "Using unmanned aerial vehicles (UAVs) as mobile sensing platforms (MSPs) for disaster response, civil security and public safety," *Drones*, vol. 3, no. 3, p. 59, 2019, https://doi.org/10.3390/drones3030059.

[23] S. A. H. Mohsan, M. A. Khan, F. Noor, I. Ullah and M. H. Alsharif, "Towards the unmanned aerial vehicles (UAVs): A comprehensive review," *Drones*, vol. 6, no. 6, p. 147, 2022, https://doi.org/10.3390/drones6060147.

[24] A. Abdelmaboud, "The Internet of Drones: Requirements, Taxonomy, Recent Advances, and Challenges of Research Trends," *Sensors*, vol. 21, no. 17, p. 5718, 2021, https://doi.org/10.3390/s21175718.

[25] M. Waliszkiewicz, K. Wojtowicz, Z. Rochala and E. Balestrieri, "The Design and Implementation of a Custom Platform for the Experimental Tuning of a Quadcopter Controller," *Sensors*, vol. 20, no. 7, p. 1940, 2020, https://doi.org/10.3390/s20071940.

[26] A. Tahir, J. Böling, M. H. Haghbayan, H. T. Toivonen and J. Plosila, "Swarms of unmanned aerial vehicles—a survey," *Journal of Industrial Information Integration*, vol. 16, p. 100106, 2019, https://doi.org/10.1016/j.jii.2019.100106.

[27] A. Menshchikov *et al*., "Data-Driven Body-Machine Interface for Drone Intuitive Control through Voice and Gestures," *IECON 2019 - 45th Annual Conference of the IEEE Industrial Electronics Society*, pp. 5602-5609, 2019, https://doi.org/10.1109/IECON.2019.8926635.

[28] W. S. Yao and C. Y. Lin, "Dynamic Stiffness Enhancement of the Quadcopter Control System," *Electronics*, vol. 11, no. 14, p. 2206, 2022, https://doi.org/10.3390/electronics11142206.

[29] W. Myeong and H. Myung, "Development of a Wall-Climbing Drone Capable of Vertical Soft Landing Using a Tilt-Rotor Mechanism," in *IEEE Access*, vol. 7, pp. 4868-4879, 2019, https://doi.org/10.1109/ACCESS.2018.2889686.

[30] S. Komarizadehasl *et al*., "A Novel Wireless Low-Cost Inclinometer Made from Combining the Measurements of Multiple MEMS Gyroscopes and Accelerometers," *Sensors*, vol. 22, no. 15, p. 5605, 2022, https://doi.org/10.3390/s22155605.

[31] J. Sandino, F. Maire, P. Caccetta, C. Sanderson and F. Gonzalez, "Drone-based autonomous motion planning system for outdoor environments under object detection uncertainty," *Remote Sensing*, vol. 13, no. 21, p. 4481, 2021, https://doi.org/10.3390/rs13214481.

[32] D. Nar and R. Kotecha, "Optimal waypoint assignment for designing drone light show formations," *Results in Control and Optimization*, vol. 9, p. 100174, 2022, https://doi.org/10.1016/j.rico.2022.100174.