International Journal of Engineering and Techniques - Volume 12 Issue 2, March-April - 2026

RESEARCH ARTICLE OPEN ACCESS

AERIAL SURVEILLANCE AND AIR POLLUTION DETECTION SYSTEM

N.Sivakamasundari [1], Manav Srihari[2] , J. Aqil Rehab[3] ,Firdous. M[4] ,Gokul. V[5]

1 (Department of Mechatronics, Hindustan Institute of Technology and Science, Chennai
Email: sksundari@hindustanuniv.ac.in)
2 (Department of Mechatronics, Hindustan Institute of Technology and Science, Chennai
Email: manavsrihari@gmail.com)
3 (Department of Mechatronics, Hindustan Institute of Technology and Science, Chennai
Email: aqilrehabpro@gmail.com)
4 (Department of Mechatronics, Hindustan Institute of Technology and Science, Chennai
Email: firdousmohammad3636@gmail.com)
5 (Department of Mechatronics, Hindustan Institute of Technology and Science, Chennai
Email: 22125061@hindustanuniv.ac.in)

Abstract:

The project's objective is to design and construct a surveillance drone that can take aerial photos and monitor air quality in real time. The main objective is to develop a lightweight, portable, and reasonably priced aerial system that can provide accurate environmental data from various locations and heights. By combining a camera module, a microcontroller unit, and air-quality sensors to simultaneously collect atmospheric data and visual footage, the drone guarantees a comprehensive approach to environmental monitoring.

The drone is made of lightweight parts to increase its stability, maneuverability, and flying time. The propulsion system is adjusted for efficient thrust generation and power consumption, and a robust power management circuit ensures consistent voltage distribution to all components. Users may accurately assess pollution levels, including particulate matter and hazardous gas concentrations, thanks to the C++-developed onboard software that allows real-time data gathering, processing, and transmission.

I. INTRODUCTION

Air pollution has become one of the most pressing environmental problems in today's world, especially in rapidly growing cities and industrial regions. Regular monitoring of air quality is essential to understand the sources of pollution, predict health risks, and take preventive action. However, traditional monitoring systems are often fixed in one place and expensive to set up, which limits their ability to cover large or diverse areas. To overcome this limitation, drones—or Unmanned Aerial Vehicles (UAVs)—are now being explored as an effective tool for real-time environmental monitoring. They are portable, flexible, and capable of collecting data from different heights and locations. This project focuses on building a pollution-monitoring surveillance drone that can perform aerial observation while measuring air quality at the same time. The goal is to develop a compact and affordable system that combines reliable flight performance with accurate environmental sensing. The drone uses two key sensors: the PMS5003 for detecting fine particulate matter (PM2.5 and PM10) and the MQ-135 for identifying harmful gases such as carbon dioxide (CO_2), ammonia (NH_3), benzene, and volatile organic compounds (VOCs). For flight control, the system is based on a Pixhawk 2.4.8 controller, carbon-fiber 1045 propellers, FA2812 900 KV brushless motors, and a 4S 5200 mAh Li-Po battery. The carbon-fiber frame keeps the drone lightweight while providing high strength and vibration resistance. During testing, a FlySky FS-iA6B receiver is used for manual control to ensure safe operation. The sensor data is handled using C++ programming, which enables real-time data logging and potential wireless transmission of air-quality information. Power distribution across the components is managed through an XT60 board to ensure efficient and stable energy flow. Although the current version is manually operated, the setup has been designed to support future upgrades like GPS-based navigation and onboard computing for autonomous flight. By integrating aerial surveillance with environmental data collection, this project bridges the gap between traditional ground-based monitoring and modern UAV technology. The proposed system highlights how low-cost drones can play a valuable role in public health studies, smart city initiatives, and environmental research.

II. LITERATURE REVIEW

A. Introduction

Bernabeo et al. (2024) introduced a new approach that uses unmanned aerial vehicles (UAVs) to monitor air quality more effectively. Their research demonstrated that drones equipped with air-quality sensors can gather real-time pollution data from different altitudes. Compared to traditional ground-based systems, this method focused on improving both accuracy and mobility by employing compact, energy-efficient sensors capable of detecting gases and particulate matter. The study highlighted the strong potential of UAVs as affordable and adaptable tools for mapping pollution levels in complex urban areas [1].

Choudhury et al. (2022) proposed a versatile surveillance drone designed for the real-time study of tropospheric pollutants. Their system combined multiple air-quality sensors with onboard data-processing modules to measure and transmit concentrations of pollutants such as carbon dioxide (CO_2), carbon monoxide (CO), and particulate matter. The findings revealed that UAVs can deliver continuous, location-specific air-quality data, proving their value for smart city applications and environmental assessment projects [2].

Similarly, Bakirci (2024) developed a drone-based air quality management system tailored for smart cities. The project aimed to integrate UAVs with Internet of Things (IoT) networks to achieve high-resolution, real-time pollution mapping. The study emphasized that precise environmental data collected through drone-assisted systems could play a vital role in improving urban sustainability and supporting data-driven decision-making in pollution control [3].

De Fazio et al. (2021) built a drone platform equipped with sensors for detecting air pollutants in environmentally focused communities. Their research discussed both the hardware setup and the calibration process of gas and particle sensors, along with a framework for analyzing collected data. The results illustrated how UAV systems can serve as effective tools for intelligent environmental monitoring and contribute to sustainable city management [4].

Fascista (2022) conducted an extensive review of environmental monitoring systems that combine Wireless Sensor Networks (WSN), UAVs, and crowdsensing technologies. The study explored advances in signal processing and data fusion for air-pollution analysis. It concluded that hybrid UAV–WSN frameworks offer scalable, accurate, and flexible monitoring options suitable for large-scale environmental applications [5].

In a similar direction, Shakhatreh et al. (2019) reviewed the civil applications of UAVs and outlined the main research challenges in this field. Their paper covered drone usage in areas such as surveillance, disaster response, and environmental observation. They identified key limitations in data integration, autonomy, and communication systems, suggesting potential improvements for future UAV-based smart city and environmental frameworks [6].

Finally, Ghamari et al. (2022) provided an in-depth analysis of UAV communication systems for environmental and civil use. The study examined how different wireless communication methods—such as satellite networks, LTE, and Wi-Fi—impact data transmission range and reliability. Their findings stressed the importance of stable communication infrastructure to ensure efficient real-time monitoring and data collection in UAV-based environmental systems [7].

B. Research Gap

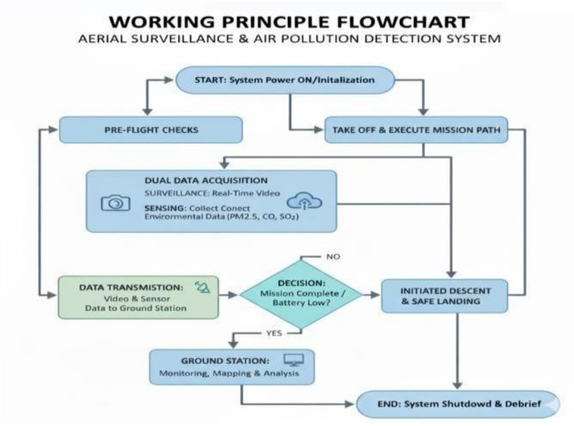
Although many studies have highlighted the potential of drones in air-quality monitoring and environmental assessment, developing a fully integrated, affordable, and adaptable UAV-based pollution monitoring system still faces several major challenges. Most existing research either concentrates on hardware design or focuses mainly on data analysis, without giving much attention to real-time integration of multiple sensors on lightweight drone platforms. Another limitation is that many of the systems rely on costly, bulky sensors with high power requirements, which makes them impractical for large-scale use or for adoption in educational and low-budget applications.

C. Objective

The main objective of this project is to develop a drone-based air pollution monitoring system that can detect significant pollutants like PM2.5, PM10, CO_2, and NH_3 using onboard sensors. The collected air quality data will be wirelessly transmitted to a ground station for real-time processing and display.

III. METHODOLOGY

A. Block Diagram

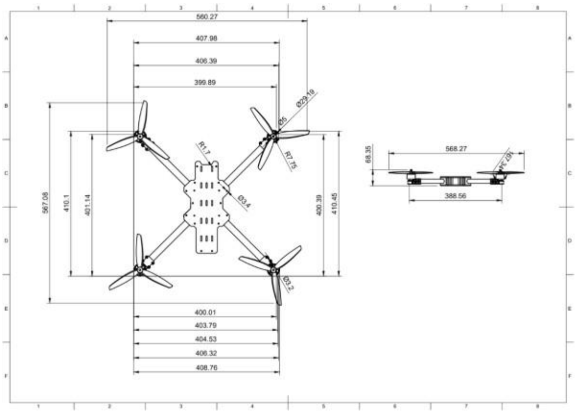


The proposed aerial surveillance and air pollution monitoring system operates through a structured process designed to ensure both flight safety and effective data collection. Before the mission begins, all onboard components—such as the Pixhawk 2.4.8 flight controller, PMS5003 and MQ-136 sensors, and communication modules—are powered on and carefully calibrated. Pre-flight checks are then conducted to confirm GPS stability, motor responsiveness, sensor connectivity, and adequate battery charge levels. Once these steps are verified, the drone takes off and follows a predefined flight path to carry out its dual objectives. During the flight, the UAV performs continuous video surveillance while simultaneously measuring air-quality parameters, including particulate matter (PM2.5 and PM10) and harmful gases like CO_2, CO, and NH_3. The gathered data is transmitted in real time to the ground control station, allowing operators to view live footage and monitor environmental readings as the mission progresses. A built-in decision algorithm monitors mission status and battery health to determine whether the operation should continue or initiate a safe return. Based on this assessment, the drone either proceeds with data collection or performs a controlled descent and landing. After landing, the system is powered down, and the recorded data is analyzed at the ground station to generate air-quality maps and interpret pollution levels in the surveyed region. This systematic approach ensures seamless integration between aerial surveillance and environmental monitoring, maintaining operational safety while producing accurate and reliable data for further study.

IV. MECHANICAL DESIGN

A. Design

The design phase of this project focuses on developing a practical and efficient framework for air pollution monitoring and aerial surveillance. Key objectives include achieving stable flight performance, accurate data collection, and overall system reliability. The design approach prioritizes functionality under varying environmental conditions while maintaining simplicity, flexibility, and ease of implementation, ensuring that the drone can perform its tasks effectively in real-world scenarios.

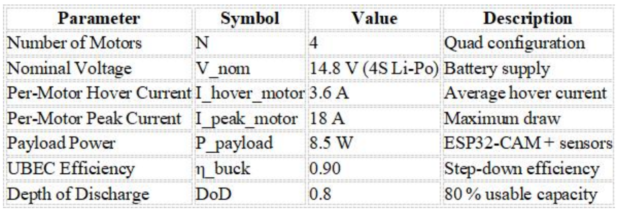


Design measurements play a critical role in turning conceptual ideas into precise, functional components, as illustrated in Figure 4.1. The carefully defined lengths, widths, and radii of the drone parts provide the exact specifications needed for accurate fabrication, proper assembly, and reliable operation. Every measurement, no matter how small, contributes to the overall mechanical integrity of the system. Linear dimensions, such as lengths and widths, define component boundaries and ensure that each part fits correctly within the larger assembly. Precise measurements are essential for alignment, as even minor deviations can lead to problems like mismatched parts, increased friction, or premature wear. Curved edges and radii are equally important. Sharp corners can concentrate stress, increasing the risk of failure or cracking under impact or repeated loads. Smooth curves distribute stress more evenly, enhancing structural strength and longevity. Rounded edges also improve manufacturability, as they are easier to handle in cutting, machining, and molding processes. These measurements implicitly account for tolerances and allowances, accommodating small variations caused by material properties, manufacturing limitations, or environmental factors such as temperature changes. Proper tolerances ensure consistent part fit and performance, enabling cost-effective and repeatable production without compromising quality. Material behavior, such as plastic deformation or metal thermal expansion, is also considered to maintain dependable performance under real operating conditions. Overall, precise design measurements provide a clear communication link between engineers, fabricators, and quality controllers. They bridge digital design, prototyping, and final manufacturing, ensuring that each part is produced accurately and functions efficiently. By balancing precision, manufacturability, and operational requirements, these measurements are essential for achieving the drone system's reliability, durability, and overall performance.

V. CALCULATION AND SIMULATION

A. Introduction

This chapter presents the simulation studies and analytical calculations conducted to validate the design and performance of the quadcopter. The analyses cover electrical, mechanical, and structural aspects, using SolidWorks Simulation alongside engineering calculations for thrust, load distribution, and power requirements. The primary objective is to confirm that the drone's structural framework, propulsion system, and power components can withstand operational loads while maintaining stable and efficient flight performance.



Parameter	Symbol	Value	Description
Number of Motors	N	4	Quad configuration
Nominal Voltage	V_nom	14.8 V (4S Li-Po)	Battery supply
Per-Motor Hover Current	I_hover_motor	3.6 A	Average hover current
Per-Motor Peak Current	I_peak_motor	18 A	Maximum draw
Payload Power	P_payload	8.5 W	ESP32-CAM + sensors
UBEC Efficiency	η_buck	0.90	Step-down efficiency
Depth of Discharge	DoD	0.8	80 % usable capacity

B. Electrical Calculations and Analysis

Summary of Findings:

Total hover current ≈ 20 A (170 W).
With a 6000 mAh battery at 80 % DoD, estimated flight time ≈ 18 minutes.
Peak current ≈ 72 A – 75 A, requiring ≥ 25 C rated battery and 30–35 A ESCs for reliability

C. *Thrust and Force Calculations*

Thrust Equation: T=CT×ρ×n2×D4T=C_T×sρ×n^2×D^4T=CT×ρ×n2×D4
Where:
CT=0.1C_T = 0.1CT=0.1 (thrust coefficient)
ρ=1.225kg/m^3 ρ = 1.225 kg/m^3ρ=1.225kg/m^3 (air density)

D=0.254m D=0.254m D=0.254m (10-inch propeller)
n=100rev/sn = 100 rev/sn=100rev/s (6000 RPM)

T=0.1×1.225×1002×0.2544=14.7N (per motor)
T = 0.1 ×1.225 × 100^2 ×0.254^4 = 14.7 N{ (per motor)}T=0.1×1.225×1002×0.2544=14.7N (per motor)

Total Thrust:
Ttotal=4×14.7N=58.8NT_{total} = 4 × 14.7 N = 58.8 NTtotal=4×14.7N=58.8N
This exceeds the total drone weight (≈ 18.9 N), ensuring safe lift-off and hovering with thrust-to-weight ratio > 3.

D. *Motor RPM and Performance*

Given T=6kgf≈58.9NT = 6 kgf ≈ 58.9 NT=6kgf≈58.9N,

Rearranging the thrust formula: n=TCT×ρ×D4=10260RPM n = sqrt{frac{T}×{C_T ×s ρ ×D^4}} = 10260
RPMn=CT×ρ×D4T=10260RPM

The calculated motor speed (≈ 10,200 RPM) confirms that 900 KV brushless motors can provide sufficient lift under 14.8 V input.

E. *Load Distribution Study*

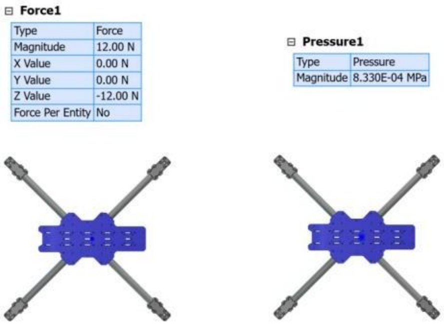
Weight Estimation:

Component	**Mass (kg)**
Frame	0.33
Battery	0.55
Electronics (FC, GPS, ESCs)	0.30
Motors & Propellers	0.40
Camera & Sensors	0.20
Landing Gear	0.15
Total	**1.93 kg**

F. *Center Plate Simulation*

The pressure across the plate was 8.33×10^{-4} MPa.

The results show that there is very little deformation and that the maximum stress is much below the yield strength, indicating structural safety.



⊟ Force1

Type	Force
Magnitude	12.00 N
X Value	0.00 N
Y Value	0.00 N
Z Value	-12.00 N
Force Per Entity	No

⊟ Pressure1

Type	Pressure
Magnitude	8.330E-04 MPa

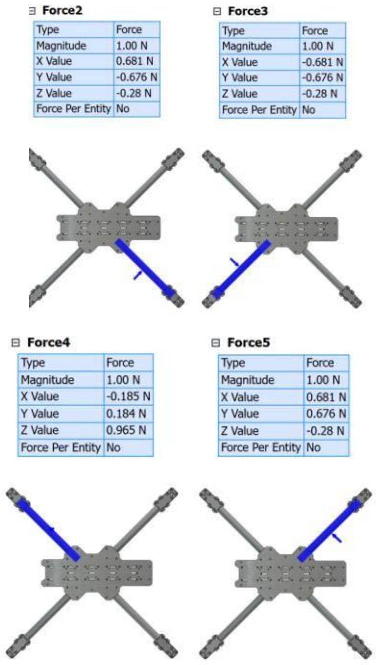
G. *Arm Load Simulation*

Each drone arm was subjected to axial and vertical tests using 1 N weights in order to simulate in-flight stress.

The yield strength of the material exceeds the 1.116 MPa maximum stress.

The safety factor is more than eight, and the maximum displacement is 0.003 mm.

The arms are therefore incredibly stiff and capable of securely supporting flight loads.



⊟ **Force2**

Type	Force
Magnitude	1.00 N
X Value	0.681 N
Y Value	-0.676 N
Z Value	-0.28 N
Force Per Entity	No

⊟ **Force3**

Type	Force
Magnitude	1.00 N
X Value	-0.681 N
Y Value	-0.676 N
Z Value	-0.28 N
Force Per Entity	No

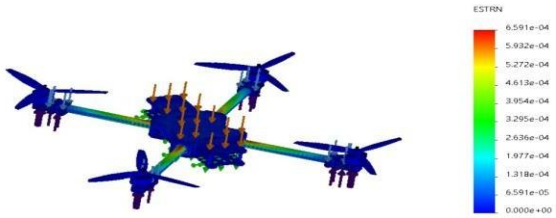
⊟ **Force4**

Type	Force
Magnitude	1.00 N
X Value	-0.185 N
Y Value	0.184 N
Z Value	0.965 N
Force Per Entity	No

⊟ **Force5**

Type	Force
Magnitude	1.00 N
X Value	0.681 N
Y Value	0.676 N
Z Value	-0.28 N
Force Per Entity	No

H. Static Structural Analysis of 10-inch Drone



The static structural analysis of the 10-inch drone model serves as a crucial step in verifying the assembly's integrity and safety prior to real-world deployment. This simulation examines how key components—such as the arms, motors, and central plate—respond to external loads encountered during typical operations, including hovering or ground handling. The graphical output uses downward-pointing arrows to represent applied loads, realistically simulating the effects of gravity and the weight of mounted equipment and payloads. A color gradient provides a clear visualization of strain distribution across the drone chassis, ranging from deep blue for minimal strain to red for areas experiencing higher deformation.

Analysis of the strain map reveals which parts of the frame are more susceptible to bending or stretching, guiding engineers in refining design or material choices. Overall, the assembly exhibits low strain throughout, with maximum values reaching only 6.591×10^{-4}, indicating effective load sharing and minimal deformation. These results instill confidence that the drone will maintain its structural shape and functional integrity during regular operation, protecting critical electronics and supporting precise flight control.

I. Simulation Summary

Parameter	**Result**	**Remarks**
Max von Mises Stress	1.1–1.7 MPa	Safe (< yield)
Max Displacement	0.003–1.2 mm	Negligible
Equivalent Strain	5.18×10^{-5}	Elastic zone
Factor of Safety	> 8	Highly stable
Material	CFRP & Aluminum	Lightweight & durable

In conclusion, the finite element and electrical performance analyses confirm that the proposed quadcopter is structurally robust, electrically efficient, and capable of safe and reliable flight under operational conditions.

J. Overview of the Chapter

The simulations and analytical calculations confirm the operational feasibility and design integrity of the quadcopter system. Electrical analyses demonstrate efficient power utilization, while thrust and load estimations verify sufficient lift capability. Structural simulations further confirm that the chosen frame materials can safely withstand static, dynamic, and nonlinear loads. Overall, the system design meets the necessary performance, safety, and stability requirements for effective environmental monitoring and aerial surveillance missions.

VI. RESULTS AND DISCUSSIONS

The surveillance and air pollution monitoring drone was successfully built, calibrated, and tested in controlled outdoor environments. The Pixhawk 2.4.8 flight controller, paired with the FlySky FS-i6 transmitter and FS-iA6B receiver, provided excellent flight responsiveness and stability. During test flights, the drone demonstrated precise altitude control and steady hovering, confirming the reliability of its propulsion and control systems.

The ESP32-CAM module effectively captured and transmitted a live video feed via Wi-Fi to a ground station, enabling clear real-time surveillance. Simultaneously, the PMS5003 and MQ-135 sensors collected accurate environmental data, detecting variations in gas and particulate matter concentrations at different altitudes and locations. This indicates that the drone can reliably map air quality spatially.

Powered by a 4S Li-Po battery, the drone achieved sufficient flight duration for short-range environmental monitoring missions, while the LM2596S DC-DC converter ensured stable voltage supply to all onboard electronics. The seamless integration of hardware and software validated the system design.

Overall, the drone performed effectively in both surveillance and pollution monitoring tasks, demonstrating its potential as a compact, adaptable aerial monitoring platform suitable for smart city and environmental applications

The quadcopter prototype provides a clear perspective on the assembly and structural layout. The truss-style carbon fiber frame emphasizes both mechanical strength and lightweight characteristics, allowing it to withstand aerodynamic forces and minor impacts during testing. The four propellers, positioned at the ends of each arm, deliver consistent lift and evenly distributed propulsion. Sturdy mounts and hardware secure the arms and propeller assemblies, reflecting careful construction and attention to long-term durability. System integration is still in progress, as shown by visible auxiliary components and packaged electronics. The open design of the central frame facilitates easy maintenance, allowing quick replacement or adjustment of cabling and electronics, while promoting airflow around sensitive parts. Additionally, lab equipment and a smaller drone frame in the background indicate ongoing research and iterative prototyping. Overall, the side view highlights the prototype's adaptability, functional design, and readiness for further testing and development

VII. CONCLUSION

The development of the surveillance and air pollution monitoring drone represents a significant advancement in integrating aerial technology with environmental assessment. The system effectively combines real-time video surveillance, precise flight control, and air quality sensing into a single, cohesive platform. The Pixhawk 2.4.8 flight controller ensures stable flight, responsive maneuverability, and seamless control, while the ESP32-CAM microcontroller provides live video and sensor data transmission, enabling real-time monitoring from remote locations.

Accurate detection of air pollutants—including PM2.5, PM10, CO_2, NH_3, and other harmful gases—is achieved through the combined use of the PMS5003 particulate matter sensor and the MQ-135 gas sensor. This dual-sensor setup enhances the reliability of environmental measurements by simultaneously monitoring both particulate and gaseous pollutants. The LM2596S buck converter and 4S Li-Po battery form an optimized power distribution network, ensuring consistent and efficient energy delivery for prolonged flight operations.

Overall, this project demonstrates the potential of drones for aerial surveillance, pollution mapping, and environmental data collection. It offers an affordable and scalable approach for monitoring industrial emissions and assessing urban air quality. With future integration of AI-driven pollution analysis, cloud data storage, GPS waypoint navigation, and autonomous flight capabilities, this prototype could evolve into a fully automated smart aerial monitoring system.

ACKNOWLEDGMENT

First and foremost, I would like to express our sincere gratitude to our most valued guides and Mentors for their presence and immense motivation throughout the project work. We are exceptionally obligated to our project coordinators

Dr. N Sivakamasundari for their direction and steady supervision throughout our project. We would like to thank all the technical and teaching staff, the Department of Mechatronics Engineering, for all the support.

REFERENCES

1. *Bernabeo RA, D'Alessandro G, Ceruti A, Tositti L, Nguyen N, Ho TP. Air quality monitoring using drones (UAV). InIOP Conference Series: Earth and Environmental Science 2024 Jul 1 (Vol. 1372, No. 1, p. 012065). IOP Publishing.*
2. *Choudhury R, Yadav N, Kala J, Bhandari S, Samal C, Jhanjhi NZ. Real-Time Monitoring and Analysis of Troposphere Pollutants Using a Multipurpose Surveillance Drone. InThe Internet of Drones 2022 Nov 3 (pp. 107-132). Apple Academic Press.*
3. *Bakirci M. Smart city air quality management through leveraging drones for precision monitoring. Sustainable Cities and Society. 2024 Jul 1;106:105390.*
4. *De Fazio R, Dinoi LM, De Vittorio M, Visconti P. A sensor-based drone for pollutants detection in eco-friendly cities: Hardware design and data analysis application. Electronics. 2021 Dec 24;11(1):52.*
5. *De Fazio R, Dinoi LM, De Vittorio M, Visconti P. A sensor-based drone for pollutants detection in eco-friendly cities: Hardware design and data analysis application. Electronics. 2021 Dec 24;11(1):52.*
6. *Shakhatreh H, Sawalmeh AH, Al-Fuqaha A, Dou Z, Almaita E, Khalil I, Othman NS, Khreishah A, Guizani M. Unmanned aerial vehicles (UAVs): A survey on civil applications and key research challenges. IEEE access. 2019 Apr 9;7:48572-634.*
7. *Ghamari, M., Rangel, P., Mehrubeoglu, M., Tewolde, G.S. and Sherratt, R.S., 2022. Unmanned aerial vehicle communications for civil applications: A review. IEEE Access, 10, pp.102492-102531.*
8. *Hafeez, S., Khan, A.R., Al-Quraan, M.M., Mohjazi, L., Zoha, A., Imran, M.A. and Sun, Y., 2023. Blockchain-assisted UAV communication systems: A comprehensive survey. IEEE Open Journal of Vehicular Technology, 4, pp.558-580.*
9. *Hu, X. and Assaad, R.H., 2023. The use of unmanned ground vehicles (mobile robots) and unmanned aerial vehicles (drones) in the civil infrastructure asset management sector: Applications, robotic platforms, sensors, and algorithms. Expert Systems with Applications, 232, p.120897.*
10. *Yanmaz, E., 2023. Joint or decoupled optimization: Multi-UAV path planning for search and rescue. Ad Hoc Networks, 138, p.103018.*
11. *Xu, H., Wang, L., Han, W., Yang, Y., Li, J., Lu, Y. and Li, J., 2023. A survey on UAV applications in smart city management: Challenges, advances, and opportunities. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 16, pp.8982-9010..*
12. *Heo, K., Lee, W. and Lee, K., 2024. UAV-assisted wireless-powered secure communications: Integration of optimization and deep learning. IEEE Transactions on Wireless Communications, 23(9), pp.10530-10545.*