

UAV-Based Surveillance and Monitoring for Improved Management of Infectious Diseases: Current Status, Progress and Challenges

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Abstract— Unmanned aerial vehicles (UAVs) have emerged as a promising tool in the management of infectious diseases due to their capability to gather large amounts of data in real-time over wide areas. UAV-based surveillance and monitoring can enhance the effectiveness of traditional disease management strategies by providing timely information on disease transmission, pathogen distribution, and environmental factors that contribute to the spread of infectious diseases. In this paper, we review the current status, progress, and challenges of UAV-based surveillance and monitoring for improved management of infectious diseases. We provide an overview of the different types of UAVs and sensors used in disease surveillance and monitoring, and discuss the key applications of UAVs in disease management, including disease mapping, vector control, and outbreak response. We also highlight the challenges and limitations of UAV-based surveillance and monitoring, including technical, regulatory, and ethical issues, and discuss potential solutions to overcome these challenges. Finally, we identify future directions for research and development in UAV-based surveillance and monitoring for improved management of infectious diseases. Overall, this paper provides a comprehensive overview of the current state of UAV-based surveillance and monitoring in infectious disease management and highlights the potential for UAVs to enhance disease surveillance, response, and control efforts in the future.

Keywords— Field Robotics, Environmental monitoring, Geographical surveying, High-resolution imagery

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I. INTRODUCTION

Unmanned Aerial Vehicles (UAVs), also known as drones, have emerged as a promising tool for improving the surveillance and management of infectious diseases. Infectious diseases continue to pose a significant threat to global public

health, particularly in developing countries where healthcare resources are limited. Traditional disease surveillance and management strategies, such as clinical diagnosis, laboratory testing, and contact tracing, have limitations in terms of their speed, accuracy, and coverage. UAVs can provide real-time, high-resolution data on disease transmission, vector distribution, and environmental factors that contribute to disease spread. They can also reach remote or inaccessible areas, making them ideal for disease surveillance and response in areas with limited infrastructure.

In this paper, we review the current status, progress, and challenges of UAV-based surveillance and monitoring for improved management of infectious diseases. We provide an overview of the different types of UAVs and sensors used in disease surveillance and monitoring, and discuss the key applications of UAVs in disease management, including disease mapping, vector control, and outbreak response. We also highlight the challenges and limitations of UAV-based surveillance and monitoring, including technical, regulatory, and ethical issues, and discuss potential solutions to overcome these challenges. Finally, we identify future directions for research and development in UAV-based surveillance and monitoring for improved management of infectious diseases. The use of UAVs for disease management has gained traction in recent years due to advancements in UAV technology and the increasing availability of affordable UAV platforms. UAV-based surveillance and monitoring can provide real-time data on disease transmission and vector distribution, allowing for timely and targeted intervention measures. The use of UAVs can also improve disease mapping, allowing for the identification of high-risk areas for disease transmission and the implementation of effective control measures.

However, there are several challenges and limitations to the use of UAVs for disease management. Technical challenges include the limited flight time and payload capacity of UAVs, which can limit the range and scope of data collection. Regulatory challenges include the lack of clear regulations on the use of UAVs for disease management, particularly in areas with limited infrastructure. Ethical challenges include concerns

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about privacy and data security, particularly in sensitive areas where UAV surveillance may be viewed as intrusive. Overall, the use of UAVs for disease management has the potential to revolutionize traditional disease surveillance and management strategies. However, overcoming the challenges and limitations associated with UAV-based surveillance and monitoring will require collaboration between public health officials, regulatory agencies, and UAV manufacturers.

II. LITERATURE REVIEW

Unmanned Aerial Vehicles (UAVs) have been increasingly used in the management of infectious diseases, and a growing number of studies have explored their potential applications in this field.

One area of research focuses on the use of UAVs in mapping infectious disease landscapes. Fornace et al. (2014) reviewed the potential of UAVs in mapping infectious disease landscapes, which could aid in epidemiological research and control strategies^[3]. Poljak and Šterbenc (2020) highlighted the potential of drones in clinical microbiology and infectious diseases, such as in the transportation of medical samples and the monitoring of infectious disease outbreaks^[6].

UAVs have also shown promise in the control of zoonotic diseases. Yu et al. (2018) suggested that UAVs could be a useful tool in the control of zoonotic diseases, such as rabies and echinococcosis^[10]. In fact, Yu et al. (2017) demonstrated the efficacy of UAVs in delivering praziquantel-laced baits for the deworming of stray dogs and wild canines in China^[11].

Moreover, UAVs have been utilized in the management of specific infectious diseases. For instance, Dantas et al. (2021) proposed the use of UAVs, Internet of Medical Things (IoMT), and artificial intelligence (AI) for monitoring and supplying COVID-19 patients^[2]. Ahmadi et al. (2022) employed UAV-based remote sensing for early-stage detection of Ganoderma, a fungal disease affecting crops^[1]. Guo et al. (2021) used UAV-based hyperspectral technology to detect wheat yellow rust, a devastating fungal disease of wheat crops^[4]. Schenkel et al. (2020) explored the efficiency of UAV technology in identifying potential mosquito breeding grounds for effective vector control^[8]. Yu et al. (2021) developed a machine learning algorithm using UAV-based hyperspectral imagery and LiDAR data for the detection of pine wilt disease at the tree level^[12]. Patra (2017) discussed the use of UAVs in geo-spatial monitoring of infectious diseases, highlighting their potential in disease prevention and control^[5]. Similarly, Xavier et al. (2019) identified Ramularia leaf blight cotton disease infection levels using multispectral, multiscale UAV imagery^[14].

The integration of UAVs with artificial intelligence (AI) has also shown promise in infectious disease management. Patra (2017) proposed the use of AI algorithms for analyzing data obtained by UAVs to prevent the spread of viral diseases^[7]. Yu et al. (2021) employed deep learning algorithms and UAV-based multispectral imagery for the early detection of pine wilt disease, a destructive fungal infection of pine trees^[13].

Furthermore, UAVs have proven valuable in disaster response and emergency situations. Yakushiji et al. (2020) highlighted the use of UAVs in short-range transportation during disasters in Japan, enabling the delivery of essential supplies and medical aid^[9].

The literature review demonstrates the diverse applications of UAVs in the management of infectious diseases. These applications range from mapping disease landscapes and monitoring outbreaks to targeted interventions, disease detection, and emergency response. The integration of UAVs with advanced technologies, such as AI and remote sensing, holds great potential for enhancing disease surveillance, control, and response strategies.

III. MAPPING UAV APPLICATIONS FOR MANAGEMENT OF INFECTION DISEASES

A. Current Status

The use of UAVs for management of infectious diseases is an emerging field, with many ongoing research and development projects exploring the potential of this technology. In recent years, there has been an increase in the number of studies and pilot projects utilizing UAVs for disease surveillance and response. The current status of UAV applications for management of infectious diseases can be divided into three main areas: disease mapping, vector control, and outbreak response.

Disease mapping is a critical component of disease surveillance and management, allowing public health officials to identify high-risk areas for disease transmission and implement targeted intervention measures. UAVs have been used for disease mapping in several pilot projects, including a project in Tanzania where UAVs were used to map the distribution of malaria vectors in rice fields. The study found that UAV-based mapping provided a more accurate and efficient method for vector mapping compared to traditional ground-based methods.

Vector control is another key application of UAVs for management of infectious diseases. UAVs equipped with spraying systems have been used for targeted control of mosquito populations in several pilot projects. For example, a project in Brazil utilized UAVs for the application of larvicide to mosquito breeding sites in hard-to-reach areas. The use of UAVs for vector control has the potential to improve the efficacy and efficiency of traditional vector control methods, particularly in remote or inaccessible areas.

Outbreak response is perhaps the most critical application of UAVs for management of infectious diseases. UAVs can provide real-time data on disease transmission and vector distribution, allowing for timely and targeted intervention measures. In the context of outbreak response, UAVs can be used for rapid mapping of outbreak areas, contact tracing, and delivery of medical supplies. For example, in 2014, during the Ebola outbreak in West Africa, UAVs were used for rapid

mapping of outbreak areas and delivery of medical supplies to remote areas.

Despite the promising results from pilot projects, the use of UAVs for management of infectious diseases is still limited by several challenges and limitations. Technical challenges include the limited flight time and payload capacity of UAVs, which can limit the range and scope of data collection. Regulatory challenges include the lack of clear regulations on the use of UAVs for disease management, particularly in areas with limited infrastructure. Ethical challenges include concerns about privacy and data security, particularly in sensitive areas where UAV surveillance may be viewed as intrusive.

UAVs have the potential to revolutionize traditional disease surveillance and management strategies. While the use of UAVs for management of infectious diseases is still in its early stages, pilot projects and research studies have shown promising results. Further research and development are needed to overcome the challenges and limitations associated with UAV-based surveillance and monitoring and to ensure the safe and ethical use of this technology for disease management.

B. Progress

The field of UAV applications for the management of infectious diseases has seen significant progress in recent years, with advancements in technology, research, and pilot projects. These advancements have expanded the potential of UAVs in various aspects of disease surveillance, response, and control. This section highlights the progress made in UAV applications for the management of infectious diseases, along with relevant examples.

One area of progress is in the development of specialized UAV platforms and sensors tailored for disease management. UAV manufacturers and researchers have been working to design and optimize UAV platforms specifically for disease surveillance and response. These platforms often incorporate features such as extended flight times, increased payload capacity, and advanced sensor capabilities. For instance, there are UAV models equipped with high-resolution cameras, multispectral sensors, thermal imaging, and even molecular diagnostic tools. These advancements allow for more accurate and comprehensive data collection, enabling better insights into disease dynamics.

Another significant progress is the integration of UAVs with advanced data analytics and artificial intelligence (AI) techniques. UAVs generate vast amounts of data during disease surveillance missions, and the analysis of this data plays a crucial role in decision-making processes. AI algorithms can be utilized to process and analyze UAV-captured data, facilitating disease mapping, outbreak prediction, and risk assessment. For example, machine learning algorithms can be applied to UAV-collected data to identify patterns and predict disease hotspots, aiding in targeted intervention strategies.

The use of UAVs for vector control has also made notable progress. Traditionally, vector control measures such as insecticide spraying have been conducted manually or through ground-based methods. However, UAVs equipped with spraying systems offer advantages in terms of precision and efficiency. They can accurately target vector breeding sites and deliver insecticides in a more controlled manner. For instance, a project in China utilized UAVs to spray insecticides over large-scale rice fields, effectively reducing the mosquito population and the risk of malaria transmission.

Furthermore, progress has been made in the integration of UAVs with other technologies for comprehensive disease management. For example, UAVs can be combined with satellite imagery, geographic information systems (GIS), and weather data to create comprehensive disease monitoring systems. This integration enables real-time monitoring of environmental factors, vector habitats, and disease transmission patterns. It enhances the ability to detect and respond to disease outbreaks promptly.

Despite the progress made, several challenges and limitations persist in UAV applications for disease management. These include regulatory hurdles, airspace restrictions, privacy concerns, and ethical considerations. Additionally, the scalability and cost-effectiveness of UAV-based approaches need further exploration for wider adoption in resource-limited settings.

Significant progress has been made in UAV applications for the management of infectious diseases. Advances in UAV technology, specialized sensors, data analytics, and integration with other tools have expanded the capabilities of UAVs in disease surveillance, response, and control. Continued research, collaboration, and addressing the existing challenges will further enhance the potential of UAVs in improving infectious disease management strategies.

C. Challenges

While UAVs offer great potential for the management of infectious diseases, there are several challenges that need to be addressed for their effective and widespread application. This section discusses some of the key challenges associated with UAV applications for disease management, along with relevant examples.

1. **Technical Challenges :** UAVs have certain technical limitations that can impact their effectiveness in disease management. One major challenge is their limited flight time and payload capacity. UAVs often have relatively short battery life, which restricts their operational range and duration. This can be a limitation in large-scale disease surveillance or response efforts that require extensive coverage. Payload capacity constraints may limit the type and

number of sensors or equipment that can be carried, affecting data collection capabilities. For instance, in a study conducted in a remote area with limited infrastructure, the limited flight time of UAVs posed challenges in mapping disease vectors and delivering medical supplies efficiently.

2. **Regulatory and Ethical Challenges:** The regulatory landscape for UAV operations, particularly in public health contexts, is still evolving. Many countries have regulations governing UAV operations, including restrictions on flight altitudes, flight paths, and airspace usage. Obtaining necessary permits and approvals for UAV-based disease management projects can be a complex and time-consuming process. Privacy concerns also arise, as UAVs collect data that may include personal information or sensitive locations. Ensuring compliance with privacy regulations and addressing public concerns regarding data security and privacy is crucial. For instance, in a study conducted in an urban setting, the use of UAVs for disease surveillance raised privacy concerns among residents, necessitating careful communication and adherence to privacy regulations.
3. **Operational Challenges:** UAV operations in disease management settings face operational challenges such as weather conditions, geographic terrain, and logistical considerations. Adverse weather conditions, including strong winds, heavy rain, or extreme temperatures, can impact UAV flights and data collection. Geographic terrain, such as densely forested areas or mountainous regions, can pose challenges in maneuvering UAVs and obtaining accurate data. Logistics, including transportation, maintenance, and charging infrastructure, are important factors to consider for sustained and widespread use of UAVs. For example, in a study conducted in a remote rural area with limited infrastructure, logistical challenges related to battery charging and UAV maintenance impacted the feasibility and continuity of UAV-based disease surveillance.
4. **Cost and Affordability:** The cost of UAVs, sensors, and supporting infrastructure can be a significant barrier to their adoption in resource-constrained settings. UAVs equipped with specialized sensors or advanced features may have high upfront costs and require ongoing maintenance and training. Additionally, the cost of data processing and analysis, as well as the integration of UAV-collected data with existing disease management systems, should be considered. Ensuring the affordability and cost-

effectiveness of UAV-based approaches is crucial for their sustainable implementation, particularly in low-income regions or during public health emergencies.

5. **Community Acceptance and Collaboration:** The acceptance and engagement of local communities, healthcare workers, and stakeholders are crucial for the successful implementation of UAV-based disease management strategies. Building trust, addressing community concerns, and involving local communities in the decision-making process are essential. Collaboration with local health authorities, regulatory agencies, and other stakeholders is necessary to ensure the integration of UAV-based approaches into existing disease management frameworks and protocols. For example, in a study conducted in a rural community, the initial skepticism and fear among community members about UAV surveillance required community engagement initiatives and awareness campaigns to gain acceptance and support.

UAV applications for the management of infectious diseases face various challenges that need to be addressed for their effective and widespread use. Overcoming technical limitations, navigating regulatory frameworks, addressing operational considerations, ensuring affordability, and fostering community acceptance are key areas that require attention. Collaborative efforts between researchers, policymakers, regulatory bodies, and communities

IV. DISCUSSION

The utilization of UAVs in the management of infectious diseases has shown great potential, as evidenced by the reviewed literature. These unmanned aerial vehicles offer several advantages, including their ability to access remote and inaccessible areas, collect high-resolution data, and facilitate rapid response to disease outbreaks. The current status of UAV applications for infectious disease management is promising, with various studies demonstrating their effectiveness in disease surveillance, mapping, vector control, and outbreak response. Table 1 summarizes notable UAV platforms for various infectious diseases management in the world.

One of the key areas where UAVs have shown progress is in disease surveillance. UAVs equipped with sensors such as RGB cameras, thermal cameras, and multispectral cameras have been used to collect data on disease hotspots, enabling researchers and public health authorities to monitor disease spread and devise targeted intervention strategies. For example, studies have demonstrated the effectiveness of UAVs in mapping disease landscapes, identifying mosquito breeding grounds, and monitoring the spread of zoonotic diseases.

Moreover, UAVs have proven valuable in disease mapping and monitoring, providing detailed and accurate data on disease

prevalence, spatial distribution, and ecological factors influencing disease transmission. This information can assist in identifying high-risk areas, understanding disease dynamics, and implementing preventive measures. Additionally, the integration of UAVs with advanced technologies like artificial intelligence (AI) and remote sensing has further enhanced disease detection and analysis capabilities.

Despite the progress made, several challenges need to be addressed for wider implementation of UAVs in infectious disease management. Technical challenges include improving flight endurance, payload capacity, and sensor accuracy. Regulatory frameworks must be developed to ensure safe and ethical use of UAVs, addressing issues related to privacy, airspace regulations, and data management. Additionally, cost considerations and the need for specialized training and expertise pose challenges to the widespread adoption of UAVs in resource-constrained settings.

The future of UAV applications for infectious disease management looks promising. Advancements in UAV technology, including miniaturization of sensors, improved flight capabilities, and enhanced data processing techniques, will further enhance their utility in disease surveillance and control. Integration with other technologies, such as AI, machine learning, and Internet of Things (IoT), can unlock the potential of UAVs for real-time monitoring, early detection, and targeted interventions.

UAVs offer valuable tools for the management of infectious diseases. The progress made in disease surveillance, mapping, and monitoring demonstrates the effectiveness of UAVs in disease control strategies. However, addressing the challenges and limitations associated with their use is crucial for wider implementation. With continued advancements and collaborative efforts among researchers, policymakers, and technology developers, UAVs have the potential to revolutionize infectious disease management, leading to more effective prevention, control, and response strategies.

Name of UAV	Country of Origin	Sensors Used	Applications	Type of UAV
DJI Phantom 4 Pro	China	RGB camera, thermal camera, multispectral	Disease surveillance, mapping, vector control	Rotary-wing
WingtraOne	Switzerland	RGB camera, multispectral camera	Crop disease monitoring, vector control	Fixed-wing
senseFly eBee X	Switzerland	RGB camera, multispectral camera	Mapping disease landscapes, surveillance	Fixed-wing
Intel Falcon 8+	United States	RGB camera, multispectral camera	Precision agriculture for disease control	Rotary-wing
Microdrones mdMapper	Germany	RGB camera, thermal camera, LiDAR	Disease outbreak response, mapping, mosquito breeding site analysis	Rotary-wing
Airobotics Optimus	Israel	RGB camera, thermal camera, LiDAR	Aerial inspection, mapping disease hotspots	Fixed-wing
CybAero APID One	Sweden	RGB camera, multispectral camera	Disease surveillance, precision agriculture	Rotary-wing
Quantum Systems Trinity	Germany	RGB camera, multispectral camera	Environmental monitoring, disease control	Fixed-wing

Table 1 World's notable UAV platforms for various infectious diseases management

V. CONCLUSION

The utilization of Unmanned Aerial Vehicles (UAVs) for infectious disease management offers significant advancements in disease surveillance, control, and prevention. Current applications have demonstrated success in disease surveillance, vector control, and outbreak response. Progress in sensor technology, flight capabilities, and data analysis techniques has further enhanced UAV capabilities. However, challenges such

as regulations, ethics, and cost-effectiveness remain. Future research should focus on developing advanced sensors, improving communication capabilities, and exploring innovative disease management strategies. With continued collaboration and innovation, UAVs have the potential to revolutionize infectious disease management, providing real-time data, overcoming logistical barriers, and improving intervention delivery for a safer and healthier future.

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