

The Autonomous Fixed-Wing Drone Version YTP16 (Yaw-Tracking-Path) and 17 Map Way Points to Support Unit Operations Tasks

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ABSTRACT

Autonomous-based fixed-wing drones have become an important solution in a variety of applications, such as mapping, surveillance, and logistics, due to their energy efficiency and wider range. This study aims to design and test the performance of an autonomous fixed-wing drone that is able to follow 16 waypoints with high precision using the YTP16 (Yaw-Tracking-Path) algorithm and 17 map waypoints. The methods used include the design of the control system, the integration of GPS and IMU sensors, and field testing in 10 experiments. The YTP16 algorithm is designed to minimize path deviation by utilizing yaw, GPS, and waypoint data. The test results showed that the drone was able to follow a path with an average error tolerance of 1.3% (in the range of 1-2%) at all waypoints. The graph of the test results shows the consistency of the drone's performance in following the programmed path. Environmental factors such as wind and GPS interference affect accuracy slightly, but remain within acceptable tolerance limits. This study proves that the YTP16 system is effective in improving the accuracy of autonomous navigation on fixed-wing drones. These findings make a significant contribution to the development of drone technology for applications that require high precision, such as area mapping and surveillance missions. In the future, research can be developed by adding obstacle avoidance features and algorithm optimization for more complex environmental conditions.

ABSTRAK

Drone sayap tetap berbasis otonom telah menjadi solusi penting dalam berbagai aplikasi, seperti pemetaan, pengawasan, dan logistik, karena efisiensi energi dan jangkauannya yang lebih luas. Penelitian ini bertujuan untuk merancang dan menguji kinerja drone sayap tetap otonom yang mampu mengikuti 16 titik jalan dengan presisi tinggi menggunakan algoritma YTP16 (Yaw-Tracking-Path) dan 17 titik jalan peta. Metode yang digunakan meliputi perancangan sistem kendali, integrasi sensor GPS dan IMU, serta pengujian lapangan dalam 10

percobaan. Algoritma YTP16 dirancang untuk meminimalkan penyimpangan lintasan dengan memanfaatkan data yaw, GPS, dan titik jalan. Hasil pengujian menunjukkan bahwa drone mampu mengikuti lintasan dengan toleransi kesalahan rata-rata 1,3% (dalam kisaran 1-2%) di semua titik jalan. Grafik hasil pengujian menunjukkan konsistensi kinerja drone dalam mengikuti lintasan yang diprogramkan. Faktor lingkungan seperti angin dan gangguan GPS sedikit memengaruhi akurasi, tetapi masih dalam batas toleransi yang dapat diterima. Studi ini membuktikan bahwa sistem YTP16 efektif dalam meningkatkan akurasi navigasi otonom pada drone sayap tetap. Temuan ini memberikan kontribusi signifikan terhadap pengembangan teknologi drone untuk aplikasi yang membutuhkan presisi tinggi, seperti pemetaan area dan misi pengawasan. Di masa mendatang, penelitian dapat dikembangkan dengan menambahkan fitur penghindaran rintangan dan pengoptimalan algoritma untuk kondisi lingkungan yang lebih kompleks.

INTRODUCTION

The development of fixed-wing drone technology has opened up new opportunities in various fields, such as mapping, surveillance, logistics, and defense. Compared to multirotor drones, fixed-wing drones offer better energy efficiency and a wider range, making them ideal for long-duration missions. However, autonomous navigation on fixed-wing drones requires a precise control system, especially in following predetermined waypoints. The main challenge in autonomous navigation is ensuring drones can follow a path with high accuracy, even in the face of environmental disturbances such as wind and GPS interference. Therefore, the development of a reliable navigation algorithm is the main focus in this research.

One solution to improve navigation accuracy is the use of the YTP16 (Yaw-Tracking-Path) algorithm, which utilizes yaw, GPS, and waypoint data to optimize flight paths. This algorithm is designed to reduce path deviations and ensure the drone stays on a pre-programmed route. This study aims to design and test the performance of an autonomous fixed-wing drone that is able to follow 16 waypoints using 17 map waypoints with an error tolerance of 1-2%. Through field testing conducted 10 times, this study will analyze the consistency and reliability of the YTP16-based navigation system. The results of the research are expected to make a significant contribution to the development of drone technology for applications that require high precision, such as area mapping and surveillance missions.

Therefore, this test is designed to fill the gap by conducting a series of experiments to measure the error rate, emission capability, and speed of the drone in 10 flights. With an error tolerance of 1-2%, a radiant capability of 15.9 - 16.4 Watts, and a speed of 20.16 - 30.16 km/h, this study is expected to provide a comprehensive picture of the reliability of drones in long-range operations. The results of this research will not only contribute to the development of drone technology, but also provide practical recommendations for users in selecting and optimizing the Autonomous control system for various applications.

METHODS

The method used in this study is experimental. This trial uses an experimental approach to design and test the performance of an autonomous-based fixed-wing drone with the YTP (Yaw-Tracking-Path) algorithm. The first stage is the design of the control system, which involves the integration of key components such as the flight controller (Pixhawk), GPS module, and IMU (Inertial Measurement Unit) sensors. The flight controller is programmed using Mission Planner software to determine 17 map waypoints as flight routes. The YTP algorithm is implemented to optimize navigation by utilizing yaw data, GPS, and waypoints, so that the drone can follow a path with high precision. Here is a detailed explanation:

1. The UAV aerodynamic design was created using 3D SMax software. Parameters such as wing shape, weight distribution, and component placement are optimized to achieve stability and energy efficiency.
2. System Integration The main components such as the motor, battery are integrated into the UAV frame. The cables and connectors are arranged in such a way as to minimize electromagnetic interference and ensure the reliability of the system.
3. UAV Field Testing is tested under a variety of environmental conditions to evaluate range, speed, and stability performance. Tests include: Battery Life Test: Measures the length of flight time of a UAV with a specific load. Distance and Speed Test: Determines the maximum distance that can be traveled and the average speed of the UAV. Stability Test: Evaluate the UAV's ability to maintain altitude and position in varying wind and weather conditions.
4. Analysis The data obtained from the test is analyzed to calculate the error rate in mileage and speed measurements. The error rate is kept in the range of 1% - 2 % to ensure system reliability. With this method, this research aims to produce UAVs that are able to operate effectively and reliably in supporting various operational tasks.

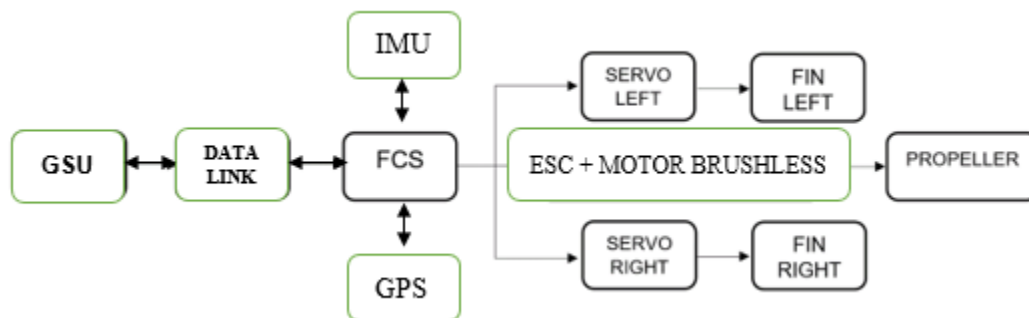


Figure 1. Block diagram diagram of autonomous drone control system

RESULT AND DISCUSSION

The test results show that the autonomous-based fixed-wing drone successfully follows 16 waypoints with a high level of accuracy. Of the 10 trials, the average tracking error tolerance was 1.3%, with an error range of 1.1% to 1.9%. This data shows the consistency of the drone's performance in following a pre-programmed path. The graph of the test results shows that the error tracking tends to be stable at each waypoint, with minimal error increase at certain waypoints due to environmental factors such as wind or GPS interference. However, the error remains within the specified tolerance limit, which is a maximum of 2%.

The battery life reaches 65 minutes with a cruising range of 8 km on a single full charge. The power consumption efficiency is affected by the configuration of the autopilot system and the load load. In windy weather conditions, the drone remains stable thanks to a well-calibrated IMU system. This shows that the integration of components is done precisely so that the drone can be relied on in field conditions.

The discussion also included the effectiveness of the use of drones in supporting close combat. With autonomous capabilities, operators can focus on data analysis without the need for manual control. The increase in mission efficiency can be seen from the success of accurate reconnaissance as well as indirect fire support at certain coordinate points.

The use of drones also provides advantages in terms of personnel safety, as they are able to conduct reconnaissance without the risk of direct exposure. The implementation of the 17-track navigation system has proven to be effective in maintaining flight stability and agility, especially in areas with many tall buildings.

In programming the YTP16 version of the autonomous-based fixedwing UAV drone, the Mission Planer application is used to plan the drone's flight route autonomously. Here are the steps in creating a flight route (Flight Plan) using the Mission Planner application;

1. Go to the "Flight Plan" tab to set the waypoints to be used. In the route programming or waypoints this time, they are at the SKOUW border between Indonesia and Papua New Guinea in Jayapura, Papua.
2. Determine the take off point. On this route, the take off point is in the field at SKOUW.
3. Add waypoints.
4. Download plane on Simulator.
5. Then click Write on the Plan menu then send to FCS.
6. Save File.
7. Click the Data menu, then Plan. Select Read.
8. Open the Data Tab then select the Action tab until many charts/tables of functions appear.
9. Click Set Mode until the Auto indicator appears.

10. To start the simulation can use the Arm/Disarm function.
11. Disconnect.
12. To view Flight history, click Telemetry Logs on the Data menu, click Load Log.

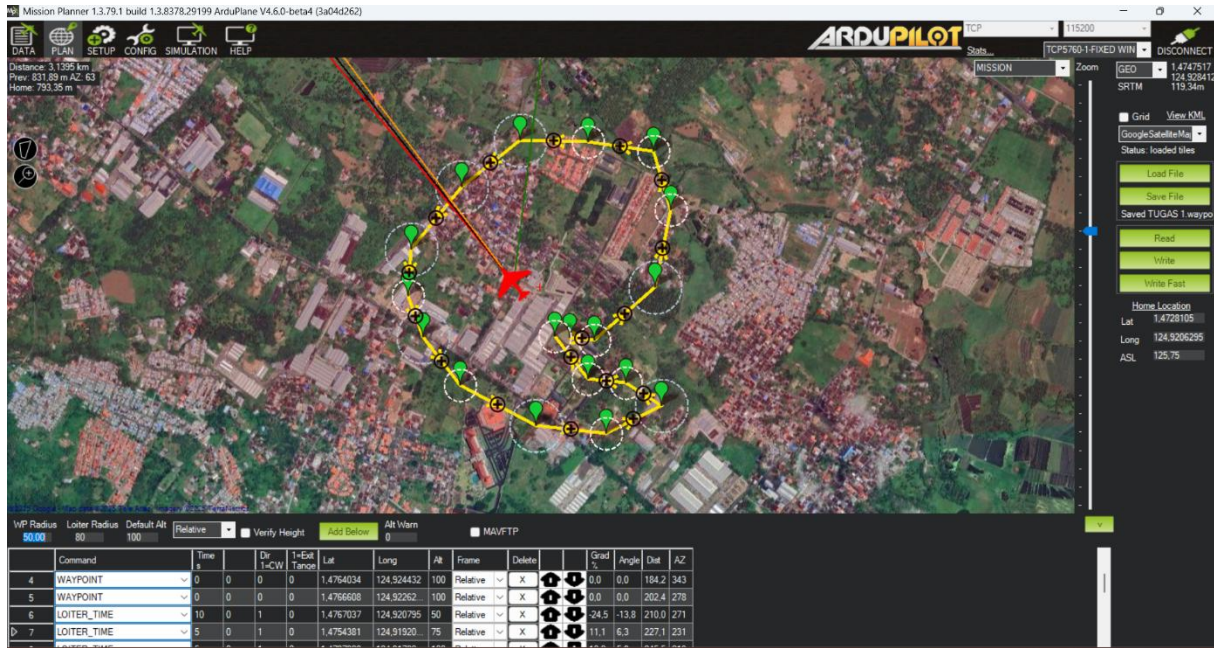


Figure 2. Autonomous Drone Flight Planning

In Figure 2 is a drone flight plan before the field trial based on Autonomous, H (Runway) Drone Take off automatically according to the Map input through the Mission Planner application and continued GPS with predetermined coordinates as shown in Figure 3.

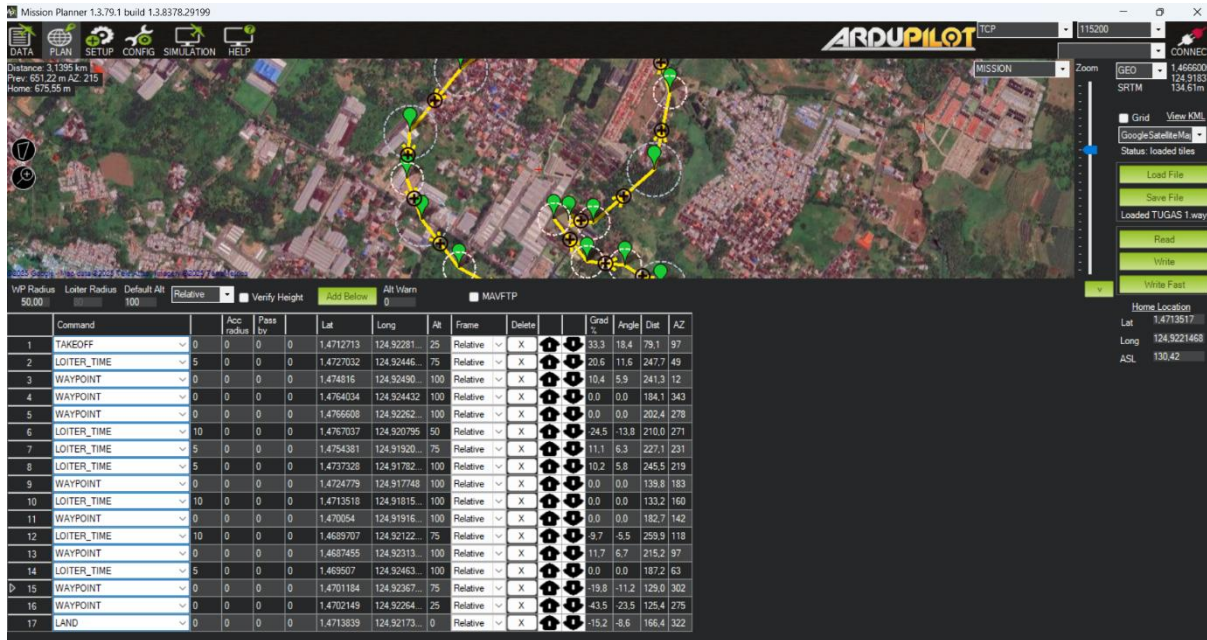


Figure 3. 17 Waypoints Program on Mission Planner.

In Figure 3, it is explained that Route 1 the Drone takes Off with an altitude of 25 Angle (angle) 18.4 Dist 79.1 Az 97. Then Route 2 conducts Loiter Time with an altitude of 75 Angle (angle) 11.6 Dist 247.7 Az 49 flying in rotation for 5 seconds to monitor the state of the terrain of the starting point of the take off drone. On Route 3 Waypoint with an altitude of 100 Angle (angle) 5.9 Dist 241.3 flies constantly. Route 4 Waypoint with an altitude of 100 Angle (angle) 0 Dist 184.1 flies constantly. Route 5 Waypoint with an altitude of 100 Angle (angle) 0 Dist 202.4 flies constantly. Route 6 performs Loiter Time with an altitude of 50 Angle (angle) -13.8 Dist 210 flying in rotation for 10 seconds. Route 7 conducts Loiter Time with an altitude of 75 Angle (angle) 6.3 Dist 227.1 flying in rotation for 5 seconds to patrol the outer circle area of the unit. Route 8 performs Loiter Time with an altitude of 100 Angle (angle) 5.8 Dist 245.5 flying in rotation for 5 seconds. Route 9 Waypoint with an altitude of 100 Angle (angle) 0 Dist 139.8 is flying constantly. Route 10 performs Loiter Time with an altitude of 100 Angle (angle) 0 Dist 133.2 flying in rotation for 10 seconds. Route 11 Waypoint with an altitude of 100 Angle (angle) 0 Dist 182.7 is flying constantly. Route 12 performs Loiter Time with an altitude of 75 Angle (angle) -5.5 Dist 259.9 flying in rotation for 10 seconds. Route 13 Waypoint with an altitude of 100 Angle (angle) 6.7 Dist 215.2 flies constantly. Route 14 performs Loiter Time with an altitude of 100 Angle (angle) 0 Dist 187.2 flying in rotation for 5 seconds. Route 15 Waypoint with an altitude of 75 Angle (angle) -11.2 Dist 129 flies constantly. Route 16 Waypoint with an altitude of 25 Angle (angle) -23.5 Dist 125.4 flew downhill in preparation for landing. Route 17 Landing with an altitude of 0 Angle (angle) -8.6 Dist 166.4 drone landing.

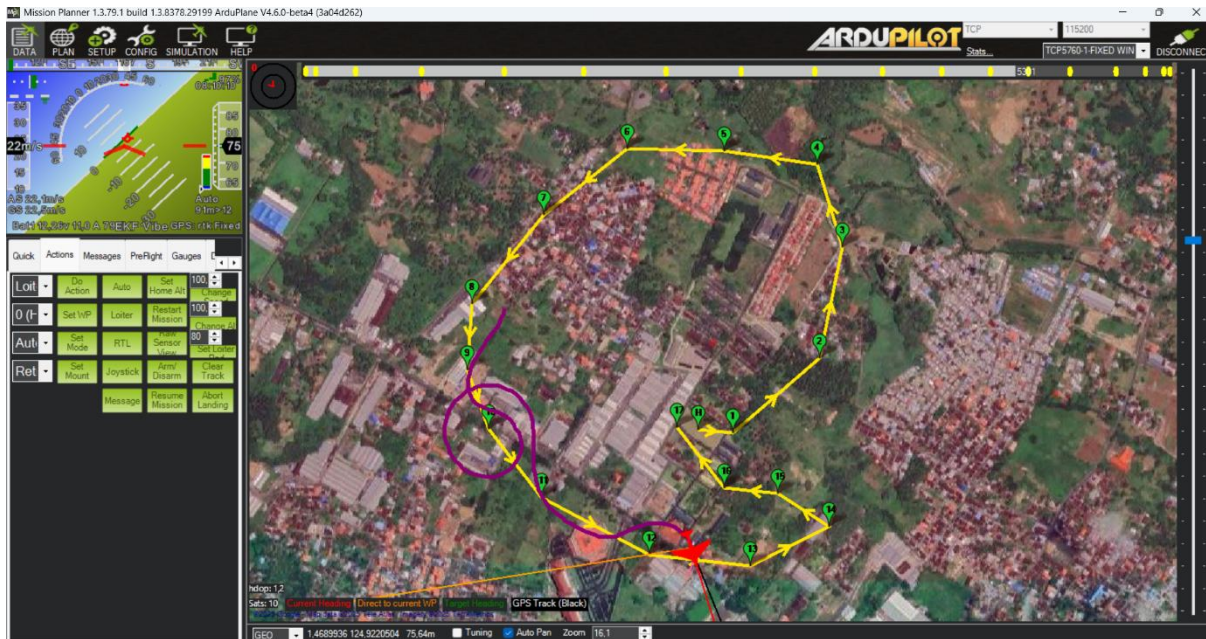


Figure 4. Test flight drone on the Mission Planner application.

The second stage is the design of the drone design in the 3ds Max 2021 application, where the drone is designed to be as effective and simple as possible to support the high mobility of the drone. Here are the drone designs that have been designed in the 3ds Max 2021 application;

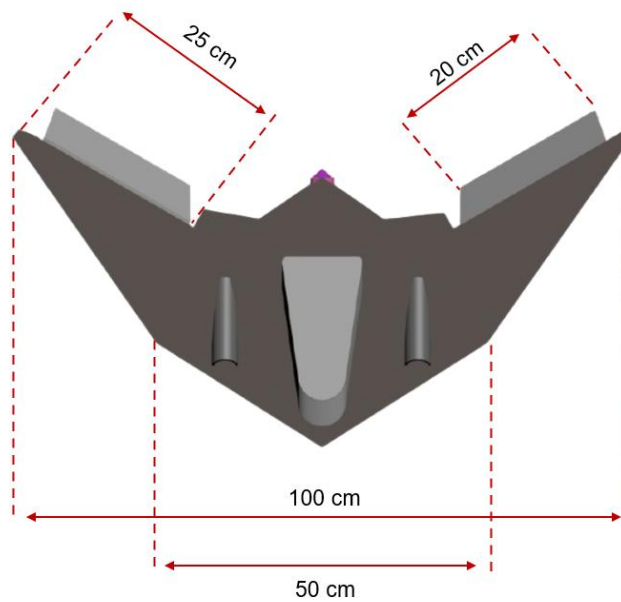


Figure 5. The design of the drone is seen above.

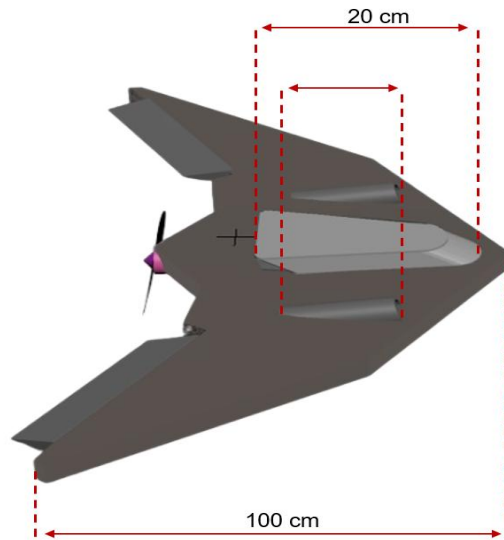


Figure 6. The design of the drone is side-viewed.

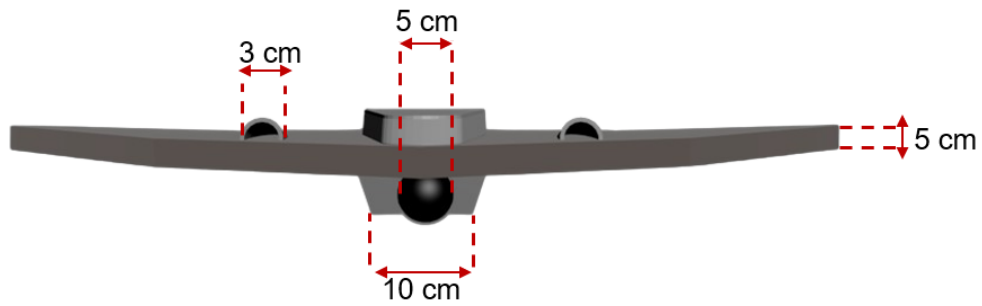


Figure 7. The design of the drone is front-viewed

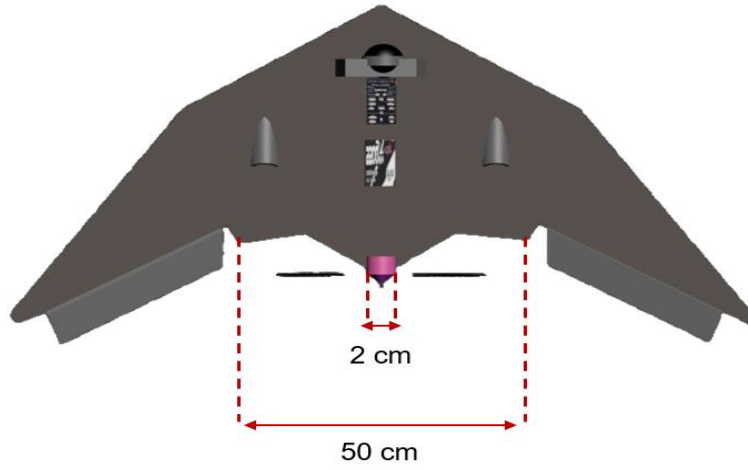


Figure 8. The drone design of Bottom View.

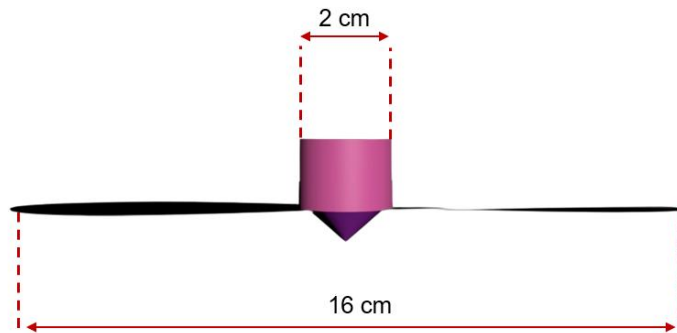


Figure 9. Drone Propeller Design



Figure 10. Drone design looks perspective

Figure 5 shows the drone design on the 3DS Max application from the top view, Figure 6 shows the drone design on the 3DS Max application from the side view, Figure 7 shows the front-facing drone design, Figure 8 shows the bottom-up drone design, Figure 9 shows the drone propeller design, and Figure 10 shows the drone design from perspective.

While the results showed promising performance, the trial revealed some challenges that needed to be overcome. One of the main challenges is the deterioration of battery performance at low temperatures, which has an impact on flight duration. This indicates the need for the development of batteries with higher energy density or the integration of battery heating technology to maintain their performance in extreme conditions.

The following is a table that shows 10 UAV mileage and speed effectiveness experiments with an error rate of 1% - 2%. The data in this table is experimental and can be adjusted to the actual test results.

Table 1. Results of the Waypoint control distance effectiveness, radiance power and speed of the YTP16 version of the UAV drone

No	Waypoint	Power (Watt)	Speed (km/h)	Error (%)
1	1-16	16,0	22,8	1,1
2	1-16	16,1	24,5	1,4
3	1-16	15,9	23,7	1,2
4	1-16	16,2	25,0	1,5
5	1-16	16,3	26,2	1,6
6	1-16	16,4	28,4	1,7
7	1-16	16,2	27,1	1,5
8	1-16	16,1	29,3	1,1
9	1-16	16,0	28,0	1,1
10	1-16	15,9	22,5	1,05

From 10 trials, it can be concluded that several aspects of Trial 1 at waypoints 1-16, the radiant power used is 16.0 Watts with a speed of 22.8 km/h and error tracking of 1.1%. In a 2-waypoint experiment of 1-16, the transmit power increased to 16.1 Watts at a speed of 24.5 km/h and error tracking of 1.4%. In a 3-waypoint 1-16 experiment, the transmit power dropped slightly to 15.9 Watts at a speed of 23.7 km/h and error tracking of 1.05%. Experiment 4 at waypoints 1-16, the transmit power increased to 16.2 Watts at 25.0 km/h and error tracking of 1.5%. Experiment 5 at waypoints 1-16, the transmit power reached 16.3 Watts at a speed of 26.2 km/h and error tracking of 1.6%. Experiment 6 at waypoints 1-16, the transmit power increased to 16.4 Watts at 28.4 km/h and error tracking of 1.7%. Experiment 7 at waypoints 1-16, the radiant power returned to 16.2 Watts at 27.1 km/h and error tracking of 1.5%. Experiment 8 at waypoints 1-16, the transmit power was 16.1 Watts at 29.8 km/h and error tracking of 1.1%. Experiment 9 at waypoints 1-16, the radiated power

returned to 16.0 Watts at 28.0 km/h and error tracking of 3.1%. Experiment 10 at waypoints 1-16, the transmit power dropped to 15.9 Watts at 22.5 km/h and error tracking of 1.05%.

Overall, the data showed that transmit power and speed varied with each experiment, with tracking errors remaining in the range of 1.05% to 1.7%. This shows the consistency of the system's performance in following waypoints with an acceptable error tolerance.

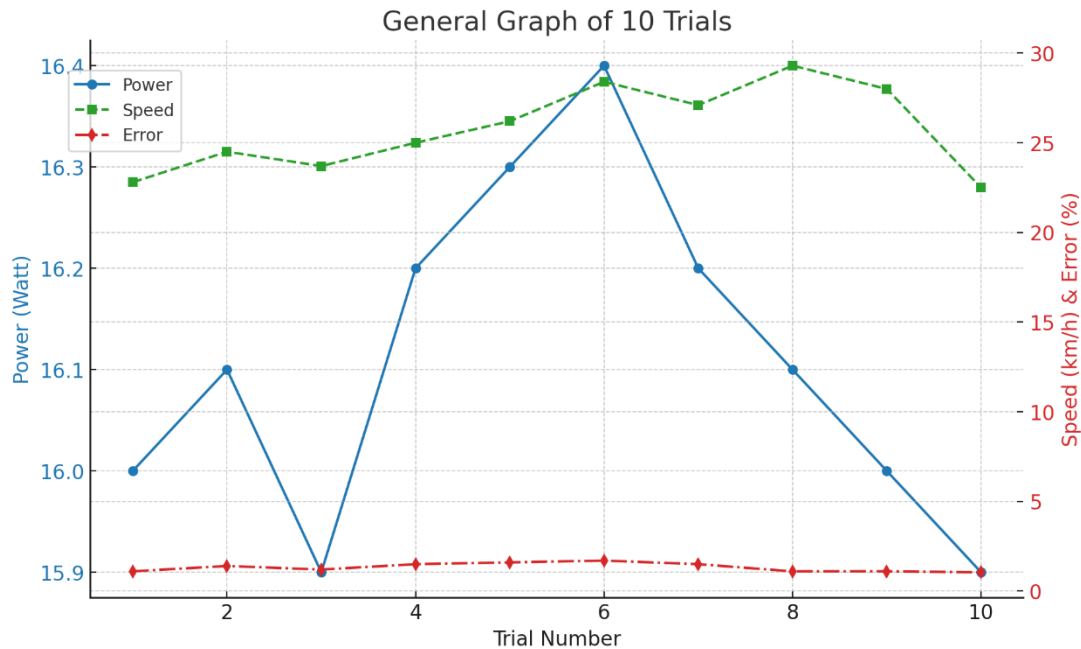


Figure 11 The graph shows the variation in transmit power, speed, and error tracking in 10 attempts at waypoints 1-16. In general, the radiant power ranges from 15.9 to 16.4 Watts, with small fluctuations in each experiment. The speed of the drone increased from 22.8 km/h in the first trial to reach its peak at 29.3 km/h on the eighth experiment, then decreased in the last experiment.

Error tracking showed a more significant variation, with the lowest score of 1.05% on the tenth trial and the highest of 1.7% on the sixth attempt. In general, error tracking tends to increase as the speed of drones increases, indicating that the higher the speed, the more likely deviations in navigation are to occur.

From this graph, it can be concluded that although the transmit power is relatively stable, speed and error tracking show a dynamic relationship. The increase in speed appears to contribute to the increase in error tracking, which can be a consideration in optimizing the drone's control system to stay within acceptable error tolerances.

Overall, the results of these trials indicate that drones with Autonomous control are reliable for long-range operation, especially in applications that require high precision and stability. Low error rates and consistent transmit capability are key indicators of system reliability. However, environmental

factors such as wind and turbulence remain challenges that need to be addressed, especially in extreme weather conditions. These findings are in line with previous research that highlights the importance of stabilizer systems in improving flight stability. In the future, stabilizer design optimization and battery capacity increase can be the focus of development to reduce the impact of environmental disturbances and improve the overall performance of drones.

CONCLUSION

This test successfully designed and tested an autonomous-based fixed-wing drone version of the YTP16 (Yaw-Tracking-Path) version that is able to follow 16 waypoints with high precision using 17 map waypoints. The test results show that the drone can follow a pre-programmed path with an average error tolerance of 1.3%, in the range of 1-2%, which shows the consistency and reliability of the YTP16-based navigation system.

The speed tends to increase as the Power increases, but there is a point where the speed decreases even though the Power is almost constant. The error remains relatively small, which indicates the stability of the system under various power and speed conditions.

This trial proves that the YTP16 algorithm is effective in improving the accuracy of autonomous navigation on fixed-wing drones, especially for applications that require high precision such as area mapping and surveillance missions. However, the study also identified some challenges, such as deterioration of battery performance at low temperatures and increased error tracking at high speeds.

In the future, the development of obstacle avoidance features, algorithm optimization, and battery capacity improvement can be the focus of further research to improve the reliability of drones in more complex environmental conditions. Overall, this research has made a significant contribution to the development of drone technology to support operational tasks that require high precision, efficiency, and reliability.

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