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Review of UAV, Applications in Air Quality Monitoring Systems and Open Issues

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***Abstract*—Unmanned Aerial Vehicles (UAVs) are becoming increasingly popular due to their application in a variety of fields. A new application is now open where the UAVs are used as a Quality Assurance instrument for stationary air quality monitoring systems to validate the data captured by stationary air quality monitoring stations, in addition to the location and localization of pollution sources, with pictorial evidence, and communicate with the ground control station, the cloud platform. This paper identifies and discusses open issues in UAV applications in air quality monitoring and surveillance.**

Indexed Terms-Air Quality Monitoring, UAV, Hazardous environment, ground control station, and cloud platform

I INTRODUCTION

Drone, an acronym for Dynamic remotely operated navigation equipment also known as Unmanned Aerial Vehicles (UAVs), represents a transformative technology in aviation. They are characterized by their ability to operate without an onboard human pilot, being controlled remotely, following pre-programmed flight paths, or operating autonomously. While their origins are in military reconnaissance, rapid advancements in materials, propulsion, communication, and sensor technology have propelled their adoption across numerous civilian fields (Khidher & Sehree, 2022; Motlagh et al., 2023; Abdulsttar & Noor, 2022; Giovanni et al., 2019; Fumian et al., 2020; Jakovlevs et al., 2018; Adeel et al, 2022; Dan, 2019; Antonio et al, 2021). The technology enabling UAVs includes GPS for navigation, various sensors for data collection, and sophisticated communication systems for real-time data relay. A significant feature is their autonomy, allowing them to operate in dangerous or hard-to-reach environments. However, their proliferation brings challenges, including evolving safety regulations, privacy concerns, and the risk of collisions with manned aircraft. The future points towards swarming UAVs, AI integration, and urban air mobility.

Some researchers see unmanned aerial vehicles (UAVs) as indispensable in sectors like agriculture, where it is used for crop monitoring, precision farming, and disease surveillance management (Javaid et al, 2022; A. Zaidi et al., 2022; Matthew, 2021). Logistics, where companies like Amazon and UPS are exploring UAVs for faster and more efficient delivery. (Ayamga et al., 2021; Hemmati et al., 2023). Disaster Management, where UAVS provide real-time aerial views for search and rescue operations in disaster-stricken areas (Batool and Malick 2022; Caruso et al., 2021). Scientific Research, where UAVs are used for geological surveys, environmental monitoring, and animal tracking (Atefeh et al, 2023; Ayamga et al., 2021). UAV, an essential instrument for monitoring air quality and conducting video surveillance in hazardous environments. Looking at its capacity to gather data in real-time, manoeuvre across difficult terrain, and reduce hazards to human life makes it an indispensable resource for a wide range of sectors with continued technology breakthroughs and coordinated efforts to overcome current obstacles, opening the door to safer and more effective monitoring and surveillance options in hazardous environments (Altyntsev et al., 2019) (Bushaw et al., 2019).

This paper systematically explores the types, design, and application of UAVs, with a specific focus on their emerging role in Air Quality Monitoring Systems (UAV-AQMS) for validating stationary sensor data and locating pollution sources, while also identifying open issues in this domain. environments.

II TYPES OF UAVS

Unmanned Aerial Vehicles (UAVs) can be classified into four broad categories: landing style, aerodynamic design, flight altitude, and size.

A. Landing Style

Vertical Takeoff and Landing (VTOL): Takes off and lands vertically (e.g., multirotor UAVs).

Horizontal Takeoff and Landing (HTOL): Requires a runway for takeoff and landing, like a conventional airplane (e.g., fixed-wing UAVs).

B. Aerodynamic Design

This is a primary way to categorize UAVs, with the two most common types being fixed wing and multirotor.

i.Fixed-Wing UAVs: Resemble traditional airplanes with fixed wings. Highly efficient for long-distance flight, long endurance, and covering large areas. Ideal for mapping, large-scale agriculture, and surveillance.

Require a runway or launcher for takeoff and landing; cannot hover.

ii. Multirotor UAVs (e.g., Quadcopters): Use multiple rotors (e.g., 4, 6, or 8) for lift and stability. Can take off and land vertically (VTOL), hover in place, and are highly agile and manoeuvrable. Perfect for close-range inspections, photography, and operations in confined spaces. Shorter flight times due to high energy consumption for hovering and lift.

iii. Hybrid UAVs: Combine features of both, with rotors for VTOL and wings for efficient forward flight. Offer the VTOL capability of a multirotor with the range and endurance of a fixed-wing. More complex and expensive to design and build.

C. Altitude

UAVs are also classified according to their altitude flight, such as High-altitude platform HAP, medium-altitude platform MAP, and low-altitude platform LAP.

D. Size

UAVs are categorized according to their sizes, such as nano, mini, micro, small, and tactical. Attention will be given to Nano and Micro UAVs. Nano and Micro-UAVs: Characterized by their very small size and light weight. High agility and discretion; can access extremely tight and complex environments where larger UAVs cannot operate. Used for covert surveillance, indoor inspections, and search and rescue in rubble. Very limited payload capacity and short flight duration.

E. Conclusion and Selection for Air Quality Monitoring and Video Surveillance**:** The choice of UAV depends entirely on the mission's requirements. Fixed-wing UAVs are best for covering large areas, while multirotor UAVs excel at precise, close-range tasks in complex environments. Due to the nature of the hazardous environment, this work will adopt a quadrotor UAV because of its Vertical Takeoff and Landing (VTOL) capability, hover stability, and agility in confined spaces.

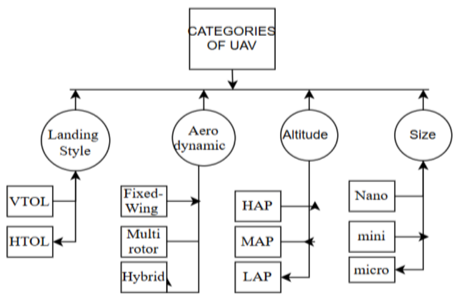

Figure 1: Categories of UAV

III UAV TECHNOLOGY

Unmanned air vehicles (UAVs) are evidence of the astonishing integration of cutting-edge technology. They can traverse the skies, gather data, and transmit critical information to operators on the ground because of these technical components, which constitute the basis of their operation (Niranjan et al, 2019). UAVs can precisely locate themselves, follow waypoints, and map out clear flight courses. GPS underlies the UAV's capacity to navigate across frequently complicated and constantly changing settings, whether for airborne monitoring, agricultural monitoring, or scientific study (Pengfei et al, 2020). The UAV's rotation may also be changed, along with other flying characteristics, including altitude, direction, and speed. UAVs are extremely adaptable tools because of these technologies, which enable operators to respond to a variety of mission needs and weather circumstances (Philipp et al. 2022). Autopilot systems, which are basically the brains behind automated flying, are included in advanced UAVs. These systems include sophisticated sensors and software to aid in making decisions while in flight. For purposes like mapping and surveying, where precision and dependability are crucial, the use of autopilots is very important (Rune et al. 2023).

UAVs receive and gather data from their environment because of sensors, which act as their sensory organs. The choice of sensors is made in accordance with the demands of the particular mission. High-resolution cameras gather visual information for uses like surveillance and aerial photography. In applications like search and rescue, thermal cameras' ability to detect heat patterns and distinguish temperature fluctuations is crucial. In contrast to multispectral sensors, which are used in agriculture for crop analysis, LiDAR systems provide comprehensive 3D maps. These sensors are essential for transforming real-world data into information that can be used (Sarah 2020). MUs are an essential part of UAVs since they include gyroscopes and accelerometers that track the movement, rotation, and direction of the UAV. For the flight to remain stable, these measures are essential. IMUs help to improve overall control of flight and safety by ensuring the UAV maintains its desired position, follows a predetermined flight route, and rarely deviates from the operator's orders (Sharifah et al 2022).

Shahen and Shah (2023) use telemetry systems to enable real-time communication between an unmanned aerial vehicle and its base station. They communicate a wide range of information, including the UAV's position, metrics for performance, and other vital details. Telemetry systems provide operators the ability to track the UAV's status while in flight and make decisions based on real-time information, improving mission security and efficiency. UAVs have multifaceted communication systems that are built to provide seamless interaction and data transfer. These systems are in charge of transmitting a variety of data, including operator commands, telemetry data, and live images from onboard cameras. Communication via satellite may be used in long-distance missions to maintain a strong and dependable connection. Real-time decision-making and mission effectiveness depend on effective communication, which is essential for both (Şiean et al, 2023).

Modern UAVs often have sophisticated obstacle discovery and avoidance systems. These systems include a variety of ultrasonic, lidar, and infrared sensors that are used to detect obstacles in the UAV's route of flight. UAVs automatically change their fly paths in reaction to identified impediments to avoid collisions, improving the safety of flight and mission effectiveness (Subramanian et al, 2021). UAV power systems are distinguished by the use of cutting-edge batteries or other power sources. Recent years have seen a noticeable progress in battery technology, with an emphasis on increasing flight duration, energy economy, and weight concerns. Longer flight periods, more effective energy use, and increased mission capability are all benefits of these improvements (Abdul et al, 2023).

The UAV's "brain" is the flight controller, which serves as its central processing unit. These onboard computers take data from numerous sensors, GPS, and other input sources, and then analyze it. Their main goals are to precisely execute predetermined flight plans, stabilize the UAV during flight, and react to operator commands. In order to maintain regulated and safe aircraft operations, flight controllers are essential (Alka et al, 2019). UAVs have onboard data storage devices that act as storage facilities for information gathered while they are in the air. Operators may collect a wide variety of data using these storage devices, which can then be retrieved and analyzed after the operation. In applications like aerial surveying, scholarly investigation, and surveillance of the environment, where the information is gathered to aid in analysis and decision-making, this data is vital (Ahnirudh et al, 2021). Operators communicate with UAVs at the ground station, which serves as a command hub. A computer, a monitor, and specialized software are often included. The ground station is used by operators to organize and launch missions, watch real-time flight data, and examine data gathered by the UAV. The ground station is crucial to the success of the operation because it provides users with the resources they need to ensure accuracy and effectiveness (Arvind et al. 2022). In a variety of industries, including UAV photography, the agricultural sector, rescue and search, monitoring the environment, scientific study, and military surveillance, UAVs are positioned to expand their capabilities and push the limits of what is possible (Christopher et al. 2023)

IV UAV CORE ENABLING TECHNOLOGIES

A. UAV Flight Control

Unmanned aerial vehicles (UAVs) operation requires precise UAV flight control. It includes all of the devices and procedures that provide users the capacity to direct the UAV's motion, keep it stable, and guarantee a precise and safe flight. The UAV can adapt in real-time to maintain stability and balance due to these sensors' capacity to detect changes in orientation and movement. For the control of UAVs, Global Positioning System (GPS) is essential. It gives the UAV location information, allowing for accurate positioning, navigation, and waypoint-based flight. Additionally, GPS information is essential for landing and homecoming processes (Xueping et al, 2023). Altimeters and barometers are used by UAVs to maintain a specified altitude. This is crucial for activities like aerial photography, where keeping a steady height is necessary to get high-quality pictures. UAVs regulate their position using systems and sensors onboard. This makes it easier for operators to manage and guide the UAV by ensuring that it retains the proper direction and angle (Yueyan et al, 2020). Abdul et al (2023), Multiple motors and propellers on UAVs may be separately controlled to change the direction and speed of the UAV. The UAV can go forward, backward, up, down, and around with this control. As technology develops, these systems' capabilities increase, enabling increased automation, security, and adaptability across a variety of applications, including photography, videography, agriculture, surveillance, and research (Adeel et al, 2022).

B. UAVs Battery Technology

Advanced battery technology is used to power the flying of unmanned aerial vehicles, or UAVs. UAV battery technology is an important component of UAV operation and design since it has an impact on things like flight time, cargo capacity, and overall performance. We'll talk about the main components of UAV battery technology in this conversation.

The great energy density, lightweight construction, and reliability of LiPo batteries make them a popular option for UAVs. Consumer and industrial UAVs both often utilise them. Li-Ion batteries are renowned for being dependable and energy-efficient. They are frequently employed in bigger UAVs or industrial settings where a long flying period is necessary. Batteries having a certain voltage and capacity are used by UAVs. The UAV's power supply is impacted by the voltage, and its flight time is determined by the capacity. Larger UAVs with bigger payloads often utilise higher voltage batteries. Many UAVs have modular battery systems that make battery replacement quick and simple. This helps to prolong flights and shorten the time in between them. The BMS is an essential part of UAV batteries. To guarantee secure and dependable functioning, it keeps an eye on the battery's condition, including voltage, temperature, and charge level. Additionally, BMS aids in preventing overcharging and over-discharging, both of which can harm the battery (Angelo et al 2021). Batool and Malick (2022), fast-charging systems have been developed as a result of the quick improvements in battery technology. These shorten the time between flights by enabling UAV pilots to swiftly recharge their batteries. Swapping out depleted batteries with fully charged ones enables continuous operation in many commercial and industrial UAVs. For applications like surveying and mapping, this functionality is useful. The tracking and communication capabilities that are integrated into smart batteries are among its sophisticated characteristics. They improve flight safety and flight planning by giving the UAV operator real-time data, such as the amount of remaining flying time. According to Dante and Marvin (2019), the amount of energy that a battery can store in a certain volume or weight is referred to as energy density. The advancement of UAV battery technology is still a top priority for manufacturers as well as researchers, as the need for longer flight times and better battery performance increases (Ghassan and Areen 2020).

C. UAV Obstacle Avoidance

Real-time obstacle detection and avoidance are made possible by this technology by combining sensors, software algorithms, and decision-making techniques. We'll explore the crucial elements of UAV obstacle avoidance in this conversation. Hannan et al (2018), UAVs have a variety of sensors to help them sense their environment. These sensors consist of cameras, radar, LiDAR (light detection and ranging), and ultrasonic sensors. These sensors give the UAV information about adjacent objects, their location in relation to one another, and their distance. In order to detect obstructions in the UAV's flight path, sensors continually monitor the environment. Obstacles can be both static (such as trees, buildings, or power lines) and dynamic (such as other aircraft or moving vehicles) in nature. To produce a complete picture of the environment, data from many sensors are frequently combined. Combining data from many sensors improves precision and dependability. Obstacle grids or maps are computerised representations of the environment and the positions of impediments that have been spotted that are produced by UAVs. Navigation and decision-making are facilitated by these maps. These routes are intended to avoid obstructions and guarantee the UAV's security (Jean et al. 2020). To enable safe and responsible UAV operations, UAV obstacle avoidance technology may need to adhere to regulatory criteria, such as those imposed by aviation authorities (Jia Liu et al. 2021). UAVs are suited for a variety of uses, from UAV photography and agriculture to infrastructural inspection and public safety missions, due to advanced obstacle avoidance capabilities that improve the safety, efficiency, and dependability of UAV operations (Khristopher et al. 2021).

D. UAVs Communication Systems

A UAV's operator, other UAVs, and ground-based control stations may all share data due to the main components of UAV (unmanned aerial vehicle) communication systems. These technologies are crucial for managing the UAV, gathering telemetry data, and occasionally, relaying gathered data back to the operator or other important parties. The essential features of UAV communication systems will be covered in this presentation. Zulfiker et al. (2019), Communication between the operator and the UAV is frequently done via radio control technologies. According to Murtaza et al (2021), a crucial aspect of UAV operations is the communication system's practical range. It establishes the UAV's maximum distance from the pilot while preserving a trustworthy connection. Between the UAV and the ground control station, data is protected against unauthorised access via encryption techniques. Santiago et al. (2022), through the use of many antennas and the selection of the one with the best reception, diversity antennas are intended to enhance signal reception. This improves communication dependability, especially in situations when there is signal interference. To go beyond line-of-sight restrictions, several UAVs employ satellite communication systems to increase their operational range. These devices offer worldwide coverage and are appropriate for far-off and distant missions. Lee et al. (2021), dedicated command and control networks may be necessary for UAVs engaged in swarm operations or cooperative missions in order to allow communication and coordination among several UAVs. Regulations established by aviation authorities, such as frequency allotments, power caps, and other communication-related laws, must be complied with by UAV communication systems. In Maher et al (2020), UAVs may include established procedures for automatic operations in the event of signal loss or emergency, such as commencing a controlled fall or returning to a predetermined home point. For UAVs to operate safely and effectively in a variety of applications, from aerial photography and recreational usage to agricultural, surveillance, and other uses, UAV communication systems are crucial. The capabilities and dependability of UAV systems continue to be enhanced by developments in communication technology, enabling more complex and autonomous missions.

V APPLICATIONS OF UAV

In Vishal and Jeevan (2023), the versatility of UAVs has led to their adoption in a vast array of fields:

A. UAV in Agriculture

UAVs have completely changed the agriculture sector. Their integration has transformed agricultural methods and crop management, giving farmers essential tools to increase output and effectiveness. We will examine the many ways that UAVs are reshaping the agricultural industry in an in-depth investigation of the technology. High-resolution cameras on UAVs are used to take aerial pictures of farms. Farmers can spot regions that need improvement due to these photos' unique viewpoint on their crops. Aerial photography may show crop health, differences in the soil, and the detection of diseases or pests, allowing for prompt actions (Ganeshkumar et al, 2023).

UAVs may be used by farmers to track the development and health of their crops in real time.

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They may prevent problems from getting worse by periodically inspecting their fields for early indications of stress, nutritional deficits, or water concerns. In order to practice precision agriculture, UAVs are essential. They make it possible to accurately administer fertilizers, insecticides, or herbicides only where they are required, minimizing waste and farming's negative effects on the environment (Gopal and Purba 2020). UAVs are used for agricultural scouting, enabling farmers to swiftly and effectively survey their crops. This airborne viewpoint provides a comprehensive picture of the whole field, making it easier to spot and quickly manage problems like growing weeds or disease outbreaks. Farmland's topography may be accurately mapped using UAVs that are equipped with LiDAR or other mapping equipment. These maps are useful for planning irrigation and land management, allowing farmers to maximize drainage and water consumption (Hao et al 2021).

Specialized sensors for soil analysis can be carried by UAVs. They can offer in-depth details regarding the composition of the soil and nutrient levels by gathering soil samples from various sites. Farmers may use this information to make well-informed decisions on soil enhancement and fertilization. Thermal camera-equipped UAVs can evaluate the effectiveness of irrigation systems. They can spot regions that are being overwatered or don't have enough irrigation, enabling modifications to maximize water use (Karuppiah et al, 2023). Throughout the growth season, aerial imagery collection can help with yield projections. Farmers may ensure they have the resources they need and storage capacity by using this data to help them prepare for harvest and logistics. UAVs are also utilized to monitor animals in addition to crops. They may offer an overview of pasture conditions, herd health, and even possible predator identification (Matthew et al, 2021).

Some UAVs are fitted with components that allow the precise release of pest control organisms or helpful insects. The environmental effect is decreased, and the usage of chemical pesticides is minimized by this precise technique. UAVs can be equipped with pollination aids for use in orchards and other agricultural settings. This is particularly useful where traditional pollination techniques are less successful, such as in regions with declining bee numbers (Mohamad et al, 2022). At various heights, UAVs can be placed to collect meteorological data. Farmers may use this knowledge to decide when to sow and harvest their crops by having a better grasp of local weather trends. UAV usage in agriculture improves security and effectiveness. They expose farmers to fewer dangers, lessen the amount of time they must spend in the field, and save time and money on labour (Noor, 2020).

In conclusion, Shutosh et. al. (2021) also added that the use of UAVs in agriculture has developed into a force for change in contemporary farming methods. Their airborne capabilities, which are outfitted with cutting-edge sensors and imaging equipment, give farmers important information on their crops and land. The incorporation of UAVs promotes precision agriculture, enhanced crop health monitoring, and resource optimization. Currently, there is a growing need for the sustainability of this industry.

B. UAV in Remote Sensing

Remote sensing has been significantly impacted by

Unmanned Aerial Vehicles (UAVs). Remote sensing is the process of gathering data about the surface of the Earth from a distance, and UAVs have been shown to be extremely useful platforms for this. We will dig into the numerous ways that UAVs are revolutionizing data collecting and processing in this thorough examination of UAVs in remote sensing (Yong et al, 2021). Aerial footage is captured by UAVs with high-resolution cameras, allowing for precise assessments of the Earth's surface. Urban planning, emergency management, and the classification of land cover all benefit greatly from this photography. UAVs are essential to the process of producing orthophotos, which entails producing highly accurate, georeferenced pictures. For accurate mapping and cartography applications, these pictures are essential (Chan, Qimei, and Deshi 2019). For topographic mapping, which includes creating elevation models and thorough topographic maps, UAVs are used. Planning for infrastructure, flood modelling, and environmental monitoring all depend on this information. LiDAR (Light Detection & Ranging) technology, which utilizes laser pulses to build incredibly precise 3D representations of the Earth's surface, is installed on certain UAVs. UAVs with LiDAR capabilities are useful for forestry, terrain study, and infrastructure evaluation (Ade 2020). Environmental factors, including soil moisture, water quality, and vegetation health, are monitored by UAVs. They may fly over vast areas, gathering information that aids in understanding environmental changes for scientists and researchers (Chen et al, 2021). UAVs are used to quickly survey the damage following natural catastrophes, including wildfires, floods, and earthquakes. To assist with search and rescue operations, they collect images and LiDAR data (Dante and Marvin 2019). UAVs have transformed agriculture by giving farmers in-depth knowledge about their crops. UAVs equipped with multispectral and thermal sensors allow farmers to monitor crop health, improve irrigation, and use fewer pesticides (Aakashjit and Debashis,2021). UAVs are used in archaeology to survey and record historical sites and landscapes. Aerial photography aids in locating obscure archaeological features (David and Thomas 2022). In order to monitor animal populations, evaluate ecosystems, and trace the migration of endangered species without disturbing them, researchers use unmanned aerial vehicles (UAVs)

(Hazim et al, 2019). By gathering geographical data, such as multispectral imaging and magnetic field data, UAVs help with mineral prospecting. This data makes it easier to locate probable mining areas (Jean et al, 2020). UAVs are used to check infrastructure, notably to evaluate pipelines, power lines, and bridges. They are indispensable for this task due to their agility and capacity to enter difficult-to-reach places (Jia et al, 2021).

UAVs monitor tree health, locate diseased or infested regions, and gauge the general health of forests, all of which help with forest management. For effective management of forests, this information is essential (Jian et al, 2022). UAVs are used in the field of cultural heritage preservation to capture images of old structures, monuments, and archaeological sites. 3D modelling and aerial photography are useful for preserving and restoring cultural artefacts (Jun et al. 2020). UAVs support search and rescue efforts, particularly in difficult terrain or disaster-affected areas. They offer a bird's-eye perspective, making it easier to find those who have gone missing (John 2019). Some UAVs have sensors for the atmosphere, which help with atmospheric research by gathering information on the temperature, humidity, and composition of the air at various altitudes (Kelvin et al, 2021).

UAV usage in remote sensing has several benefits, including low cost, quick data gathering, and access to locations that could be difficult or dangerous for ground-based surveys. UAVs are becoming essential instruments for a variety of tasks, such as environmental monitoring, disaster response, precision agriculture, and infrastructure evaluation. Remote sensing is becoming a more fascinating and dynamic field for data gathering and analysis as a result of the UAVs' ever-evolving technology (Krzysztof 2022).

C. UAV Surveillance

Unmanned aerial vehicle (UAV) surveillance is an essential use of UAV technology that has profound effects on security, monitoring, as well as data collection in a range of industries. Laura et al. (2021). UAVs improve situational awareness, enabling law enforcement to respond to events more successfully (Mitch et al. 2019). They improve national security by allowing authorities to keep an eye on isolated or dangerous locations (Murtaza et al, 2022). They are frequently employed in real estate to highlight buildings and scenery (Santiago et al. 2022). UAVs are used to check important infrastructure, such as bridges, pipelines, and electricity lines. They may enter difficult-to-reach regions and gather information and photos that help with upkeep and repair. (Thato et al., 2020). UAVs are a crucial part of search and rescue efforts. With the use of infrared cameras and other sensors, they can easily find those who have gone lost in difficult or isolated terrain (Thomas et al. 2021). In the fight for environmental protection, UAV monitoring is essential. It supports monitoring ecosystems, tracking climate change, and evaluating the condition of wetlands, forests, and helps for academics and agencies (Tomas 2020). UAV surveillance is used by farmers to monitor their crops. Farmers may use the data collected by multispectral as well as thermal imaging sensors on UAVs to make educated decisions about irrigation, pest management, and fertilization (Wen and Boo 2022). Pipelines and drilling rigs are among the oil and gas infrastructures that UAVs are used to examine. They can see possible leaks, structural problems, and equipment faults due to their airborne skills (Xingyu et al 2023). In the mining sector, UAV surveillance helps with stockpile management, land surveys, and monitoring of mine sites. This information encourages safe and effective mining operations. UAVs are used by contractors for site surveys, progress checks, and quality assurance. The precise aerial data enhances project management and planning (Xueping et al. 2023). In climate monitoring and research, UAVs with atmospheric sensors are employed. They gather information on temperature, humidity, along with other meteorological factors, which helps weather forecasting become more accurate (Tachinina and Kutiepov 2020). UAV monitoring gives firefighting team crucial information during large-scale wildfires. The spread of the fire may be understood, and firefighting actions can be directed using aerial images (Seongjoon et al. 2021). UAV monitoring also brings up ethical and privacy issues. To safeguard people's privacy and guarantee appropriate use of surveillance technologies, rules and regulations have been put in place (Xin et al. 2021). How we acquire information and keep track of many parts of our world has been revolutionised by UAV surveillance. These aerial devices provide flexible, cost-effective, and efficient solutions for a variety of uses, enhancing resource management and safety. To realize this technology's full potential while upholding human rights and civil liberties, however, ethical use and adherence to privacy laws are essential (Sharifah et al 2022).

D. UAVs Autonomous Navigation

The ability of UAVs (Unmanned Aerial Vehicles) to function autonomously, make decisions, and navigate challenging settings without direct human direction is a game-changing development in UAV technology. Sensors, onboard computing, and complex algorithms work together to enable autonomous navigation capabilities. Here, we'll look at the main features and uses of unmanned aerial vehicle autonomous navigation. (Asmaa Abdallah et al 2019). Numerous sensors that autonomous UAVs are equipped with offer real-time information about their environment. These sensors may include cameras for image identification, altimeters for measuring altitude, GPS for spot data, and IMUs (Inertial Measurement Units) for orientation (Dan 2019). To locate and avoid impediments in their flight path, UAVs use obstacle detection and avoidance systems, such as lidar, radar, or ultrasonic sensors. For safe and dependable navigation in challenging conditions, this technology is essential (Dbouk and Drikakis 2022). Path planning algorithms are used by autonomous UAVs to choose the best path while avoiding obstacles to a target. These algorithms devise effective and collision-free pathways by accounting for elements like topography, wind, and airspace limitations (Mao et al 2019). UAVs can be configured to follow a set of established waypoints, enabling them to independently travel a predetermined path or survey certain locations. Precision agriculture and aerial photography are two common uses for it. (Elena et al 2023). UAVs may plan their whole mission, including takeoff, flight, data collecting, and return to the base, independently in more complicated missions. This is especially useful for applications like surveillance and search and rescue (Jawad et al 2022). Autonomous UAVs can be designed to stay inside geofenced bounds, so they won't go outside of set limits. This is frequently employed for safety and regulatory compliance, such as making sure UAVs stay inside permitted airspace boundaries (Khalifa et al 2021). UAVs using precision landing technologies can make an autonomous touchdown on a landing pad or other predetermined target location. This is particularly helpful in situations like those where manual landing would be difficult, as on a moving platform or in confined areas (Zulfiker et al. 2019).

This makes it possible for humans to step in during emergencies or modify the mission depending on real-time data (Majed et al. 2019). This makes a number of uses possible, like as long-range delivery and infrastructure inspection (Muhammed et al. 2023). With the use of precision agriculture methods, autonomous UAVs are used in agriculture to autonomously inspect crops in order to maximise yields and make the most use of available resources (Yuwalee et al, 2018). Unmanned aerial vehicles (UAVs) with autonomous navigation are used for security and surveillance, monitoring vast regions and reacting rapidly to security breaches or incidents (Taha and Kyandoghere 2021). In order to collect information on animals, vegetation, and ecosystem health in distant or difficult terrain, autonomous UAVs are employed in environmental monitoring. (Yashika et al 2022). Autonomous unmanned aerial vehicles (UAVs) are used to examine vital infrastructure by flying over electrical lines, pipelines, or bridges while assessing and reporting on their status (Ruoxian et al. 2023). In order to undertake surveys, data collection, and observations in difficult or dangerous locations, such as the Arctic or volcanic regions, autonomous UAVs are used in support of scientific research (Maher et al. 2020). The applications and use cases for UAVs continue to grow across a variety of industries due to autonomous navigation, sensor technology, and artificial intelligence breakthroughs (Seong et al, 2020).

D. UAV Data Processing

In order to make use of the enormous volumes of data that UAVs collect throughout their flights, UAV (Unmanned Aerial Vehicle) data processing is essential. UAV data must be processed, analysed, and turned into useful information, whether it be aerial photography, LiDAR data, or sensor readings. We'll examine the essential elements, methods, and applications of transforming unprocessed data into insightful knowledge in this investigation of UAV data processing.

Data collection occurs throughout the flight mission of the UAV before any UAV processing takes place. High-resolution photographs, LiDAR point clouds, thermal pictures, multispectral information, and a variety of sensor readings are examples of the data that may be used (Tachinina et al. 2023). Following a UAV operation, the gathered data is often sent from the UAV's onboard storage to a ground station or a cloud-based platform for additional processing. In addition to physical media, data may also be conveyed wirelessly (Vijay and Ma 2020). It is ensured that the data is easily available for processing and analysis by storing it in a safe and arranged manner. Local servers and cloud-based systems are both viable storage options (Pengju et al 2019). It is frequently necessary to do pre-processing on raw UAV data, which includes noise reduction, calibration, and georeferencing. The data is accurate and trustworthy due to this process (Omid and Torbjørn 2020). To build a more complete dataset, it could be necessary to combine other forms of data, such as photography and LiDAR. A comprehensive comprehension of the examined region is facilitated by this integration (Khristopher et al 2021).

To guarantee that the point clouds properly match, LiDAR data must be registered or aligned. For making topographic maps or 3D models, this is necessary (Dilan et al. 2021). To find and fix data mistakes or abnormalities, quality control checks are carried out. For reliable and accurate data, this stage is crucial. The creation of seamless, georeferenced pictures for aerial imaging involves processes including stitching, mosaicking, and orthorectification. For the creation and study of maps, this is crucial. Construction, urban planning, and environmental monitoring are just a few of the industries that might benefit from the creation of comprehensive 3D models of scanned areas using LiDAR data (Alexandru et al. 2023).

UAV multispectral data can be analysed to determine agricultural stress, determine vegetation health, or find invasive species. This is crucial for environmental control and precision agriculture. To identify and categorise items of interest, such as structures, cars, or animals, in UAV footage, machine learning and computer vision algorithms can be used. Processing UAV data might show changes over time in the examined region. This helps keep tabs on the

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development of construction projects, environmental changes, or disaster impact assessments. UAV data may be analysed to evaluate environmental factors as habitat conditions, soil composition, and water quality (Christopher et al, 2023). According to Dbouk and Drikakis (2022), experts analyse processed UAV data to derive actionable insights. This could entail spotting trends, anomalies, or patterns that guide decisions. Reports, maps, charts, and visualisations are frequently used to show the processed data. The potential and utility of UAV-based data analysis are constantly growing due to improvements in data processing methods and the ongoing development of UAV technology (Ganeshkumar et al. 2023).

E. UAV Swarm

A UAV swarm is made up of several UAVs that cooperate, frequently on their own, to accomplish a shared objective. These swarms, which have a wide range of uses, can contain anything from a few to hundreds of UAVs. Here, we'll examine the main characteristics, functions, and uses of UAV swarms. Hudan et al (2019), Swarm UAVs may be fitted with a variety of sensors, enabling them to concurrently cover a broad area and gather a wide variety of data. Applications like monitoring the environment and disaster response can really benefit from this. (Javad et al, 2022). Together, they can quickly and cheaply deliver parcels or other items in both urban and rural locations (Kelvin et al. 2021). UAV swarms contribute in humanitarian operations by quickly assessing disaster-affected areas and helping relief organisations organise and distribute assistance (Zulfiker et al, 2019).

F. UAVs Military Applications

Due to their wide variety of uses and pronounced advantages, unmanned aerial vehicles (UAVs) have completely changed military operations. UAVs are increasingly being used in the military for their improved intelligence, surveillance, reconnaissance, and even combat capabilities. Let's look at some of the main UAVs used in the military. UAVs are used to locate and target adversarial troops. They can keep visual contact with valuable targets and communicate coordinates to help with precise strikes because of their surveillance skills. As a result, there is less chance of harm coming to humans (Nader et al. 2021). This early warning enables soldiers to quickly engage in defensive measures (Omid and Torbjørn 2020). UAVs offer quick airborne search capabilities in military rescue and search missions, assisting in finding downed aircraft, missing people, or disaster survivors in difficult or isolated areas (Pengfei et al, 2020). Khalifa et al (2021), UAVs are employed in psychological operations, propaganda broadcasts, and message delivery to affect civilian populations or enemy morale in battle zones. UAVs' military uses have developed quickly, improving the efficiency and security of military operations. UAVs are essential tools in contemporary warfare because of their potential to carry out duties including information gathering, surveillance, fighting, and logistics. They also provide better situational awareness and the ability to act swiftly and decisively in demanding and dynamic circumstances (Laura et al, 2021).

G. UAVs Environmental Impact

Due to their adaptability and capabilities, unmanned aerial vehicles (UAVs), have grown significantly in popularity and utility across several sectors. Their expanding usage, nevertheless, also prompts questions about how they could affect the environment. Let's look at how UAV activities may affect the environment. Particularly in urban and residential regions with established noise limits, UAVs can contribute to noise pollution. Their incessant buzzing has the potential to harm ecosystems and negatively affects human and animal populations (Murtaza et al, 2022). Noor et al (2020), UAV use has the potential to disrupt animals, especially in their natural environment. Environmental harm might result from UAV mishaps or accidents. Accidents may result in fuel or chemical leaks, endangering aquatic life and ecosystems (Javad et al, 2022). As UAV technology develops, balancing the advantages of UAV technology with its environmental effect is a crucial problem that calls for careful thought and appropriate use (Philipp et al, 2022)

H. UAV Security

For the sake of defending lives, property, and the environment, it is essential to ensure the safe operation of UAVs. We will thoroughly address the important facets of UAV safety in this conversation. Following the rules and recommendations given out by aviation authorities is the first step in ensuring UAV safety. There are laws in every country, and they frequently address things like UAV registration, pilot certification, and no-fly zones. Observing these rules is a crucial part of making sure that everyone is secure (Rajas et al, 2019). Sarah (2022), to fly UAVs safely, UAV operators must complete training and certification requirements. Operators of unmanned aerial vehicles (UAVs) should be familiar with emergency protocols, including how to handle unforeseen events like loss of control, signal loss, or low battery alerts. These steps are essential to reducing risks and preventing accidents (Seongjoon et al, 2021). In-flight power outages must be avoided by proper battery management. For the UAV to have enough power for its task and safely land back at base, UAV pilots should adhere to manufacturer recommendations for charging, storing, and battery replacement (Şiean et al, 2023). To cover any mishaps or damage brought on by their UAVs, UAV owners may choose to get liability insurance. This offers financial security in the event of unanticipated events (Thato et al, 2020). Vishal and Jeevan (2020), To prevent UAV and manned aircraft accidents and incidents, it is crucial to increase public awareness of the existence of UAVs in the airspace and to educate the public about safety procedures.

VI SUMMARY OF RELATED LITERATURE & RESEARCH GAP

Unmanned aerial vehicles have many applications, ranging from military to civilian. Its popularity in civilian applications is due to its low preservation cost, deployment efficiency, high mobility, and ability to hover (Kardasz & Doskocz, 2016). Several civil applications are found in healthcare, disaster management, construction and inspection, and agriculture.

A. Summary of Related Literature

Some authors have worked on these research interests, such as; disaster management (Hayat et al. 2016), construction and infrastructure inspection (Greenwood, 2023b), agriculture and remote sensing (Norasma et al., 2019), healthcare (Wulfovich et al., 2018), waste management (Leizer 2018), utility inspecting (Johnsen et al., 2020), urban planning (Mohd Noor et al., 2018) Wildlife conservation (Ivošević et al., 2015), Weather forecasting (Kowshik Chennupati et al., 2018), Mining (Stelmack, 2015), and Real-time monitoring of road traffic flow (Mouna et al., 2018). For the sake of the objectives of this work, attention will be given to the hazardous environment, which falls within disaster management. A disaster can be a natural or man-made occurrence over a short or extended period of time that makes the environment hazardous. Using UAVs for disaster management can be of two types: pre-disaster and post-disaster management (Sivakumar & Naga Malleswari, 2021b). In (Alzahrani et al., 2020b; Oubbati et al., 2019), Search and disaster management teams using UAV support rescue activities, including public safety, victim identification, damage assessment, and relief delivery. In the event of disaster, UAVs are used to restore public communication networks that have been interrupted, search for missing persons/animals in disastrous situations like poisonous gas leakage, forest fires, and avalanches (Restas, 2015). These are the main areas where UAVs help to improve search and rescue missions and create before/after maps of the affected region (E. Milan & Enrico, 2016). Many scholars have researched unmanned aerial vehicles for disaster management applications (Chowdhury et al., 2017). (E. Milan & Enrico, 2016) Pre-disaster management; Disaster assessment; Disaster response and recovery. They employed thermal sensors, Optical, Thermal IR, LiDAR, Multispectral cameras, Particle sensors, and DJI Phantom 4 PRO. These gaps exist: repeated trials of Self-learning approaches, high flight energy, specific location issues, and situational awareness issues. worked on an unmanned aerial vehicle for capturing aerial photographs that identifies disasters using A VGG-based deep learning techniques. They employed Optical remote sensing and multispectral cameras. Precision Hawk; Terra UAV; SenseFly unmanned aerial vehicle; Swinglet CAM. The following gaps exist: low energy resources, inadequate computational power, Real-time data processing, geographic coverage, and flexibility of usage are hindered by problems with flight permission laws. (Xu et al., 2019) combined deep learning and aerial vision to enable autonomous navigation of unmanned aerial vehicles using a rotating camera and onboard processing module, to navigate through a hazardous environment; locating places, delivering supplies quickly, putting out flames, and airlifting people. They employed HD FPV camera, a laser scanner, GIS, GPS, and thermal infrared photos. DJI Mavic Mini, DJI Mini 2 Fly, Contixo 4K GPS Quadcopter UAV und Holy Stone HS110D FPV RC UAV. Improved precision in navigation and Lack of real-world verification were not covered.

B. Drawbacks of UAV

There are significant opportunities for research into lightweight battery technology same time, power-saving techniques need to be incorporated into all small-aircraft electronics. Furthermore, researchers may attempt to develop the new sensors, which consumes the less power and delivers the maximum output. Weather conditions and other meteorological factors affect the data obtained by the sensor. This issue affects all small-scale imaging sensors. The issue with restricted onboard battery power also restricts active sensors that may require multiple watts of power. The unavailability of commercially accessible sensors is perhaps the greatest sensor challenge. The present need and opportunity are to make the technology commercially available to researchers. PM2.5, Black Carbon (BC) DustTrak™ II Aerosol Monitor 8530 for PM2.5,microAeth AE51 for black carbon Hexacopter (25 min) (B Liu et al., 2020) An UAV fitted with small sensors was used to study the vertical profiles of PM2.5 and black carbon (BC) from the ground to 500 m above ground level (AGL) inMacau, China. A total of 46 flights were flown from 05:00 to 06:00 AM local time for a 12-d measurement in February 2018 and an 11-d measurement in March 2018. Concentrations of PM2.5 typically decreased with height, with a vertical decrease of 0.2 µg/m3 per 10 m. BC concentrations display different vertical profiles with a vertical decrease of µg/m3 per 10 m overall. Additionally, the burning of firecrackers and fireworks on February 16 (Chinese New Year's first day) resulted in higher PM2.5and BC concentrations within 150 m AGL. CO_2, CO, NH_3, SO_2, PM, O_3, and NO_2 Quadrotor (15 min). (Rohi et al., 2020)The E-UAV was evaluated to produce maps of AQHI at five different locations. The data collected by the E-UAV from test flights were not matched with any other data in published literature. The benefits of this system are its ability to

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measure CO_2, CO, NH_3, SO_2, PM, O_3, and NO_2 concentrations of air pollution, detect when they are too high, and implement onboard pollution abatement solutions where necessary.

CO, SO_2, NO_2, O_3 Air Information Acquisition Card Quadrotor (15 min) (Andaluz et al., 2019b). A mathematical kinematic model has been developed to control the UAV at different elevations for measuring air quality. Air parameters have been measured in rural and urban areas, and it was observed that air parameters in both the areas differ from each other. But also, the developed model can be used to control the UAV for air quality monitoring. PM2.5, NO2 OPC-N2 for PM2.5, NO2-B43F for NO2 Hexacopter (20 min) (Gu & Jia, 2019). The UAV and the onboard monitoring devices shared the same power source. There was a good agreement between the sensor and ground values of the PM2.5 data. On the other hand, NO2 sensor data has higher variation than ground data because the ripple of the UAV current produces large noise into the sensor which affects the accuracy of the sensor. PM2.5 A3-IG Quadcopter (15 min) (Hu et al., 2019). An IoT-based, 3D air quality sensing system has been developed. The UAV has been rovered for 5 s. For the processing of data, the spatial fitting technique has been used. Their location-aware sensor system (LASS) with an R^2=0.91. CO plume Linkit Smart 7688 Duo; IoT board, MQ135 for CO Quadcoptor (8 min) Seiber et al. (2018) Sensor-based particulate detection systems were placed on the swarm of the autonomous UAVs for plume identification and tracking. This enables the visual identification of plume movement. The plume movement has been done only in the horizontal direction and not in vertical direction.

PM2.5 LoRa PM sensor module Quadcoptor (15 min) (Liang-Yu et al., 2018) For measuring PM2.5 in real-time environment, a new sensor has been created. PM2.5, BC SidePak AM510 for PM2.5, microAeth AE51 for BC Fixed wing (X. B. Li et al., 2018b). A total of 16 UAV flights were conducted from summer to winter of 2014 at a height of 1000 m above ground level. The results show that concentrations of PM2.5 at ground level showed a declining trend from February to July and an increasing trend from August to January. In the winter, the mean vertical PM2.5 concentrations within the mornings at 1000 m lower troposphere were much higher (approx. 87.5 µg/m3) than those in the summer and autumn (approx. 20 µg/m3).

CH4 Figaro TGS 2600 Quadcoptor (Falabella et al., 2018). This study has been done to identify the methane emission hotspots and to test the developed UAV. The 1 m/s flights received a more reliable detection than the 3 m/s flights. CH4, CO, CO2 MQ-4 sensor for CH4, MQ-7 sensor for CO, MG811 sensor for CO2 Hexacoptor (Hussein et al., 2018) In this study, a hexarotor UAV has been fitted with fault tolerant control (FTC) techniques for measuring and detecting air quality inurban environments for air data collection. The focus was on sensor quality and power consumption. PM2.5 Environmental dust monitor module Quadcoptor (15 min) (Krishna et al., 2018) This study demonstrates the feasibility of Quadcopter being effectively equipped with dust sensors and versatility to measure three-dimensional PM2.5 concentration at an altitude of 8 m, particularly at peak hours of a day and measured for 3 months. PM, NO2 OPC-N2 for PM, NO2-B43F for NO2 Quadcoptor (15 min) (Gu et al., 2018). An air quality monitoring system based on the UAV was developed to calculate and view concentrations of air pollutants in real time. The unique design allows the user to hold several different air pollutant detectors and integrate real-time data with GPS location details from all onboard sensors. The UAV collected fine particulate matter concentrations equivalent to those calculated by the reference method in field tests, demonstrating the ability of this device to function under real-world conditions. The field tests showed that the instruments on board did not affect the power consumption and flight time of the UAV.

C. Research Gap and open issues

In summary, the application of unmanned aerial vehicles (UAVs) for air quality monitoring and video surveillance in hazardous environments has great potential to transform safety protocols, environmental surveillance, and emergency response in a variety of sectors (Chiang et al., 2019). Their capacity to gather real-time data, conduct surveillance, and support well-informed decision-making significantly aids risk mitigation, environmental health preservation, and the enhancement of safety standards in hazardous environments, ultimately leading to safer and more sustainable operations (Xiong et al., 2023). In this regard, monitoring the accuracy and condition of the sensor nodes becomes necessary. This is to ensure the integrity, accuracy, and reliability of the data collected at the edge network (sensors) and transmitted over the network are implemented (Jin et al., 2017). The research on data reliability and false data detection is not entirely new; contributions on data quality and false data detection with a focus on discrete-time systems have been made by (Casado-vara et al., 2019; Jin et al., 2017), a continuous-time system using feedback control of nonlinear systems was studied by (Liu et al., 2018), time-delay communications (Lin et al., 2017), control of marine surfaces (Zhang et al., 2018), and wind turbines (Wu & Wang, 2020). (Casado-vara, et al., 2019) approached the problem with the Continuous-Time Markov Chains algorithm (CTMCA) for monitoring and control of the edge of the IoT network, with attention on only temperature sensor data. Therefore, the interest of this work is in air quality sensor data, where researchers like (Ogu et al, 2022a; Ogu et al, 2022b) approached air quality monitoring using stationary sensors on a robust IoT network, and (Andaluz et al, 2019; Hernandz-Vega et al, 2023) approached air quality monitoring using Unmanned Aerial Vehicle.

However, a critical analysis of existing research reveals a significant gap. While many studies have successfully used UAVs to gather air quality and environmental data, they have largely taken the accuracy and integrity of this data for granted. The data is gathered and processed without a systematic method for verifying its quality. Therefore, these Research Gaps have been identified:

i. Lack of Quality Assurance: There is an absence of UAVs being used as a Quality Assurance instrument to validate the data captured by stationary air quality monitoring stations (SAQMS).

ii. Incomplete Pollution Source Identification: While UAVs can locate pollution sources, there is a need for better integration of pictorial evidence to enhance the localization and verification of these sources.

iii. The core problem is that none of the reviewed works questioned the confidentiality, integrity, and accuracy of the sensor data itself, particularly with reference to sensor failures or data manipulation.

VII UAV REGULATIONS

Unmanned aerial vehicles (UAVs), are being used in a wide range of industries. Countries throughout the world have put in place a comprehensive system of UAV rules to guarantee the safe and responsible usage of these devices. These rules aid in the development of the UAV sector while acting as a precaution against possible dangers (Angelo et al., 2021). The complex world of UAV laws is presented in this thorough review.

According to Abdelrahman et al., (2022), the main focus of UAV legislation is safety. Regulations are made to reduce the dangers of using unmanned aerial vehicles, especially when sharing the sky with manned aircraft. The main objective is to avoid mid-air accidents and related mishaps. The guidelines for managing airspace are set out by UAV rules. This involves the classification of several airspace classes, some of which include restrictions on the use of unmanned aerial vehicles. No-fly zones guarantee that UAVs don't interfere with human aircraft or pose security risks around airports, military sites, and other sensitive places (Asmaa Abdallah et al. 2019). Privacy issues have become more prominent since the introduction of UAVs. Regulations sometimes contain clauses that limit the taking of pictures or recordings of private property and people without their permission in order to safeguard their right to personal privacy. For aviation authorities, finding the ideal balance between modern technology and privacy for individuals is a never-ending task (Alexandru et al., 2023)

In Andy et al. (2021), no-fly zones may include places where huge people gather in addition to sensitive sites, such as stadiums or gatherings of the public. These limitations prevent unmanned aerial vehicles (UAVs) from flying overpopulated regions, where mishaps might cause major injury, to ensure safety. Operators are usually required to get licenses and complete training under UAV rules. A license for operators guarantees that those using UAVs are knowledgeable about aviation safety, airspace laws, and regulations. The safe and ethical use of UAVs depends on proper training.

Many nations have put in place UAV registration policies that mandate operators to register their Unmanned Aerial Vehicles (UAVs) with the relevant aviation authority. Each UAV that has registered is given a special identifying code or number. Authorities can monitor compliance with this registration system and find operators in the event of an incident or a violation (David and Thomas 2019). Altitude restrictions are established by regulations for UAV operations, guaranteeing a secure distance from manned aircraft. To reduce the possibility of UAVs interfering with manned aircraft's takeoff and landing, distance limitations around airports and other key airspace zones are also put in place (Bertold and Sofie 2019).

Regulations may set operating restrictions in order to guarantee secure and stable UAV functioning. These constraints may be placed on the maximum flying time, payload weight, and flight speed. These limitations are intended to minimize mishaps brought on by a UAV's overuse of its capabilities (Elena et al. 2023). Remote identification technology on UAVs may be required by upcoming legislation. These technologies improve the security and accountability of the airspace by enabling authorities to detect and monitor UAVs remotely in real time. This lessens the possibility of rogue or illegal UAV activities (Deepan et al 2021). In Ghassan and Areen (2020), environmental and animal issues are taken into account in UAV legislation. To avoid disruptions or damage to natural surroundings, UAV flights may be prohibited in delicate ecosystems, animal habitats, or breeding regions. Some rules demand that UAV operators carry liability insurance to cover mishaps and damages. In the event of occurrences involving property damage, bodily injury, or other obligations, this insurance offers financial protection. It guarantees that accountable parties can pay for any potential harm brought on by UAV activities (Andy et al., 2021).

Regulations are only useful if they are put into practice. Regulatory agencies conduct enforcement measures and set fines for noncompliance. Fines, equipment seizure, and legal action are all possible penalties in more serious situations. These measures act as a disincentive to discourage careless usage and promote adherence to the guidelines. UAV technology is quickly developing, bringing with it new possibilities and difficulties (Hariprasanth 2023). Regulations are continuously updated and altered to reflect these improvements. In order to guarantee that

UAV rules adequately handle the changing environment of UAV operations, authorities must stay up to date with new technological developments (Ihab et al 2020).

The globally harmonization of UAV rules is necessary due to the transnational character of aviation. To enable unmanned aerial vehicles to operate within international airspace while upholding safety and security, uniform standards and norms are being established. Public education and awareness, in addition to legislation, are essential for encouraging responsible UAV usage. Numerous agencies run outreach initiatives to inform users of the laws and recommended procedures for respectful and safe UAV operating (Javad et al 2020).

In conclusion, Deepan et al (2021) also added that UAV regulations are complex and dynamic collection of guidelines created to meet the issues brought on by the fast spread of UAV technology. These rules are essential for striking a balance between the creative potential of UAV technology and the protection of privacy, security, and safety. To guarantee that UAVs are incorporated into the airspace with the least amount of danger and greatest amount of benefit, it is imperative that these regulations be continuously improved and adjusted. An effective framework is provided by responsible regulation to facilitate the UAV industry's ongoing expansion and development

VIII CONCLUSION

This paper establishes UAVs as a highly versatile technology with transformative applications across military, commercial, and scientific domains. Their ability to carry sophisticated sensor payloads and navigate complex environments makes them particularly valuable for environmental monitoring and disaster management. The detailed examination of UAV types, technologies, and regulations provides a comprehensive foundation for understanding their capabilities and limitations. The paper successfully identifies a critical, unaddressed challenge in the specific application of UAV-AQMS: the assurance of data quality. The proposed research direction is to fill this gap by developing a framework or system that uses UAVs not just as data collectors, but as a quality assurance tool. This would involve verifying the data from stationary sensors, ensuring its integrity against failures or attacks, and robustly documenting pollution sources with visual evidence. This focus on data reliability and validation represents a novel and necessary contribution to the field of UAV-based air quality monitoring and surveillance in hazardous environment.

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