Control of Autonomous Aerial Vehicles to Transport a Medical Supplies

RICARDO YAURI[1,2], SANTIAGO FERNANDEZ[1], ANYELA AQUINO[3,4]
[1]Facultad de Ingeniería,
Universidad Tecnológica del Perú,
Lima,
PERU

[2]Universidad Nacional Mayor de San Marcos,
Lima,
PERU

[3]Institut National des Sciences Appliquées de Rennes,
Rennes,
FRANCE

[4]Telecom Sudparis,
FRANCE

Abstract: - Public health surveillance must guarantee the safety of people by limiting human mobility, in cases of isolation, through product deliveries, making it necessary to use drones to guarantee safety because they play a crucial role in several sectors. The literature review highlights the benefits of automation in-home delivery using drones, focusing on time efficiency and competitiveness in various sectors, and provides crucial design parameters to ensure its implementation in urban areas using different control techniques. A contribution was proposed to a solution that aims to realize the honeycomb design, which drones create during flight, controlled by a flight and delivery algorithm in a simulation environment applying an iterative methodology and continuous transport tests. medical burden. The results indicate a qualitative advance in the successful creation of simulated terrain, although the lack of numerical data on takeoffs and landings suggests the need for additional quantitative measurements. The current results support the efficiency of drones in route planning, precise management of medical cargo, and reduction of delivery time is numerical evidence that reinforces the robustness of the solution. In conclusion, this study developed a functional prototype to control drones with a flight planning algorithm and a swarm formation system for the transport of medical supplies in urban environments, although the need for future research to implement artificial intelligence technologies is noted. that improve transportation efficiency.

Key-Words: - Drones, medical supplies, transportation, simulation, Honeycomb, UAV.

Received: May 29, 2023. Revised: November 15, 2023. Accepted: December 19, 2023. Published: January 18, 2024.

1 Introduction

Contemporary society grapples with a significant dilemma concerning the efficient surveillance of public health and health emergencies across various nations. The core of this issue lies in the limited resources, insufficient technology, and the lack of coordination between health agencies and governments.

Contributing to the care of people's health and well-being is necessary in events of sanitary isolation, which has generated that the delivery of products directly to the doors of homes has increased, [1], [2]. Health authorities support reducing people's mobility to safeguard their well-being during events such as pandemics, [3].

An important solution has been the use of drones (UAVs), which is useful in different civil and military applications due to their reliability in various tasks. These solutions incorporate many functionalities, such as the integration of cameras and radars. This allows the collection and analysis of data, which can be applied in traffic surveillance, emergency response, and aerial monitoring, [4], [5], [6]. Additionally, there has been a substantial surge in the demand for unmanned drones to provide support in the realm of medical emergencies, [7], [8].

Hence, a comprehensive examination of the package loading procedure is imperative, as it involves the implementation of novel trajectories, enhancements in algorithms, and flight optimization through simulations across diverse urban settings. Furthermore, due to the rise of electronic commerce, there is a need for efficient transportation of packages, which has led numerous companies to explore technologies to improve the efficiency of transportation, trying to solve the problem of flying autonomous aerial vehicles in formation, [9], [10], [11].

The literature review shows that the proposed solutions have a common approach to using drones in the automatic delivery of items at home, automating processes, saving time, and improving competitiveness in fields such as surveillance, tracking, telecommunications, and delivery of medical supplies. This literature review allows us to obtain design parameters for the drone, considering economic and legal aspects to guarantee its circulation in any city.

For all the above, this research raises the following research question: How to carry out the control process of drones in formation to transport a medical supply in a simulation environment? Given this research question, the objective to be met is to design a control system for autonomous aerial vehicles using a flight and delivery configuration algorithm, the creation of a simulation environment, and the design of a honeycomb system with control systems.

The innovative value of this research lies in the exhaustive analysis of the parameters and functions of delivery drones, considering so many technical aspects of simulation, proposing an innovative "honeycomb" design, controlled by a configuration algorithm for flight and Delivery. This paper is structured in the following chapters: Section 2 presents related papers; and Section 3 describes the concepts used for drone flight simulation processes. Section 4 details the implementation of the system. Finally, the results are presented in Section 5, and the conclusions are presented in Section 6

2 Literature Review

A bibliographic review of research articles was conducted using specific keywords related to the topic. This literature review made it possible to identify existing theories, concepts, solutions, and systems in the field of drones and automated delivery. From this review, the most relevant theories and concepts have been explored and selected, which are applied to improve control and automation in the delivery of medical supplies.

Development methodologies usually use PID controls for UAVs in various environments. Some research compares traditional PID control with a new non-smooth control strategy (improving precision by 2.03 degrees), [12], [13], while others use a mechanism for stable flight control in a Hexa-rotor UAV with two PID controllers, [14]. Furthermore, the Flux Guided method that enables efficient displacement using electrical flow in leader-follower UAVs with PID control is also explored (circling a target in times of 0.52 and 0.88 seconds), [15].

In the case of other types of PID controls, some research, [16], [17], [18] (PID diffuse gain provides a better response with 10% overshoot and 15-second settling time) choose to use the Parrot "AR Drone" drone to implement them (The result shows that the PSO technique adjusts the PID controllers better, saving time). In [16], a gradient descent approach with automatic adjustment of the PID control is used, while in [17], LabVIEW software is used to modify the control and improve the flight position according to a predefined path. Other investigations, [15], [19], implemented a PID control called Flux Guided, where its advantage is highlighted by significantly reducing the degrees of freedom by requiring only nodes at the limit of the surface area (LQR controller has 0.0% overshoot and 4.1% settling time).

UAVs can be used in surveillance tasks, tree counting, and humidity studies, [20], [21]. They demonstrate their usefulness in data collection processes, using, in some cases, a UAV hexacopter with brushless motors to control takeoff and movement, [14], or using lightweight materials and brushless motors, [13]. For simulation processes, some research used Parrot AR drones to evaluate two types of different PID controls (one based on fuzzy gain and the other on gradient descent autotuning), [16], [18], [21], with simulations to compare their performance in navigation by waypoints.

The integration of Internet of Things technologies with drones allows for strengthening their use for the automatic delivery of items, automating processes, allowing remote control, and saving time, with a significant impact on the delivery industry, [18], [22], [23], (It is demonstrated that a wireless data rate of 100 Gbps can be achieved at frequencies below 20 GHz). Its results focus on proposing a drone flight control design, in a simulation environment.

3 Unmanned Autonomous Air Vehicles

Drones, or unmanned aerial vehicles (UAVs), are autonomous aircraft that can fly without human intervention and be operated remotely from ground control stations or through autopilot and sensors such as global positioning systems. These UAVs have various applications, including wireless coverage, military use, medical applications, and transportation of goods, being a more economical option than manned systems in several situations, [4], [24].

Applications of UAVs include Multi-UAV Cooperation, where multiple drones collaborate for common goals, improving efficiency in sectors such as agriculture; UAV-to-VANET Collaborations, which streamline traffic surveillance by identifying accidents more quickly than conventional techniques, [5], [25]. In [26], drone control is classified into several categories: manual control, where the pilot uses a remote control or a mobile application, [27]; automatic control with a predefined route, [28]; sensor control to improve the precision of UAV movement, [29]; and artificial intelligence control using machine learning algorithms and swarm control, [30].

3.1 UAVs Transport Methods

There are several ways to transport cargo with drones, including attaching packages directly to the drone, using containers, and delivering using a dedicated system. Some drones are designed to carry heavy or bulky loads, while others can carry multiple packages simultaneously, [25].

Furthermore, according to [31], drones represent an alternative to current land transportation methods, allowing traffic to be avoided and delivery times to be reduced. Figure 1 illustrates how a drone performs inspections on high-voltage towers and cables, facilitating maintenance work, [32].

3.2 Simulation Tools

For drone simulation and synthetic data generation, there are essential tools that allow you to create detailed and realistic virtual environments. These tools play a vital role in providing detailed information about objects, sensors, and three-dimensional simulations. Together, these solutions form a comprehensive process to diversify simulation pools and assess the gap between simulation and reality in drone detection, [33]. Among some tools, we have:

- Unreal engine. is a game engine that is used with other modules and software to generate synthetic data in virtual simulations, [34].
- AirSim. is an open-source drone simulation software for creating realistic 3D environments, facilitating the generation of synthetic data to train deep learning models.

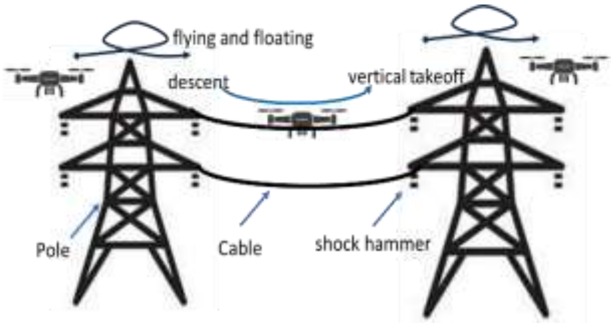

Fig. 1: Tower inspection using drones, [32]

4 Proposed System

The proposed solution involves a honeycomb design that the drones will create during flight, controlled by an algorithm for flight and delivery in a simulation environment. This process begins with the flight controller that sends commands to the actuators, moving the medical load and facilitating the interaction with sensors and navigation control for communication with the logistics area (Figure 2).

To develop the system, Kanban and Scrum methodologies were applied, performing iterations at each stage to allow continuous adjustments before moving forward. An iterative approach was adopted, performing multiple cycles of design, implementation, verification, and maintenance within each phase. Additionally, rapid prototyping was used to create agile versions of the system and obtain early feedback. The incremental development divided the project into progressive and functional phases, adapting to the needs of medical cargo transportation. Continuous feedback and early, continuous testing ensured the quality of the system, identifying problems and making corrections throughout the process.

4.1 Formation Flight Configuration Algorithm

The flight configuration algorithm is responsible for defining the starting point and destination for package delivery. Initially, a connection is established with AirSim (an application specialized in simulating drone flights) and then the specific route of the drone is programmed, which includes the collection of the package at the point of origin, followed by the flight to the destination. Once the delivery is complete, the drone lands safely, thus ending its mission (Figure 3).

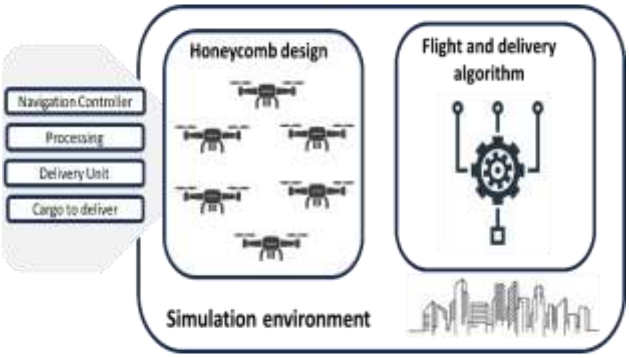

Fig. 2: System diagram

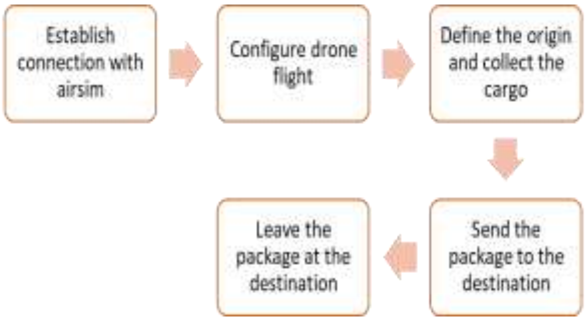

Fig 3: Flight configuration diagram

The complexity of the algorithm is determined by the number of drones, being efficient in setting up a honeycomb pattern in the simulation. The algorithm sets the initial position in the form of a hexagon for each drone using a for loop, highlighting that the calculation involves constant mathematical operations per drone, and the drones are then moved to their initial and final positions using moveToPositionAsync(). In Visual Studio Code a script called “primera_test.py” was implemented, the connection to the simulator was started, and the control of the drone was enabled through the AirSim API. Next, the drone takes off and is guided from an initial position entered to a target position and after a pause of 5 seconds, the drone lands and the control is deactivated, thus ending the connection with the simulator (Figure 4).

Fig. 4: Algorithm flowchart

4.2 Simulation Environment to Transport a Medical Supply

To facilitate the transportation of medical cargo using autonomous aerial vehicles, a simulation environment was designed using Unreal Engine, which offers a highly realistic 3D virtual space. In this environment, drone and medical payload models were precisely incorporated and control algorithms were applied.

Creating a drone simulation environment in Unreal Engine is crucial to evaluate and improve system performance in a safe and controlled context. This process involves downloading specific content to configure key elements in the editor. In this case, the Epic Games Launcher software is used, and the "Landscape Mountains" option is selected, followed by configuring AirSim plugins in the project. Making sure to adjust the location of the "PlayerStart" and setting the GameMode Override to AirSimGameMode are critical steps to ensure proper drone behavior. Furthermore, it is essential to optimize the editor settings, avoiding overloading the CPU and ensuring smooth performance. The creation of a specific mountain environment is shown in Figure 5 and can be modified to simulate different flight and payload control scenarios for the drone.

4.3 Honeycomb System using a Control Process

The honeycomb system plays a fundamental role in allowing the configuration of a hexagonal formation of drones through coordinated control systems. It is essential to develop an algorithm that facilitates this swarm flight control for coordinated flights requiring precise instructions, maintaining their positions in the hexagonal formation.

Fig. 5: Simulation environment

Mutual communication between drones is essential to exchange data and adjust flight as necessary and a control system ensures smooth and efficient formation flight, which is essential for the success of drone transport missions, including activities such as takeoff, flight, landing, and understanding the origin and destination of each drone (Figure 6).

Figure 7 shows the beginning of the drone simulation process in the AirSim program, simultaneously with Visual Studio Code, which houses the code responsible for automating the drone's actions, according to the instructions in Table 1. This process is the fundamental beginning of the process, highlighting the integration of the code and the real-time simulation of the drone.

The instructions in Table 1 are used to calculate and configure the initial position of multiple drones in a honeycomb formation in a flight simulation program. First, it calculates honeycomb positions for the drones, then takes them off and moves them to their respective starting positions. This allows the coordinated flight of multiple drones in a hexagonal formation to be simulated in the simulation environment.

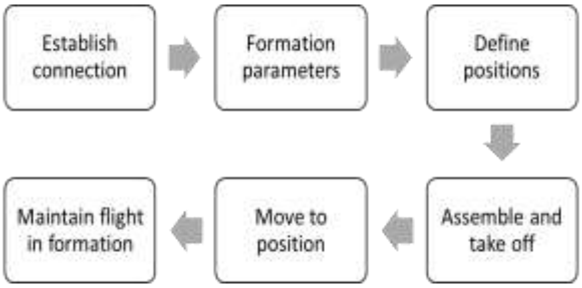

Fig. 6: Honeycomb System Diagram

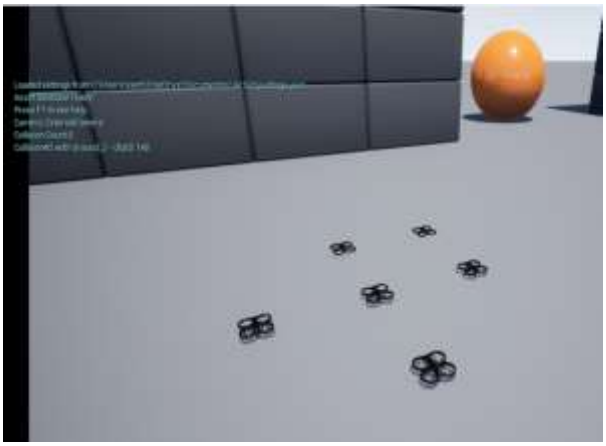

Fig. 7: Drone motion simulation environment

Table 1. Honeycomb System Instructions

```
# Calculate honeycomb position
center_position = airsim.Vector3r(0, 0, 0)
radius = 5.0
angle_deg = 60.0
angle_rad = math.radians(angle_deg)

# Set initial position. honeycomb. Ascend
for drone_name, drone_data in drones.items():
    client = clients[drone_name]
    posicion_inicial = drone_data["posicion_inicial"]

# Calculate honeycomb position
    angle = drones.keys().index(drone_name) * angle_rad
    x = center_position.x_val + radius * math.cos(angle)
    y = center_position.y_val + radius * math.sin(angle)
    z = posicion_inicial.z_val + 5.0

    # Despegar y mover a la posición inicial
    client.takeoffAsync().join()
client.moveToPositionAsync(x, y, z, 5).join()
```

The algorithm depicted in Table 1 initiates by establishing a central point for the hexagon at coordinates (0, 0, 0) and configuring a hexagon with a radius of 5.0 units. A 60.0-degree angle separates each point of the hexagon. Subsequently, through a for loop, the initial drone positions are computed in the shape of a hexagon, utilizing the drone's index from the dictionary. Trigonometric functions, along with the angle and radius, determine the "x" and "y" coordinates, while the "z" coordinate is elevated 5 meters above the starting point. To transition the drones to their initial hexagonal positions, the moveToPositionAsync() method is employed.

It is crucial to adjust the settings.json file within Visual Studio to customize simulator parameters, as exemplified in a segment of the file outlined in Table 2. The customization encompasses drones denoted as "Drone1" to "Drone5," each furnished with a specialized sensor named "MyDistanceX" designed for distance measurement. Furthermore, the configuration version is stipulated as "1.2" on line 2, ensuring compatibility with the anticipated structure mandated by the simulator. In addition, the simulation mode is defined as "Multirotor" in line 3, which allows simulating vehicles with multiple propellers, such as quadcopters, allowing complex flights and specific studies on these aircraft. This enriches the user experience and facilitates more accurate and realistic investigations.

5 Results

5.1 Flight Configuration Algorithm

The use of swarm algorithm was chosen for its computational efficiency, which depends on the number of drones to be used. In addition, it can calculate the initial positions in a hexagon, being efficient in generating a honeycomb flight pattern.

Table 2. Drone 1 settings in settings.json file

Line	Instruction
1	"SeeDocsAt": "https://github.... ",
2	"SettingsVersion": 1.2,
3	"SimMode": "Multirotor",
4	"Vehicles": {
5	"Drone1": {
6	"VehicleType": "SimpleFlight",
7	"X": 0,
8	"Y": 4,
9	"Z": -2,
10	"Yaw": -180,
11	"Sensors": {
12	"MyDistance1": {
13	"SensorType": 5,
14	"Enabled": true,
15	"NumberOfChannels": 4,
16	"PointsPerSecond": 10000,
17	"X": 0,
18	"Y": 0,
19	"Z": 0,

The connection with AirSim software ensures an efficient process from collection to delivery. As a result, a code was generated resulting from the implementation of an algorithm (Table 3) that shows the flight configuration and distribution process in autonomous flight formation, representing only the final product of an extensive simulation and testing process. This detailed approach ensures real-world system safety and effectiveness, highlighting the importance of rigorous testing in the development of autonomous technologies.

In the drone flight simulation code, the statement, client.takeoffAsync().join(), allows the drone to take off in the simulator, preparing it for flight. The second instruction is client.moveToPositionAsync(x, y, z, speed).join(), guide the drone to a specific position defined by three-dimensional coordinates (x, y, z) with a given speed. These instructions are essential for simulating precise drone movements, providing a fundamental basis for the evaluation of flight algorithms before their implementation in the real world (Table 3).

5.2 Simulation Environment Creation

A coordinated flight control system was implemented to control cargo transported through three distinct areas: a mountainous terrain, a city, and an urbanized area. Although the simulation accurately represents the natural and urban environments, it does not include details about the takeoff and landing of the drone, nor does it show the final location of the medical cargo after the mission (Figure 8).

Table 3. Drone flight configuration

Line	Instruction
1	import airsim
2	import time
7	…
8	# Drone setup
9	client.enableApiControl(True)
10	client.armDisarm(True)
11	client.takeoffAsync().join()
12	…
16	# Take off and fly to the target position
17	client.moveToPositionAsync(posicion_inicial.x_val, posicion_inicial.y_val, posicion_inicial.z_val, 5).join()
18	client.moveToPositionAsync(posicion_objetivo.x_val, posicion_objetivo.y_val, posicion_objetivo.z_val, 5).join()

Fig. 8: Simulation environment of an urbanization

5.3 Honeycomb System for Drones

In Figure 9, the transport of medical cargo in a city is simulated, where efficient route planning is conducted and adapted to changing conditions, where it is highlighted, that drones manage to reduce delivery times and avoid collisions, which suggests a successful performance. In Figure 10, the visual representation shows how drones operate in a more complex environment, with urban structures that imitate a more densely populated area, evidencing adaptability to changing conditions in this context. During testing, the drones demonstrated efficient route planning and adaptability to changing conditions in the virtual environment, reducing delivery times and avoiding collisions.

The interaction of the drone for the delivery of medical cargo allowed a reliable landing, to ensure the care of supplies and care of patients. On the other hand, managing variations in supplies to be delivered for different weights demonstrates the need for the robustness of the honeycomb system. In addition, updates to the AirSim program generated the possibility of adaptation to a simulation environment, allowing a realistic experience that can be improved in other research such as medical logistics.

6 Conclusions

In this article, a prototype was implemented to evaluate drones with a flight planning algorithm and swarm formation. The appropriate use of this technology was evidenced by the evaluation of its efficiency in the transportation of medical loads in urban environments and cities.

Fig. 9: Swarm formation in the city

Fig. 10: Swarm formation in an urbanization

The design and implementation of the simulation environment were suitable for test flights with drones, using AirSim which was important for autonomous systems. The delivery algorithm was integrated into this environment, analyzing its behavior through flight tests.

Despite the results achieved, it must be considered that the approach and type of load prevent the results from being generalized. Furthermore, the use of laboratory simulations avoids generalizing to actual transportation conditions, indicating the need for field testing to evaluate their effectiveness in the real world. This study does not address aspects of regulation and legislation necessary to implement this technology in urban areas. Future work can investigate the feasibility of implementing artificial intelligence technologies in autonomous aerial vehicles in training, to improve efficiency and safety in transportation.

References:

[1] P. L. Nedelea, T. O. Popa, E. Manolescu, C. Bouros, G. Grigorasi, and D. Andritoi, “Telemedicine System Applicability Using Drones in Pandemic Emergency Medical Situations,” *Electron. 2022, Vol. 11, Page 2160*, vol. 11, no. 14, p. 2160, Jul. 2022, doi: 10.3390/ELECTRONICS11142160.

[2] A. Dolcini, L. Iuppariello, D. Calderone, M. Cesarelli, and F. Clemente, “Guardian Angel 2.0: A Telemedicine Service for Children with Home Mechanical Ventilation,” *Rev. Roum. des Sci. Tech. Ser. Electrotech. Energ.*, vol. 67, no. 3, pp. 355–358, Oct. 2022.

[3] M. F. Molina de Juan, “Child care in times of pandemic. Notes to rethink the Argentine

experience," *Actual. Juridica Iberoam.*, pp. 190–201, 2020.

[4] M. A. Al-Shareeda, M. A. Saare, and S. Manickam, "Unmanned aerial vehicle: a review and future directions," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 30, no. 2, pp. 778–786, May 2023, doi: 10.11591/ijeecs.v30.i2.pp778-786.

[5] F. Pasandideh, J. P. J. da Costa, R. Kunst, N. Islam, W. Hardjawana, and E. Pignaton de Freitas, "A Review of Flying Ad Hoc Networks: Key Characteristics, Applications, and Wireless Technologies," *Remote Sens.*, vol. 14, no. 18, p. 4459, Sep. 2022, doi: 10.3390/rs14184459.

[6] L. Diels, M. Vlaminck, B. De Wit, W. Philips, and H. Luong, "On the Optimal Mounting Angle for a Spinning LiDAR on a UAV," *IEEE Sens. J.*, vol. 22, no. 21, pp. 21240–21247, Nov. 2022, doi: 10.1109/JSEN.2022.3208434.

[7] S. Cui, Q. Sun, and Q. Zhang, "A Time-Dependent Vehicle Routing Problem for Instant Delivery Based on Memetic Algorithm," *Comput. Intell. Neurosci.*, vol. 2022, 2022, doi: 10.1155/2022/5099008.

[8] M. Lin, Y. Chen, R. Han, and Y. Chen, "Discrete Optimization on Truck-Drone Collaborative Transportation System for Delivering Medical Resources," *Discret. Dyn. Nat. Soc.*, vol. 2022, 2022, doi: 10.1155/2022/1811288.

[9] P. Lohan and D. Mishra, "Utility-Aware Optimal Resource Allocation Protocol for UAV-Assisted Small Cells with Heterogeneous Coverage Demands," *IEEE Trans. Wirel. Commun.*, vol. 19, no. 2, pp. 1221–1236, Feb. 2020, doi: 10.1109/TWC.2019.2951770.

[10] J. L. Mishra, K. D. Chiwenga, and K. Ali, "Collaboration as an enabler for circular economy: a case study of a developing country," *Manag. Decis.*, vol. 59, no. 8, pp. 1784–1800, 2019, doi: 10.1108/MD-10-2018-1111/FULL/XML.

[11] M. Mozaffari, W. Saad, M. Bennis, Y. H. Nam, and M. Debbah, "A Tutorial on UAVs for Wireless Networks: Applications, Challenges, and Open Problems," *IEEE Commun. Surv. Tutorials*, vol. 21, no. 3, pp. 2334–2360, 2019, doi: 10.1109/COMST.2019.2902862.

[12] H. Guo, M. Chen, and Y. Shen, "Sliding Mode Attitude Control for a QUAV Based on a Nonlinear Disturbance Observer," in *Lecture Notes in Electrical Engineering*, vol. 934, Springer Science and Business Media Deutschland GmbH, 2023, pp. 859–868. doi: 10.1007/978-981-19-3998-3_82.

[13] S. Li, Z. Sun, and M. A. Talpur, "A finite time composite control method for quadrotor UAV with wind disturbance rejection," *Comput. Electr. Eng.*, vol. 103, p. 108299, Oct. 2022, doi: 10.1016/j.compeleceng.2022.108299.

[14] R. Schacht-Rodriguez, G. Ortiz-Torres, C. D. Garcia-Beltran, C. M. Astorga-Zaragoza, J. C. Ponsart, and A. J. Perez-Estrada, "Design and development of a UAV Experimental Platform," *IEEE Lat. Am. Trans.*, vol. 16, no. 5, pp. 1320–1327, May 2018, doi: 10.1109/TLA.2018.8408423.

[15] J. Hartley, H. P. H. Shum, E. S. L. Ho, H. Wang, and S. Ramamoorthy, "Formation control for UAVs using a Flux Guided approach," *Expert Syst. Appl.*, vol. 205, p. 117665, Nov. 2022, doi: 10.1016/j.eswa.2022.117665.

[16] V. M. Babu, K. Das, and S. Kumar, "Designing of self tuning PID controller for AR drone quadrotor," in *2017 18th International Conference on Advanced Robotics (ICAR)*, Jul. 2017, pp. 167–172. doi: 10.1109/ICAR.2017.8023513.

[17] C. Copot, C. Muresan, T. MacThi, and C. Ionescu, "An Application to Robot Manipulator Joint Control by Using Constrained PID Based PSO," in *2018 IEEE 12th International Symposium on Applied Computational Intelligence and Informatics (SACI)*, May 2018, pp. 000279–000284. doi: 10.1109/SACI.2018.8440927.

[18] A. Prayitno, V. Indrawati, and I. Immanuel Trusulaw, "Fuzzy Gain Scheduling PID Control for Position of the AR.Drone," *Int. J. Electr. Comput. Eng.*, vol. 8, no. 4, p. 1939, Aug. 2018, doi: 10.11591/ijece.v8i4.pp1939-1946.

[19] T. Shakeel, J. Arshad, M. H. Jaffery, A. U. Rehman, E. T. Eldin, and N. A. Ghamry, "A Comparative Study of Control Methods for X3D Quadrotor Feedback Trajectory Control," *Appl. Sci.*, vol. 12, no. 18, p. 9254, Sep. 2022, doi: 10.3390/app12189254.

[20] A. D. Boursianis, M. S. Papadopoulou, P. Diamantoulakis, A. Liopa-Tsakalidi, P. Barouchas, and G. Salahas, "Internet of Things (IoT) and Agricultural Unmanned Aerial Vehicles (UAVs) in smart farming: A comprehensive review," *Internet of Things*, vol. 18, p. 100187, May 2022, doi:

10.1016/j.iot.2020.100187.

[21] F. G. Souza, M. F. Portes, M. V. Silva, M. M. Teixeira, and M. R. Furtado Júnior, "Impact of sprayer drone flight height on droplet spectrum in mountainous coffee plantation," *Rev. Bras. Eng. Agrícola e Ambient.*, vol. 26, no. 12, pp. 901–906, Aug. 2022, doi: 10.1590/1807-1929/AGRIAMBI.V26N12P901-906.

[22] A. Y. Husodo, H. A. Wisesa, and W. Jatmiko, "Dynamic Motion Planning for Conducting Obstacle Avoidance Maneuver of Fixed Wing Autonomous Aerial Vehicle," in *2019 4th Asia-Pacific Conference on Intelligent Robot Systems (ACIRS)*, Jul. 2019, pp. 78–83. doi: 10.1109/ACIRS.2019.8936024.

[23] P. Tong, X. Yang, Y. Yang, W. Liu, and P. Wu, "Multi-UAV Collaborative Absolute Vision Positioning and Navigation: A Survey and Discussion," *Drones 2023, Vol. 7, Page 261*, vol. 7, no. 4, p. 261, Apr. 2023, doi: 10.3390/DRONES7040261.

[24] M. Jones, S. Djahel, and K. Welsh, "Path-Planning for Unmanned Aerial Vehicles with Environment Complexity Considerations: A Survey," *ACM Comput. Surv.*, vol. 55, no. 11, Feb. 2023, doi: 10.1145/3570723.

[25] H. Eskandaripour and E. Boldsaikhan, "Last-Mile Drone Delivery: Past, Present, and Future," *Drones 2023, Vol. 7, Page 77*, vol. 7, no. 2, p. 77, Jan. 2023, doi: 10.3390/DRONES7020077.

[26] Z. Li, Y. Zhang, H. Wu, S. Suzuki, A. Namiki, and W. Wang, "Design and Application of a UAV Autonomous Inspection System for High-Voltage Power Transmission Lines," *Remote Sens. 2023, Vol. 15, Page 865*, vol. 15, no. 3, p. 865, Feb. 2023, doi: 10.3390/RS15030865.

[27] A. Bono, L. D'alfonso, G. Fedele, A. Filice, and E. Natalizio, "Path Planning and Control of a UAV Fleet in Bridge Management Systems," *Remote Sens. 2022, Vol. 14, Page 1858*, vol. 14, no. 8, p. 1858, Apr. 2022, doi: 10.3390/RS14081858.

[28] H. Ranjbar, P. Forsythe, A. A. F. Fini, M. Maghrebi, and T. S. Waller, "Addressing practical challenge of using autopilot drone for asphalt surface monitoring: Road detection, segmentation, and following," *Results Eng.*, vol. 18, p. 101130, Jun. 2023, doi: 10.1016/J.RINENG.2023.101130.

[29] Y. Zhuang, X. Sun, Y. Li, J. Huai, L. Hua, and X. Yang, "Multi-sensor integrated navigation/positioning systems using data fusion: From analytics-based to learning-based approaches," *Inf. Fusion*, vol. 95, pp. 62–90, Jul. 2023, doi: 10.1016/J.INFFUS.2023.01.025.

[30] H. T. Do, L. H. Truong, M. T. Nguyen, C. F. Chien, H. T. Tran, and H. T. Hua, "Energy-Efficient Unmanned Aerial Vehicle (UAV) Surveillance Utilizing Artificial Intelligence (AI)," *Wirel. Commun. Mob. Comput.*, vol. 2021, 2021, doi: 10.1155/2021/8615367.

[31] H. E. Comtet, M. Keitsch, and K. A. Johannessen, "Realities of Using Drones to Transport Laboratory Samples: Insights from Attended Routes in a Mixed-Methods Study," *J. Multidiscip. Healthc.*, vol. 15, pp. 1871–1885, 2022, doi: 10.2147/JMDH.S371957.

[32] M. Yang, Z. Zhou, and X. You, "Research on Trajectory Tracking Control of Inspection UAV Based on Real-Time Sensor Data," *Sensors 2022, Vol. 22, Page 3648*, vol. 22, no. 10, p. 3648, May 2022, doi: 10.3390/S22103648.

[33] Z. Guo, K. Nazemi, M. Bažant, T. R. Dieter, A. Weinmann, and S. Jäger, "Quantifying the Simulation–Reality Gap for Deep Learning-Based Drone Detection," *Electron. 2023, Vol. 12, Page 2197*, vol. 12, no. 10, p. 2197, May 2023, doi: 10.3390/ELECTRONICS12102197.

[34] A. Barisic, F. Petric, and S. Bogdan, "Sim2Air - Synthetic Aerial Dataset for UAV Monitoring," *IEEE Robot. Autom. Lett.*, vol. 7, no. 2, pp. 3757–3764, Apr. 2022, doi: 10.1109/LRA.2022.3147337.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

All authors have contributed equally to the creation on this article.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflict of interest to declare.