A Critical Examination of Remote-Controlled Aircraft Technology in Terms of Their Operation in All-Weather Conditions

S. K. Vishnoo Prathap and Vikramjit Kakati

Abstract Remotely piloted aircraft (RPAs) or drones are commonly referred to as unmanned/autonomous aerial vehicles. Over the past 5–6 years, there has been a boom in the use of these vehicles in civil and defense applications worldwide. Despite very protective use guidelines, RPAs are used for surveillance and remote-sensing purposes worldwide, and few delivery services are active. On the Indian Subcontinent, the use of drones/RPAs is limited to government organizations and a few private operators that work with educational institutions. Using a case study from India, the paper explores the various requirements, current objectives, technology, and future challenges for RPA/drone operations that can be conducted in all-weather conditions. India's technology and future benefits are also examined in the paper. Additionally, this paper examines the options for monitoring civil aviation applications related to remote sensing, cargo transport, search and rescue services, and civil surveillance. The utilization of RPAs for the novel COVID-19 pandemic in India has also been reported.

Keywords RPA · All-weather operation · Civil aviation

1 Introduction

Remotely piloted aerial vehicles (RPAVs) are abundantly finding applications due to their low-cost, less maintenance, and multi-terrain launch capabilities. In India, RPAVs, also known as unmanned aerial vehicles (UAVs) according to the Government of India, can be classified into nano, micro, small, medium, and a large class of UAVs. Classification is also done by employing utilization and configurations (see Fig. 1). There are two types of UAVs, low-altitude platforms and high-altitude platforms. In UAV terms, regulations are set with the appropriate height by which a UAV can operate. In India, drones/RPAs are regulated by the Director-General of Civil

S. K. V. Prathap (✉) · V. Kakati
Department of Mechanical Engineering, Assam Don Bosco University, Guwahati, Assam, India
e-mail: du2020phd0051@dbuniversity.ac.in

J. K. Deka et al. (eds.), *Emerging Technology for Sustainable Development*,
Lecture Notes in Electrical Engineering 1061,
https://doi.org/10.1007/978-981-99-4362-3_2

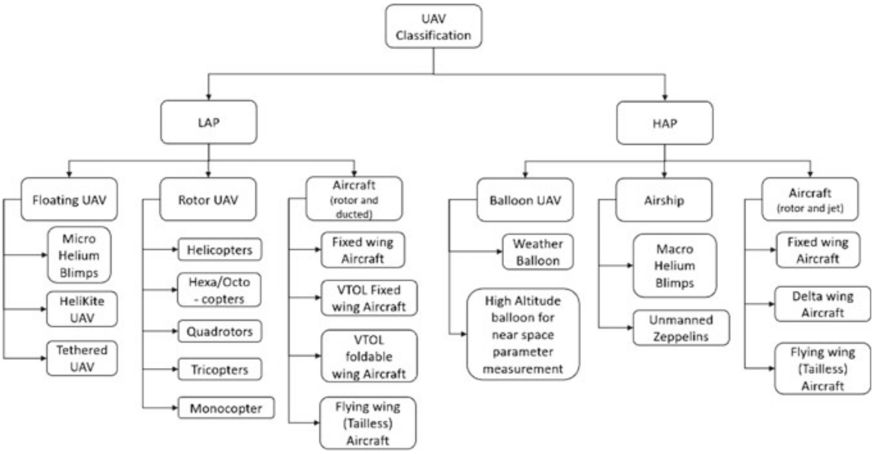

Fig. 1 Classification of UAV based on utilization and configuration

Aviation (DGCA) under the Ministry of Civil Aviation, Government of India. For regulating the usage of UAVs/RPAs in Indian airspace, the Government of India drew up the Drone Rules 2021 and paved the way for the ease of deployment of drones based on the requirements, and RPAs manual was also drafted with specific rules and regulations to be followed by public and private end-users of this technology.

Drone technology has developed tremendously in recent years (Shakhatreh et al. 2018), and the DGCA has taken a number of initiatives to make use of drones/ RPAs in commercial airspace in India. The use of drones for delivery has gained popularity in recent years. The DGCA has granted manufacturing permissions for a few companies, though there are many private players in India, such as start-ups and university-based research centers. There are, therefore, few logistics firms using drones for their operations. In India, e-commerce players such as Amazon are trying to implement the Amazon air delivery program and are yet to become certified.

Sources indicate that drones are used more in Eurasia when compared to other parts of the world (see Fig. 2).

Following the COVID-19 pandemic outbreak, local police have utilized quadrotor drones/RPAs as surveillance tools during lockdowns. Through this, the police were able to undertake non-contact patrols. In addition, drones fitted with radiometric thermal imaging sensors were used to measure the temperature of individuals in a crowd by flying at a lower altitude. The flight distance of a drone varies from 2 to 4 km, depending on the payload and objectives of the mission. While India's market and drone industry are still developing, there is immense potential for growth in the local market. India's drone market is expected to grow 18% between 2017 and 2023. It has been reported by Unearth Insight that there are about 100 start-ups in India engaged in the drone business. The drone market can create jobs for UAV operators, engineers, scientists, and data analysts. The Federation of Indian Chambers of Commerce & Industry projects that the UAV market in India will reach US$ 885.7 million by 2021.

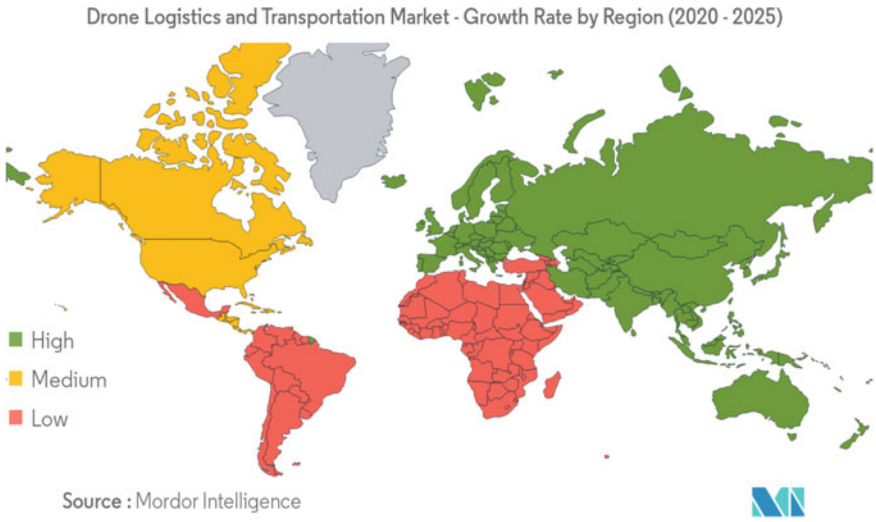

Fig. 2 Drone transportation and logistics market around the world. *Source* Mordor intelligence

2 Application of RPAVs and Their Constraints in India

2.1 Search and Rescue Operations

- Drones are utilized in natural and artificial disasters to find lost persons.
- Drones may be used on land or sea for rescue operations by surveying the field of last known contact.
- Search teams can navigate capsized shafts and natural tunnels/caverns using small, scalable drones.
- Drones can locate people buried under avalanche debris in the mountains.

Challenge: Drones are only sparsely used by national disaster relief organizations in India and are limited to police and national disaster management personnel. This hinders private companies from fully participating and requires more clearance in order to have access.

2.2 Remote Sensing

- It is possible to collect information/data from ground-based systems using UAVs.
- Using UAVs equipped with sensors, disaster monitoring, water quality monitoring, environmental monitoring, drought monitoring, and mineral survey analysis are possible.

- They are also used in agriculture, forestry, and water resources. Several datasets can be gathered for crop monitoring, yield estimates, disease detection, image processing and analysis for crop classifications, forest cover surveys, deforestation surveys, survey of water bodies and underground reservoirs, etc.

Challenge: Drones are widely used in India for remote sensing, especially by remote sensing centers and national disaster relief organizations, but weather conditions limit their flight capabilities.

2.3 Construction and Infrastructure Inspection

- With the appropriate instrumentation/sensors and optical scanners, drones have the potential to be used for pipeline inspections, powerlines inspections, cooling tower inspections, and boiler inspections.
- Using software such as ArcGIS, drones can also be used for construction site surveys, terrain modeling, landscape design, and urban planning.

Challenge: Sense and avoid technology and optical sensor technology needs to be developed for all scalable drones.

2.4 Precision Agriculture

- UAVs are used for crop management, weed detection, irrigation scheduling, disease classification, and pesticide spraying.
- Generally, in agriculture, soil and crop health monitoring is done with ground-based array of sensors and also needs to cover the entire field which is expensive to install. But with UAVs and remote sensing technology, it is easy to cover the entire field and also can be deployed on regular intervals to monitor.
- Similarly, drones are used to take inventory of crops and fruits before harvesting, which provides farmers with precise information about their crops and fruits.
- They are also utilized to protect crops from animals using ultrasonic devices.

Challenge: Low-cost affordability for farmers.

2.5 Goods Delivery

- Food packages, e-commerce supplies, and medical supplies can be transported using UAVs.
- It can also pick up an item from point A and deliver it to point B.
- It can be utilized for commercial transport of goods nationwide.

Challenge: Terrain awareness technology, satellite-based tracking systems, and all-terrain landings are needed to be developed.

2.6 Traffic Monitoring and Situation Awareness

- UAVs can undertake the task of fieldwork support teams monitoring, road surveying, traffic level monitoring, and accident monitoring.
- Smart and reliable UAVs can help automate information transfer on highways and local roads.
- Traffic police can use drones to chase suspects on foot or ground vehicles. It may produce ease in surveillance and also replace traditional cameras.

Challenge: Basic infrastructure for charging and docking with Internet access is developed at designated areas, national highways, and state highways.

2.7 Pandemic Monitoring and Control

- UAVs were used for spraying sanitizer fluid in local municipal areas.
- Pedestrian and traffic monitoring during curfews and lockdowns were essential for non-contact patrolling.

3 Requirement of All-Weather Operational RPAVs

The Indian Subcontinent is situated in a diverse geographical part of Asia, where the weather and terrain vary from state to state. Considering the cold and high-altitude Himalayan Mountain ranges in the northern and northeastern part of India, the hot desert region of Western India, the arid Deccan Plateau region of Central India, and the humid coastal regions of Southern India, the weather pattern varies based on the location. Also, the altitude at ground level varies with the mean sea level toward the north of the country. Also, current RPAVs require proper infrastructure to take-off and land accordingly. As of now, the RPAVs cannot fly in harsh weather conditions. Furthermore, the technology available for all-weather operations is not quite mature. There are many gaps to bridge in order to create a sophisticated machine or vehicle that can fly in severe weather conditions (see Fig. 3).

An RPAV needs to meet the following criteria to be able to operate in any weather.

- Subsystem environmental control and structural integrity (impact resistant and waterproof)
- High endurance capability
- Multi-terrain and vertical take-off and landing (VTOL)

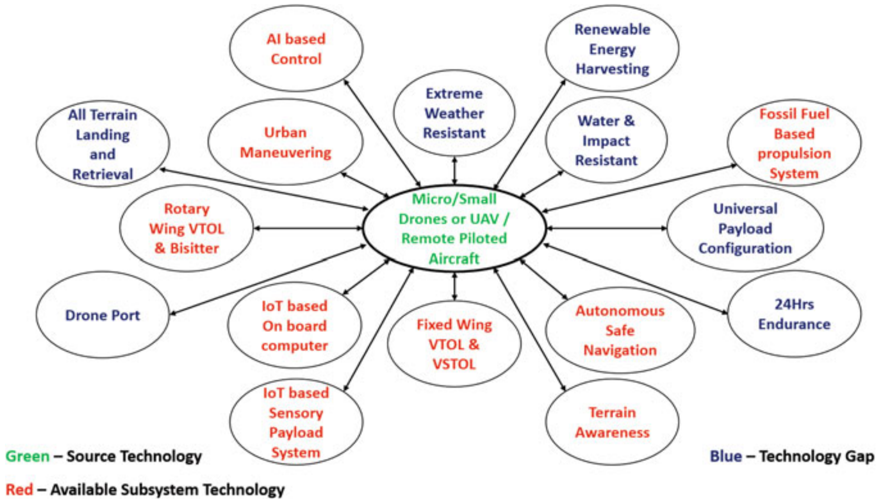

Fig. 3 Current technology status of RPAVs

- RPAV infrastructure availability
- RPAV configuration (overall sizing parameters).

4 Current Technology Development

Based on the current needs of technical requirements to be met for an actual all-weather vehicle, the following are some innovations that are considered as part of the requirements.

4.1 Subsystem Environmental Control and Structural Integrity

RPAVs have different classes and vary in size. They tend to travel in different altitudes, and the weather conditions also vary. The electronic systems inside the hull require ambient temperature monitoring (Pang et al. 2018; Wang et al. 2015; Tanda 2020). Also, they should be leak-proof in case of wet weather conditions and if the vehicle travels on water and air medium (Zufferey et al. 2019). The current technology has been tested by submerging a quadrotor UAV in a water medium. Current material science enables a leak-proof mechanism built and tested and satisfies one significant aspect for all-weather capability (Meng et al. 2018). Internet of Things (IoT)-based sensors (Xu et al. 2022) are also reliable for data analytics in RPAV vital parameter monitoring and ambient temperature monitoring and cooling. Therefore, the aspect of the ambient environment inside the RPAV and its integrity in terms of structures have improved without compromises.

4.2 High Endurance Capability

The energy systems in current RPAVs have a limit in terms of energy density and also energy utilization. The aspect of long endurance has been achieved through endurance by introducing the battery dumping concept (Chang and Yu 2015), solar energy power system (Cestino 2006), introducing fuel cell systems (Swider-Lyons et al. 2011), and optimization of the structures to improve flight capabilities (Bakar et al. 2021). Also, consideration of inclusion of a secondary power system (Chiesa et al. 2011).

4.3 Multi-terrain and Vertical Take-Off and Landing (VTOL)

Vertical landing and take-off technology of aircraft have been available since the 1970s. Also, the procedure has been implemented in the current RPAVs by having multiple multi-rotor platforms (Idrissi et al. 2022) and also introducing morphing vehicle structures like tilt-rotor, tail sitter configuration, etc. (Yuksek et al. 2016; Shanmugam et al. 2016a; Gomez and Garcia 2011; Bilgen et al. 2009; Guiler and Huebsch 2005). On the other hand, multi-terrains are still under the conceptualization stage and yet to develop a mature mechanism/technology as they now rely upon sensor-based landing (Templeton et al. 2007).

4.4 RPAV Configuration

The significant technological developments in the structure of RPAVs are related to morphed wings (Shanmugam et al. 2016b) and increased aerodynamic stability with the incorporation of hybrid variants (combination of fixed-wing and multi-rotor) (Tielin et al. 2017). This technology benefit applications in remote regions and partially comply with the all-weather operation requirements.

4.5 Infrastructure

There are still many areas around the world where drone ports are in the planning stages, and they are not yet operational. In some parts of Rwanda, Africa drone ports[1,2] have been established, but they lack the innovative technology that will allow drone traffic to be recognized. Currently, the main requirements that need to be addressed are the lack of dedicated tracking systems and docking systems for energy storage.

5 Conclusion

Technology is not available for all-weather capability as a combined package. There has been no consideration for the following aspects: (a) deserts and snow conditions, (b) hail storms and winds greater than 10 m/s, and (c) mountain valley and coastal region environmental conditions. There is, therefore, a need to develop an RPAV with universal applications. In all regions of India and around the world, the subsystems should cater to all-weather operation requirements. In addition, drones need to be equipped with the requisite infrastructure to enable cross-country operations. Satisfying these needs can lead to the development of a pure universal all-weather RPAV.

References

Bakar A, Ke L, Liu H et al (2021) Design of low altitude long endurance solar-powered UAV using genetic algorithm. Aerospace 8. https://doi.org/10.3390/aerospace8080228

Bilgen O, Kochersberger KB, Inman DJ (2009) Macro-fiber composite actuators for a swept wing unmanned aircraft. Aeronaut J 113(1144):385–395. https://doi.org/10.1017/s0001924000003055

Cestino E (2006) Design of solar high altitude long endurance aircraft for multi payload & operations. Aerosp Sci Technol 10:541–550. https://doi.org/10.1016/j.ast.2006.06.001

Chang T, Yu H (2015) Improving electric powered UAVs' endurance by incorporating battery dumping concept. In: Procedia engineering. Elsevier Ltd, pp 168–179

Chiesa S, Farfaglia S, Fioriti M, Viola N (2011) Design of all electric secondary power system for future advanced medium altitude long endurance un-manned aerial vehicles. Proc Inst Mech Eng Part G J Aerosp Eng 226(10):1255–1270. https://doi.org/10.1177/0954410011420914

Gomez JC, Garcia E (2011) Morphing unmanned aerial vehicles. Smart Mater Struct 20(10):103001. https://doi.org/10.1088/0964-1726/20/10/103001

Guiler R, Huebsch W (2005) Wind tunnel analysis of a morphing swept wing tailless aircraft. In: 23rd AIAA applied aerodynamics conference. https://doi.org/10.2514/6.2005-4981

Idrissi M, Salami M, Annaz F (2022) A review of quadrotor unmanned aerial vehicles: applications, architectural design and control algorithms. J Intell Robot Syst 104:22. https://doi.org/10.1007/s10846-021-01527-7

Meng L, Hirayama T, Oyanagi S (2018) Underwater-drone with panoramic camera for automatic fish recognition based on deep learning. IEEE Access 6:17880–17886. https://doi.org/10.1109/ACCESS.2018.2820326

[1] Droneport—Norman Foster Foundation.

[2] Zipline—Instant Logistics (flyzipline.com).

Pang L, Zhao M, Luo K et al (2018) Dynamic temperature prediction of electronic equipment under high altitude long endurance conditions. Chin J Aeronaut 31:1189–1197. https://doi.org/10.1016/j.cja.2018.04.002

Shakhatreh H, Sawalmeh A, Al-Fuqaha A et al (2018) Unmanned aerial vehicles: a survey on civil applications and key research challenges. https://doi.org/10.1109/ACCESS.2019.2909530

Shanmugam P, Raja S, Parammasivam KM, Zohra F (2016a) A study on VGTM actuation system for multi axis morphing wing of UAV. In: 34th AIAA applied aerodynamics conference. https://doi.org/10.2514/6.2016-3414

Shanmugam P, Km P, Raja S (2016b) Realization of efficient multi-axis morphing wing mechanism for a VTOL-UAV through LMA and IMU based approach

Swider-Lyons KE, Mackrell JA, Rodgers JA et al (2011) Hydrogen fuel cell propulsion for long endurance small UAVs. In: AIAA centennial of naval aviation forum "100 years of achievement and progress"

Tanda G (2020) Cooling solutions for an electronic equipment box operating on UAV systems under transient conditions. Int J Therm Sci 152:106286. https://doi.org/10.1016/j.ijthermalsci.2020.106286

Templeton T, Shim DH, Geyer C, Sastry SS (2007) Autonomous vision-based landing and terrain mapping using an MPC-controlled unmanned rotorcraft. In: Proceedings 2007 IEEE international conference on robotics and automation. https://doi.org/10.1109/robot.2007.363172

Tielin M, Chuanguang Y, Wenbiao G, Zihan X, Qinling Z, Xiaoou Z (2017) Analysis of technical characteristics of fixed-wing VTOL UAV. In: 2017 IEEE international conference on unmanned systems (ICUS). https://doi.org/10.1109/icus.2017.8278357

Wang T, Tseng KJ, Zhao J (2015) Development of efficient air-cooling strategies for lithium-ion battery module based on the empirical heat source model. Appl Therm Eng 90:521–529. https://doi.org/10.1016/j.applthermaleng.2015.07.033

Xu R, Zhang W, Wong NH et al (2022) A novel methodology to obtain ambient temperatures using multi-rotor UAV-mounted sensors. Urban Clim 41:101068. https://doi.org/10.1016/j.uclim.2021.101068

Yuksek B, Vuruskan A, Ozdemir U et al (2016) Transition flight modeling of a fixed-wing VTOL UAV. J Intell Robot Syst Theory Appl 84:83–105. https://doi.org/10.1007/s10846-015-0325-9

Zufferey R, Ortega Ancel A, Farinha A et al (2019) Consecutive aquatic jump-gliding with water-reactive fuel. Sci Robot 4