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Simulation and Performance Evaluation Of UAV

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Abstract— An Unmanned Aerial Vehicle (UAV) is referred to as a drone; as drones are used as a lower risk alternative for people on dangerous missions and employed in a range of services, they have attracted interest from many business, research, security and service sectors. However, the drone must maintain a stable altitude to avoid accidents such as unexpected falls or head-on collisions with buildings. In this paper the pid control system is proposed to maintain the altitude of the drone, PID control, also known as Proportional-Integral-Derivative control, is a feedback mechanism used in a control system. This kind of control, often known as three-term control, is offered by a PID controller, by computing and manipulating three parameters, the proportional (kp), integral (ki), and derivative (kd) of how much a process variable deviates from the target set point value. A variety of control procedures will be performed for a given piece of work. The simulation results show an improvement in the system and response parameters, the PID can therefore accurately support order performance in the UAV system.

Keywords— PID control, Drone, UAV, Civil application.

1. Introduction

The development of high-resolution sensors and cameras has led to the widespread use of drones, as they can be used in various civilian applications. Drones are able to fly into difficult, hard-to-reach locations, which reduces the risk to manned aircraft personnel. Drones are used in many various applications, such as weather, surveillance, Search and Rescue (SaR), media, journalism especially when covering catastrophes, demonstrations, firefighting, and traffic management, among other tasks. **[17].**
The drones are remotely controllable and capable of autonomous flight due to the flight plans loaded into the built-in electronics and Global Positioning System (GPS), shown in **Figure 1.**

Figure 1: Autonomous drones used for environmental studies and reconnaissance **[9].**

Due to several initiatives in the fields of electronics, optics, computer science, energy storage, etc., Unmanned Aerial Vehicles (UAVs) have advanced quickly in recent years. The first airplane containing reusable radio control technology was developed in the 1930s. Military drones equipped with conventional sensors and camera units were subsequently created. As increasing requirements develop, UAV technology evolves quickly, and UAV solutions are also being proposed more fast. Specific UAV applications and market competitiveness both influence the design of drones **[4, 5]**. For a range of applications, such as network deployment, sensor applications, and rescue operations, UAVs have attracted a lot of interest from both academics and business. Since the majority of these applications depend on accurate drone control and substantial real-time data transmission; as a result, they require wireless technologies that can effectively connect drones and terrestrial networks. One possible technology for the use of UAV systems is cellular technology, such as the current Long-Term Evolution (LTE) standard and the upcoming 5G standard. This paper will explore the challenge of getting the drone to stay at a stable altitude. In order to prevent drops and collisions, the drone must maintain a steady altitude. By using the PID control algorithm in MATLAB, drones can be guided to in order to improve system performance and enhance the drone's altitude and control the drone's altitude.

2. Literature Reviews

The dayton-wright airplane company created an unmanned aerial torpedo that would detonate at a preset moment, which marked the beginning of the first uas experiments during World War I. The Hewitt-Sperry Automatic Aircraft, flew for the first time in 1917 **[3, 10].** The first airplane containing reusable radio control technology was developed in the 1930s. Military drones equipped with conventional sensors and camera units were subsequently created. Due to significant technological advancements, it is now simple to identify a wide range of drones that might be used for civilian purposes. According to a recent update, google and amazon are advancing their drone technology to make package delivery by air easier. As increasing requirements develop, UAV technology evolves quickly, and UAV solutions are also being proposed more fast. In **[7],** there was a survey of the most significant UAV uses in the cyosphere. The research in **[12]** shows how fast UAV solutions become a part of daily life. They suggest creating a system employing IOT-Based drone technology that can rapidly and efficiently detecting coronavirus automatically from the thermal image. An optical camera and a thermal camera are also both part of the UAV system. It transmits the person's image, the GPS location, and a thermal image of the heated body discovered to the Ground Control Station (GCS). In this paper, the PID control system is used to maintaining the drone at a fixed altitude. By adding a PID controller before the pitch, roll, and yaw controls. The simulation result shows an enhancement in the system and response parameters.

3. The Mechanism of Action of Drones

3.1 *Moments and Forces*

A drone's range of motion and the amount of time it can fly are both considered to be part of its endurance. This is strongly related to the battery's capacity and how much electricity the motor is producing to keep the drone in the air. The limits for each drone are defined by a number of different drone variables, however in order to maintain simplicity, the bearing computation will be roughly calculated using the equation below **[14].**

$$\text{Endurance(hrs)} = \frac{\text{Battery Capacity(Ah)}}{\text{Current(Amps)}} \quad (1)$$

The distance a drone is capable of travelling is known as its range. Using the following equation, the range calculation for both the fixed and quadruple wings may be approximated.

$$R = \frac{\text{kV.V.60.Pitch}}{12.5260} * \text{Endurance(hrs)} \quad (2)$$

Where:

- The KV value represents how many times per minute the motor will revolve when given 1 volt.
- The "Pitch" value represents the propeller's pitch (measured in inches) on the UAV.
- The aircraft's maximum time in the air, measured in hours, is its endurance value.

Rotors or propellers are used by drones for power and control. Because all forces naturally work in opposition to one another, the air pushes the rotor upward while it is dragged downward by the rotor. The main idea behind lifting is to manage the strength both up and down. The elevator will rise higher as the rotor spins more quickly, and vice versa. For the drone to move up, the net push of its four rotors must be greater than the force of gravity pulling it downward. The total angular momentum is 0 since the rotors are spinning in the opposite directions, as shown in **Figure 2** below. The rotors' rotational speed has an impact on angular momentum. In this illustration, the clockwise rotors in green have negative rotational momentum, whereas the anticlockwise rotors have positive angular momentum. The system's total angular momentum must stay constant if there is no torque acting on it (zero in this instance).

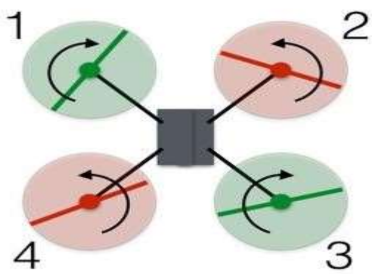

Figure 2: The rotors of drone (from the top) [**14**]

3.2 *Rotational Dynamics*

The rules that apply to rotational motions are [**14**]

About The X axis (Pitch): $Mx = Ix * \theta x$ (3)

About The Y axis (Roll): $My = Iy * \theta y$ (4)

About The Z axis (Yaw): $Mz = Iz * \theta z$ (5)

Where M is the torques in Nm, i is the moments of inertia in kg.m² and θ the rotational acceleration in rad/s².

A. Calculating the yaw moment of inertia

Yaw orients the drone in a certain direction depending on the angle θz. Where θz is the rotation about the z-axis going through the center of mass of the drone.

Development of our embedded rod around its end we can write the following [**14]**

$$I = \frac{1}{3} M L^2 \quad (6)$$

With M the mass of the rod in kg and L its length in m.

$$Iz = \frac{1}{3} * \frac{0.743}{4} * \left(\frac{0.335}{2}\right)^2 * 4 \quad (7)$$

$$Iz = 0.007\ Kg.m^2$$

B. Calculating the roll and pitch moments of inertia

$$Ix, y = \frac{1}{3} * \frac{0.743}{4} * \left(\frac{0.237}{2}\right)^2 * 4 = 0.003\ Kg.m^2 \quad (8)$$

3.3 *Linear Dynamics*

The second law of newton states that the total external forces acting on an object with mass m, must equal that object's mass times its acceleration, as shown in **Figure 3** below.

$$Fpropx = \sin(\theta y) * \cos(\theta x) * (F1 + F2 + F3 + F4) \quad (9)$$

$$Fpropy = \sin(\theta x) * \cos(\theta y) * (F1 + F2 + F3 + F4) \quad (10)$$

$$Fpropz = \cos(\theta y) * \cos(\theta y) * (F1 + F2 + F3 + F4) \quad (11)$$

$$\theta xy = -atan^2 * \left(\frac{Fpropx}{Fpropy}\right) \quad (12)$$

$$XY2D = \sqrt{F^2Propx + F^2Prop\ y} \quad (13)$$

$$Fpropx = XY2D * \sin(\theta XY +/- \theta z) \quad (14)$$

$$Fpropy = XY2D * \cos(\theta XY +/- \theta z) \quad (15)$$

Where θz is the rotation about the z-axis going through the center of mass of the drone.

4. Communications Media for Drone Applications

Radio Frequency (RF) transmission is used by the data link to send and receive data to and from drones. This information, both given and received, contains details on the intended target location. In addition to the load information, airspeed, altitude, and many other characteristics, such as the remaining flight time, distance to the pilot, and the position of the pilot are also available. In order for the pilot and ground crew to keep an eye on even the slightest details, the data connection may also transfer live video from drones to GCS. The data system Employs a number of frequencies, and the type and model of the drone in issue determines which one is used, as well as the duties you will be doing.

4.1 *Cellular Technology for UAVs Operation*

Unmanned Aerial Vehicles (UAVs) have drawn a lot of attention from both academia and business for a variety of uses, including network deployment, sensor applications, and rescue operations. The bulk of these applications rely on reliable drone control and large real-time data exchange, thus they need wireless technology that can link drones and terrestrial networks appropriately. Cellular technology, such as the present LTE standard and the impending 5G standard, is one potential technology for the usage of UAV systems. The following features of cellular technology are available:

- High levels of dependability and service quality.
- Robust security.
- Easy navigation
- Modify the cellular network to better suit the needs of drones.

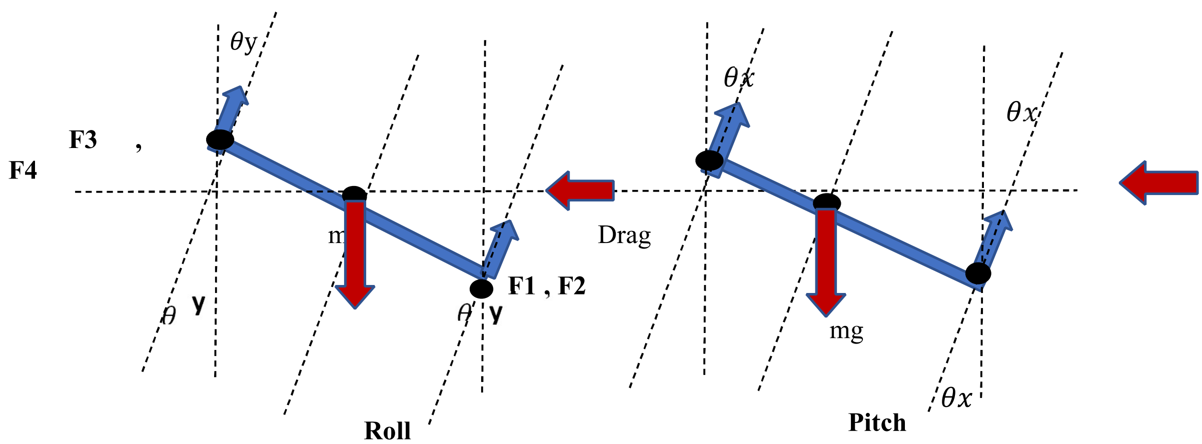

Figure 3: Thrust vectors and linear forces on the drone **[14].**

4.2 *UAV Communications in 3GPP Cellular*

The Third-Generation Partnership Project (3GPP) has four key goals:

• Comprehend the conditions for drone movement.
• The creation of a channel model to describe how sound travels from the air to the earth.
• Examine if it is possible to deliver cellular service to aerial devices using the current lte infrastructure.
• Specify the improvements needed to successfully service UAVs.

Deliveries can be facilitated by using UAV position and flight plan knowledge. The Full-Dimensional Multi-Mimo BS (FD-MIMO) aerial defined in LTE improves UAV communications via beam-shaped transmission, enabling to reduce the amount of interference caused to the confined geographical areas where the UAV is situated . Drones with beam-forming skills and directional antennae help to lessen the amount of downlink interference that air devices detect.

5. The Uses of Drones on the Civilian Side

Applications for drones are not only restricted to the military sector; they also contribute significantly to the economy thanks to their cutting-edge technology and strong capabilities. Drones are used in many different industries now, and as technology develops continuously, it will only make these robots more potent and practical in the future. Compared to their earlier iterations, they can now carry enormous weights and provide customers with extended flying periods. UAVs are getting a lot of new sensors as a result of advancing technology, which will considerably increase their performance and enable them to be used in specialized, high-performance applications. Drones are currently used in every field that humans employ to do business, including agriculture and the internet world. Here, this section will discuss the drone applications that can teach us about their incredible possibilities.

5.1 *Seek and Rescue (SaR)*

SaR operations are one of the most prevalent uses of Unmanned Aerial Vehicles (UAV) . In recent years, their use in SaR operations has garnered significant attention and become a topic of interest. Using onboard cameras to acquire high-resolution images and films to scan a particular target area (stricken region), UAVs are utilized for aerial survey and damage assessment after a natural catastrophe. This aids in determining the level of infrastructure damage resulting from the incident. Search and Rescue professionals may select the targeted search area and commence SaR operations appropriately after an assessment using UAVs, SaR operations may be performed automatically, accurately, and without incurring additional risks. In the alcedo project, aquadrotor UAV equipped with GPS was used to develop a prototype for detecting missing persons. In a capstone project, the usage of UAVs to aid SaR operations in snow avalanche conditions is examined. Furthermore, drones may be utilized to provide food, water, and medicine to the wounded. The drone is designed for vertical takeoff and landing, and a powerful propulsion motor has been installed to allow it to lift 10 to 15 kg of heavy things, such as pharmaceuticals, food, and water. Drones may function as airfield stations to rapidly restore service in areas when the whole telecommunications infrastructure has been destroyed. This contributes to SaR operations **[11].**

5.2 *Construction and Infrastructure Inspection*

In this section, we will examine the uses of Unmanned Aerial Vehicles (UAVs) in infrastructure inspection, as well as the associated issues, research trends. Infrastructure inspection applications may use UAVs for real-time monitoring of construction sites. Consequently, project managers may monitor the construction site using UAVs to get a deeper understanding of the project's progress without personally visiting the site. In addition, UAVs may be used to examine high-voltage electrical transmission lines. UAVs may potentially be used for autonomous navigation during inspections of power line infrastructure to detect and diagnose infrastructure defects. UAVs may also be used to monitor gas, oil, and water pipelines in order to detect gas pipeline breaches. Some examples of the usage of Unmanned Aerial Vehicles (UAVs) for infrastructure evaluation and construction monitoring:

• Approximately 65,000 AT&T cell towers need maintenance, repair, or installation; AT&T labs' video analytics team collaborated with other organizations (e.g., Intel, qualcomm, etc.) To develop a UAV-Based cell tower inspection system that is faster, more accurate, and more cost-effective.

• Internal infrastructure inspection; since 1994, maverick has offered industrial uav inspection services for equipment, pipelines, tanks, and stack interiors throughout western Canada. Shown in **Figure 4** below.

Figure 4: Usage of single drone systems for infrastructure inspection and construction **[11].**

5.3 *Delivery of Goods*

Drones are able to deliver packages, food, and other things. Unmanned ambulances drones may be used in the healthcare industry to deliver and collect blood samples, vaccines, and medications.

5.4 *Providing Wireless Coverage*

UAVs may be used to supply wireless coverage in emergency scenarios when each UAV functions as an aerial wireless base station when the cellular network goes down. **Figure 5** illustrates the fundamental networking architecture of UAV-Aided wireless communications. When compared to the features of terrestrial communication channels, these channels have a number of distinctive qualities. Due to reflection, scattering, and diffraction by structures like buildings and the ground, low-altitude uav ground channels may potentially experience many multipath components.

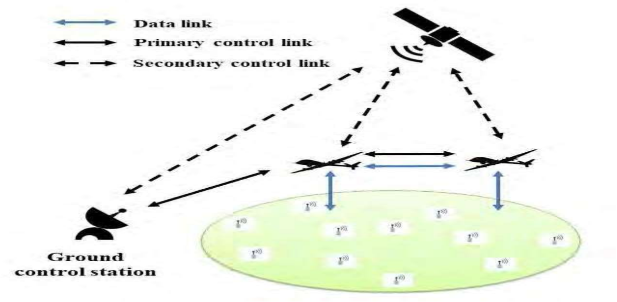

Figure 5: The Fundamental Network Design for UAV-Assisted Wireless Communications **[11].**

6. Drone Modelling System

6.1 *Model Diagram*

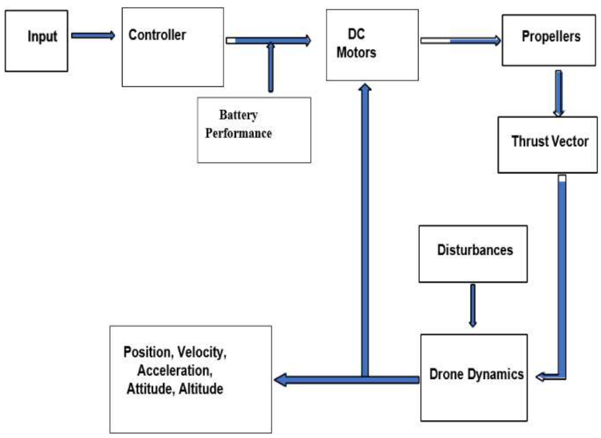

Figure 6: The block diagram of the drone system **[1].**

6.2 *PID Control System*

Proportional-Integral-Derivative control, or PID control is a feedback technique used in a control system. A PID controller provides a control of our drone in order to reach a specified altitude. Various control actions can be implemented for a specific part of the task by calculating and controlling three parameters: the proportional, integral, and derivative of how much a process variable deviates from the desired set point value. For a specific piece of work, many control actions can be done with PID. Each of the two parameters of the PID controller can be used to complete specific control tasks. It is possible to use two parameters while setting the third to 0. The terms kp, kd, and ki can be used to represent the proportional, derivative, and integral parameters. These three variables each have an impact on closed loop control **[18].**

$$u(t) = Kp\ e(t) + Ki \int_0 e(t)dt + Kd\ \frac{d\ e(t)}{dt} \qquad (16)$$

Where kp , ki and kd, all are non-negative. Automated altitude control will be used in this section. In effect, the basic open-loop model will be converted to a closed-loop model to ensure that it can independently control the pedal of the drone to raise it to a certain height. PID control technology will be employed to carry out this program. The control system will play with the throttle to give the desired altitude given the wind conditions and all that stuff. Then the actual altitude obtained based on the values mentioned. DMX block routing signal is added. The multiplexer or DMX block needs three outputs.

Following the input of these values for PID control:

Proportional (P): 9
Integral (I): 1
Derivative (D): 100
Filter coefficient (N):100

$$\mathrm{P} + \mathrm{I}\frac{1}{\mathrm{s}} + \mathrm{D}\frac{\mathrm{N}}{1 + \mathrm{N}\frac{1}{\mathrm{s}}} \qquad (17)$$

The block diagram design become as shown in **Figure 7** below:

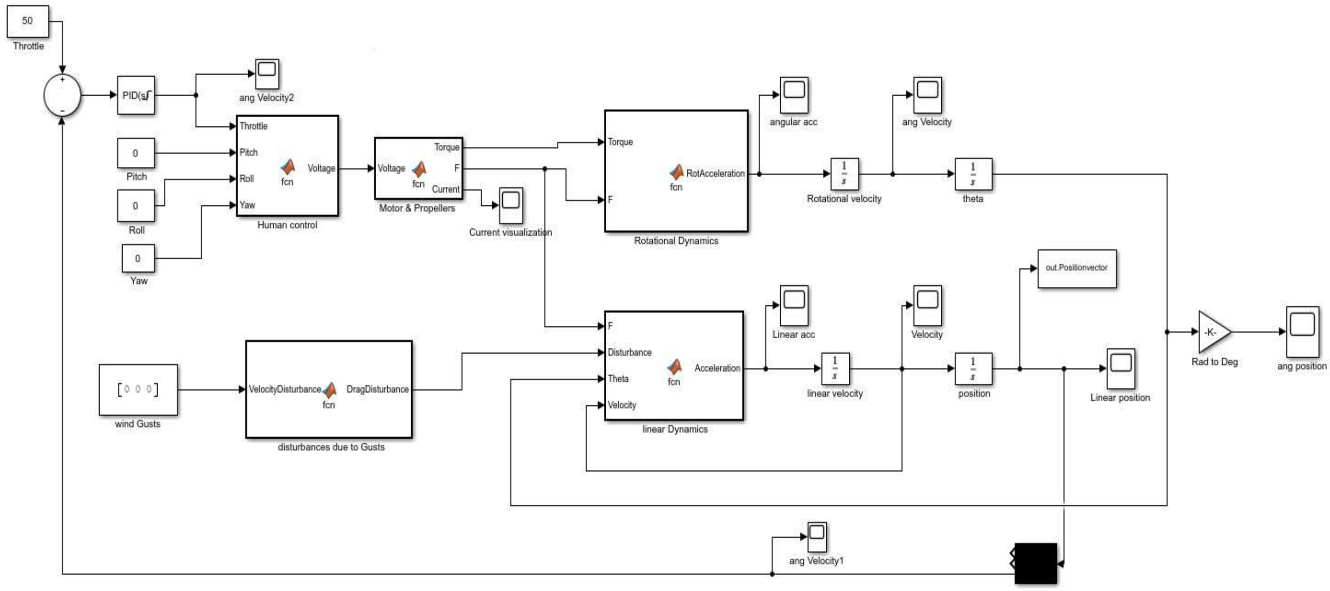

Figure 7: The Block Diagram design in the closing loop

The outcomes for the Angular Velocity are as follows in **Figure 8** below:

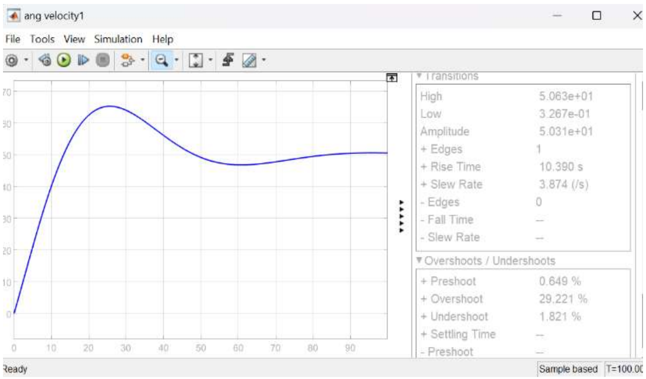

Figure 8: The output of the Ang Velocity after add the PID controller

7. Simulation Result and Discussion

In this part, How to implement a PID feedback control system will be highlighted. The improvement in the drone's altitude and how to control its altitude will be noticed after using the PID controller. The terms Kp, Kd, and Ki . All three of these variables have an impact on closed-loop control. It can affects on the steady-state error as well as the rise time, settling time, and overshoot as shown in **Table 1** below.

Table 1: The Rise t., Setting t., Overshoot and Steady state error in the closed loop control system

Control Response	**Rise time**	**Settling time**	**Overshoot**	**Steady state error**
K_p	decrease	small change	increase	decrease
K_d	small change	decrease	decrease	no change
K_i	decrease	increase	increase	eliminate

A look will be given to how a PID control system implements feedback. PID controller will be added before pitch, roll, and yaw.
The Final design will look as shown in **Figure 9** follows:

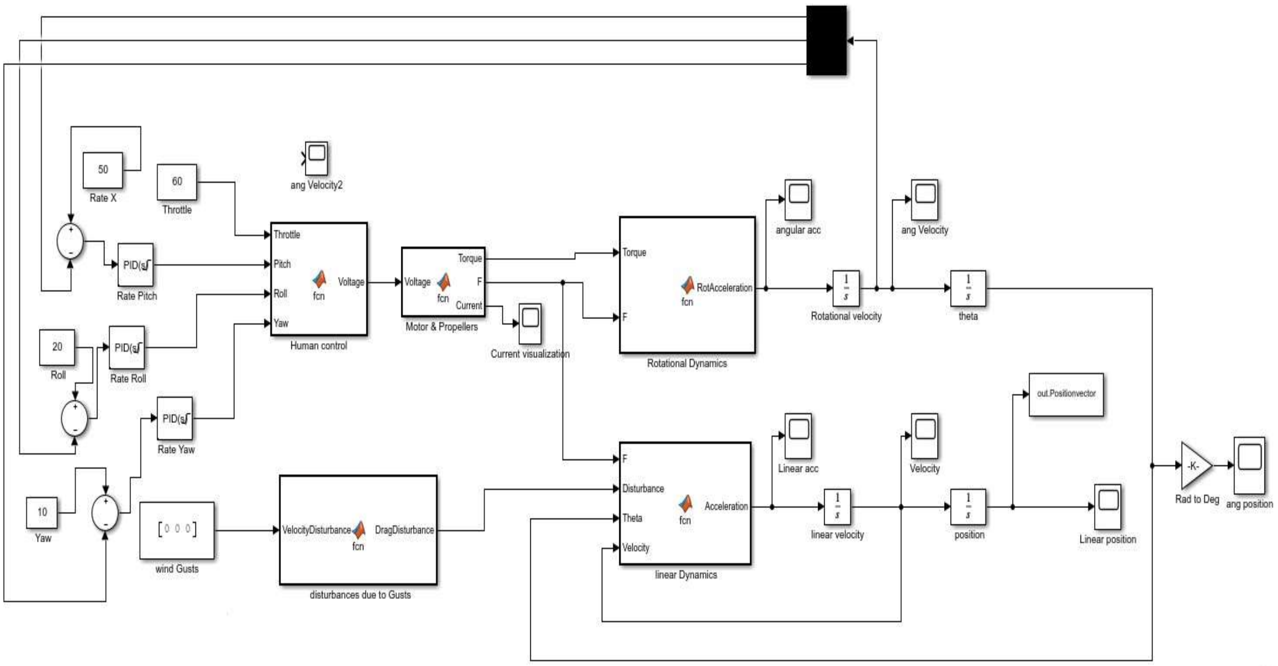

Figure 9: block diagram after addition of PID control

Following the input of these Values for PID control:

Proportional (P): 5
Integral (I): 0.5
Derivative (D): 0
Filter coefficient (N):100

We get this result for Angular Velocity shown in **Figure 10** below:

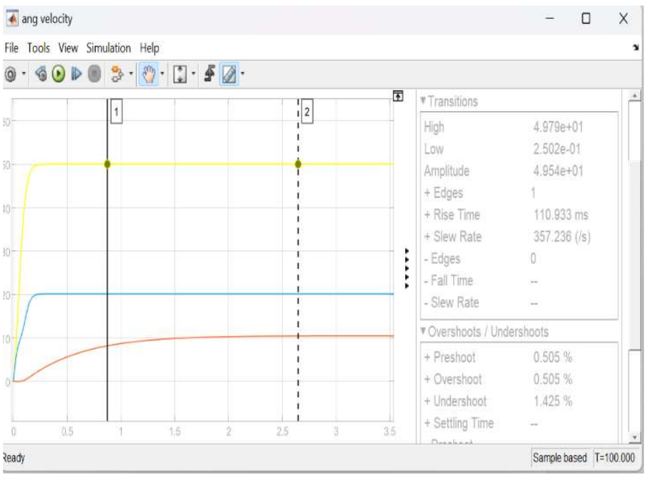

Figure 10: The Angular Velocity after using the PID control

Through the matlab results, the following can be concluded: It is necessary for the drone to maintain a constant altitude to prevent accidents such as unexpected falls or direct collisions with buildings; the altitude of the plane has improved significantly after using PID, and the plane is more stable than before. It can be said that users can guide the height of the drone to achieve the ideal height by applying the PID control method. The proportional gain (Kp), integrated gain (Ki), and derivative gain (Kd), the three PID control parameters, are recorded live while flying. Before and after the employment of the PID, the findings of simulation and testing were both given.

8. The Conclusion

In this paper, the uses of UAVs for civilian purposes and the difficulties they face are highlighted. UAVs equipped with sensors can be used as an air sensor network in remote sensing for environmental monitoring and disaster control. Drones are more affordable than traditional surveillance equipment, and can monitor vast areas of open highways or narrow their attention to a specific location. In the context of 5G and B5G wireless networks, drone communications are also discussed. First, relevant design issues that may significantly help in better understanding the newly introduced new network architecture were discovered and an integrated space-to-Earth network of B5G communication systems was imagined. It was also explained in a simplified manner how to design the drone with an explanation of each mass with equations. The design was practically applied using the MATLAB program, then the problem we were facing was identified and how to solve it, which is how to obtain a fixed height of the aircraft. The altitude of the drone has been controlled using the PID algorithm in MATLAB software. Finally, it found a lot of unresolved research issues that were expected to be future research directions. This is an important and recent topic with the aim that it will provide a solid foundation for 5G/B5G iot applications. The market value of unmanned aerial vehicles is expected to reach $45 billion in the next several years.

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Figures

Figure 1: Autonomous drones used for environmental studies and reconnaissance. (1)

Figure 2: The rotors of drone (from the top). (2)

Figure 3: Thrust vectors and linear forces on the drone (3)

Figure 4: Usage of single drone systems for infrastructure inspection and construction (4)

Figure 5: The fundamental network design for UAV-Assisted Wireless Communications (5)

Figure 6**:** The block diagram of the drone system (5)

Figure 7: The block diagram design in the Closing Loop (6)

Figure 8: The output of the Ang Velocity after add the PID Controller (7)

Figure 9: Block diagram after addition of PID control (8)

Figure 10: The Angular velocity after using the PID control (8)

Tables

Table 1: the Rise t., Setting t., overshoot and steady state error in the closed loop control system (7)

محاكاة وتقييم أداء مراقبة الطائرات بدون طيار للتطبيقات المدنية

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الخلاصة – يشار إلى مركبة جوية بدون طيار على أنها طائرة بدون طيار. نظرًا لاستخدام الطائرات بدون طيار كبديل أقل خطورة للأشخاص الذين يقومون بمهام خطيرة ويعملون في مجموعة من الخدمات ، فقد جذبت اهتمام العديد من قطاعات الأعمال والبحث والأمن والخدمات. ومع ذلك ، يجب أن تحافظ الطائرة بدون طيار على ارتفاع ثابت لتجنب الحوادث مثل السقوط غير المتوقع أو الاصطدامات المباشرة مع المباني. في هذا البحث ، تم اقتراح نظام التحكم PID للحفاظ على ارتفاع الطائرة بدون طيار ، والتحكم PID ، المعروف أيضًا باسم التحكم الاشتقاقي النسبي المتكامل ، هو آلية تغذية مرتدة مستخدمة في نظام التحكم. يتم تقديم هذا النوع من التحكم ، الذي يُعرف غالبًا باسم التحكم ثلاثي المدى ، بواسطة وحدة تحكم PID ، عن طريق حساب ومعالجة ثلاثة معلمات ، المتناسب (Kp) ، والتكامل (Ki) ، والمشتق (Kd) لمقدار انحراف متغير العملية من قيمة نقطة التحديد المستهدفة. تم تنفيذ مجموعة متنوعة من إجراءات التحكم لجزء معين من العمل. تظهر نتيجة المحاكاة تحسنًا في معلمات النظام والاستجابة ، وبالتالي يمكن لـ PID دعم أداء الطلب بدقة في نظام الطائرات بدون طيار.

الكلمات الرئيسية – تحكم PID ، طائرة بدون طيار ، التحكم في الطائرات بدون طيار ، تطبيقات الطائرة بدون طيار بالجانب المدني.