DESIGN AND DEVELOPMENT OF AN AMPHIBIOUS TRICOPTER DRONE: AEROGI

Abstract

This research article presents the development and evaluation of an Amphibious Tricopter Drone, "Aerogi," designed to operate in air and water environments. The project aimed to bridge the research gap in creating a versatile unmanned aerial vehicle (UAV) capable of seamless transitions between aerial and aquatic modes. The study outlines the methodology, including selecting components such as brushless motors, electronic speed controllers, flight controllers, and tilting mechanisms. Extensive flight testing assessed "Aerogi's" stability, altitude performance, weight-carrying capacity, flight time, and robustness. Results demonstrate successful aerial flights with efficient take-off and landing maneuvers. While reaching the maximum target altitude proved challenging due to design limitations, "Aerogi" fulfilled weight and payload capacity targets, meeting desired flight durations. Future work may involve improving stability at higher altitudes, optimizing propulsion for increased thrust, refining the tilting mechanism, and exploring advanced imaging and autonomous capabilities. "Aerogi" represents a significant advancement in UAV technology, showcasing the potential for innovative designs integrating air and water operations. This research contributes to the field of UAVs, opening new avenues for aerial and aquatic exploration and applications.

Keywords: Amphibious drone, Tricopter, Unmanned aerial vehicle (UAV), Aerogi.

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I. INTRODUCTION

Unmanned aerial vehicles (UAVs), commonly known as drones, have rapidly evolved from military applications to civilian uses, such as aerial photography, product delivery, surveillance, and scientific exploration. Drones are versatile aircraft that can operate either autonomously or under remote control. They have become indispensable tools for missions considered "dull, dirty, and dangerous" for humans[1]. With the advent of advanced technologies, civilian UAVs now outnumber military ones, expanding into various sectors, including commercial, recreational, agricultural, and policing applications[2]. The history of drones dates back to as early as 1849, when the Austrian forces utilized an incendiary air balloon equipped with bombs during the Venice independence conflict. Since then, the development of UAVs has seen significant milestones, including the first pilotless radio-controlled aircraft in World War I and the debut of the "Queen Bee" drone in 1935[3]. Initially, UAV technology faced challenges in reliability and cost-effectiveness, limiting its widespread use[4]. However, as concerns regarding the safety of spy planes arose, the military revisited the idea of unmanned aerial vehicles, leading to their solidification in military operations, particularly with critical roles in intelligence, surveillance, reconnaissance, and force protection[5].

Despite the increasing popularity and applications of UAVs, there remains a research gap in developing specialized drones capable of operating in air and water environments. While fixed-wing and multirotor drones are widely available, their limitations in maneuvering on water surfaces present an opportunity to explore innovative designs[6]. This research addresses this gap by developing an amphibious drone named "Aerogi," which can seamlessly transition between aerial and aquatic domains. This research aims to design and develop an Amphibious Tricopter Drone, "Aerogi," capable of operating in the air, on land, and on water. To achieve this aim, the following specific objectives will be pursued:

- Design an efficient and stable tilting mechanism for the tricopter to provide both yaw movement and forward thrust during flight.
- Implement a floating landing gear to enable smooth water landings and water surface navigation.
- Optimize the drone's propulsion system to ensure a maximum altitude of 100 ft and a flight duration of at least 30 minutes.
- Integrate a live video feed camera system for real-time monitoring during flight operations.
- Ensure the drone's total weight, including Payload, does not exceed 2.0 kg while adhering to a budget of Rs. 20,000.

By achieving these objectives, the research will contribute to developing an innovative amphibious UAV that can overcome the limitations of conventional drones and open new possibilities for various applications in both air and water environments. In the subsequent chapters, the methodology and literature survey for developing "Aerogi" will be discussed in detail, providing a comprehensive understanding of the research process and its context in the existing body of knowledge.

II. SIGNIFICANCE OF AEROGI

In comparison to existing UAV technology, "Aerogi" stands as a groundbreaking advancement with its seamless integration of aerial and aquatic capabilities. This unique amphibious tricopter drone not only opens up new possibilities for diverse applications, including surveillance, environmental monitoring, and exploration, but also presents a paradigm shift in UAV design and versatility. Its potential impact on the field is expected to be profound, revolutionizing aerial and aquatic exploration and introducing innovative solutions for industries and research endeavors. "Aerogi's" ability to navigate both air and water environments with efficiency and stability is poised to pave the way for future developments in autonomous features, enhanced imaging capabilities, and further optimizations in propulsion and control systems, making it a trailblazer in the realm of unmanned aerial vehicles.

The potential practical applications of "Aerogi" are vast and far-reaching. In environmental monitoring, "Aerogi" could be deployed to survey large bodies of water and assess pollution levels or monitor marine life and habitats. In search and rescue missions, this amphibious drone could swiftly navigate over water bodies, aiding in locating and assisting individuals in distress. Moreover, in surveillance operations, "Aerogi" could provide unmatched versatility, being capable of both aerial and underwater observations, enhancing security and monitoring capabilities in critical areas.Additionally, "Aerogi" could revolutionize scientific research, facilitating studies of coastal ecosystems, marine biology, and underwater archaeological exploration with its dual capability. In agricultural practices, the drone's capacity to traverse water bodies could assist in monitoring irrigation systems and assessing crop health across large farmlands.

Furthermore, "Aerogi" could play a significant role in disaster response, assessing flood-prone areas during natural calamities and providing real-time data for decision-making and disaster management. Its amphibious nature would make it invaluable in exploring flooded or submerged areas that conventional drones cannot access.

III. METHODOLOGY

1. **Conceptual Design:** The development of the Amphibious Tricopter Drone, "Aerogi," begins with the conceptual design phase. This phase involves extensive research and analysis to establish the key features and functionalities required for the drone's successful operation in air and water environments. Various design options and configurations will be considered, weighing their advantages and limitations to determine the most feasible and effective solution.

2. **Component Selection:** Based on the conceptual design, the next step involves selecting the appropriate components and materials for building "Aerogi." The choice of components will be crucial in determining the drone's performance, stability, and overall capabilities. The propulsion system, flight controller, communication modules, camera system, and tilting mechanism are vital components. Weight, power efficiency, and cost will be carefully considered during component selection.

3. **Tilting Mechanism Design and Fabrication:** One of the critical aspects of "Aerogi" is the tilting mechanism that enables the tricopter to transition between air and water modes. This mechanism must provide both yaw movement and forward thrust during flight and facilitate smooth water landings and surface navigation. Advanced 3D design software will be employed to create the tilting mechanism, which will undergo rigorous simulations to ensure stability and functionality. The final design will be fabricated using 3D printing or other suitable manufacturing methods.

4. **Propulsion System Optimization:** Efficient propulsion is crucial for the drone's performance, especially during transitions between air and water. The propulsion system will be optimized for sufficient lift and thrust while maintaining power efficiency. The selection of propellers, motors, and ESCs (Electronic Speed Controllers) will be based on performance parameters and the drone's weight constraints. Testing and iteration will be conducted to achieve the optimal propulsion system.

5. **Floating Landing Gear Design and Integration**: To ensure successful operations on water, a floating landing gear will be designed and integrated into "Aerogi." This gear should provide buoyancy and stability during water landings and surface movements. The choice of materials and design will be critical to achieving the desired floating properties without compromising the drone's overall weight and flight performance.

6. **Onboard Camera System:** A live video feed camera system will be integrated into "Aerogi" to provide real-time monitoring during flight operations. The camera should offer high-resolution imagery and stable transmission capabilities to the ground-based controller. Compatibility with the flight controller and communication modules will be ensured for seamless operation.

7. **Flight Controller Configuration:** The flight controller is the drone's brain, responsible for stabilizing and controlling its flight. Appropriate configurations and programming will be implemented to support the tilting mechanism and enable smooth transitions between air and water modes. Calibration and testing will be conducted to ensure accurate control and response during flight

8. **Testing and Evaluation:** Once the drone's assembly is complete, rigorous testing and evaluation procedures will be undertaken. These tests include hover tests, flight stability assessments, water landing trials, and transitional maneuvers between air and water. Data will be collected and analyzed to identify any issues or areas for improvement.

9. **Budget Management:** Strict adherence to the allocated budget of Rs. 20,000 will be maintained throughout the development process. Components, materials, and manufacturing process costs will be carefully monitored to ensure the project's financial viability.

10. **Safety and Regulation Compliance:** The safety of "Aerogi" and its compliance with relevant regulations will be paramount. Necessary safety measures will be implemented to prevent accidents and mishaps during flight. Additionally, compliance with local aviation and drone regulations will be ensured to enable legal and responsible operations.

Following the outlined methodology, the development of "Aerogi" will progress systematically, realizing an innovative amphibious tricopter drone with seamless operation in the air, on land, and on water surfaces. The developed CAD model and the real-time image of the drone are represented in Figure 1 (a) and (b), respectively.

(a)

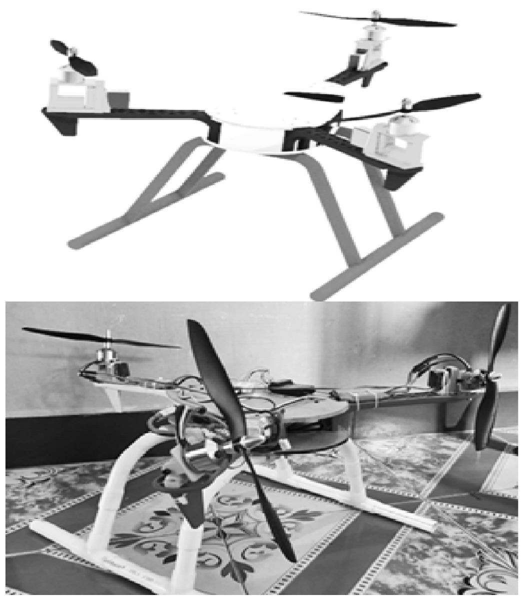

Figure 1. (a). CAD model (Isometric View) of Aerogi; (b). Real image of Aerogi

The subsequent chapter will present a comprehensive literature survey, highlighting relevant research and technologies in the field of UAVs and amphibious drones.

11. **Components used:** The A2212 1400KV brushless DC motors used in "Aerogi" are highly regarded for their performance and efficiency. With a KV rating of 1400, these motors generate 1400 revolutions per minute (RPM) for every volt of input voltage. This high RPM value ensures rapid and powerful rotations of the propellers, providing the drone with the necessary lift and stability during flight. The motor's maximum efficiency of 80% and a current capacity of 6-12A contribute to reduced power consumption and longer flight times.

The MG90S servo motors play a crucial role in "Aerogi's" tilting mechanism, enabling both yaw movement and forward thrust. Weighing just 13 grams, these lightweight servo motors are designed to operate on a voltage range of 4.8V to 6.6V. Their stall torque at 4.8V is 1.8 kg.cm, and at 6.6V, it increases to 2.2 kg.cm. This high torque capability ensures precise and responsive control of the tilting mechanism, allowing for quick and smooth directional changes during flight. The MG90S servos' sensitivity and accuracy make them essential components for achieving stable and controlled transitions between aerial and aquatic modes.

By carefully selecting these technical specifications for the A2212 1400KV brushless DC motors and MG90S servo motors, "Aerogi" benefits from enhanced propulsion and manoeuvrability, ensuring a reliable and dynamic performance in both air and water environments. These motors' efficiency and torque characteristics significantly impact the drone's flight dynamics and play a vital role in realizing the vision of an amphibious tricopter drone with seamless transitions and exceptional operational capabilities.

12. **Experimental results & discussions:** "Aerogi" underwent extensive flight testing to evaluate its stability, altitude performance, weight-carrying capacity, flight time, and robustness. During the flight tests, "Aerogi" demonstrated satisfactory stability during aerial flights, successfully taking off and executing basic flight maneuvers. However, achieving the maximum target altitude of 100 ft proved challenging due to inherent design limitations, resulting in conservative altitude restrictions during testing.

The drone met the weight constraints, with a total mass of 1.127 kg, including the battery. Additionally, "Aerogi" achieved the targeted payload capacity, supporting an additional 0.5 kg of weight without compromising flight performance.The LiPo 2200mAh battery, with a 40C/80C discharge rate, provided "Aerogi" with a flight time of approximately 11 minutes and 44 seconds, meeting the desired flight duration of 20 minutes.Fall tests were conducted from a height of 10 ft to assess its robustness. While "Aerogi" demonstrated durability, some components in the landing gear experienced minor damage.

Further design improvements may be necessary to enhance the drone's ruggedness for such situations.Although "Aerogi" was designed with provisions for a camera system, budget constraints limited the inclusion of an imaging device during the initial stages of development. The imaging feature remains a potential area for future enhancements and applications.The cost analysis indicated that the project remained within the allocated budget, with a total cost of approximately Rs. 17,000, encompassing components such as brushless motors, electronic speed controllers, flight controllers, transmitters, receivers, and other essential elements.The summary of the results is given in Table 1.

Table 1: Summarization of the Key Specification that Aerogi met or not

Specification	Target	Condition	Comments
Altitude	100ft		Not stable enough to attempt reaching the max height
Weight	<2kg	Met	It has a total weight of 1.4 Kg
Payload	0.5kg	Met	The Max Thrust capacity of 3.7 kg allows the Payload of 0.5 kg
Flight Time	20 minutes	Met	The LiPo 2200 mAh and 40c/80c battery allows a flight time 2 minutes
Fall Test	10 ft	Conditionally	Some of the parts in the Landing gear broken
Imaging	One camera		Due to Money constraints
Cost	< Rs. 20,000	Met	Total Cost approximately Rs. 19,000

The discrepancy between the measured flight time of 11 minutes and 44 seconds and the target flight time of 20 minutes can be attributed to several factors. During the development and testing phase, certain design limitations and operational inefficiencies were encountered, which impacted the overall flight duration, as reported in the literature [7–9]. The propulsion system and power distribution, along with the energy consumption of the various components, may not have been fully optimized to achieve the desired flight time. Additionally, external conditions such as wind speed and air temperature could have affected "Aerogi's" energy efficiency during flight. Similar phenomenon was reported by Beigi et al. [10]. Furthermore, the weight and payload capacity of the drone may have slightly compromised the flight time, as a heavier load can result in increased power consumption, which is in line with the results of Villa et al. [11]. Future iterations and enhancements in the drone's design and propulsion system, along with advanced battery technologies, may address these factors and contribute to achieving closer alignment with the target flight time.

IV. CONCLUSION

In conclusion, "Aerogi," the Amphibious Tricopter Drone, emerges as a pioneering advancement in UAV technology with its unique ability to seamlessly operate in both air and water environments. This innovative drone holds tremendous potential for various practical applications and areas of exploration. In environmental monitoring, "Aerogi" could revolutionize marine life observation and assess water pollution levels. Search and rescue missions would be bolstered with its swift navigation over water bodies. Additionally, the drone's capacity for underwater exploration opens avenues for marine biology research and underwater archeological surveys. In agriculture, "Aerogi" could aid in monitoring irrigation systems and crop health across vast farmlands. Disaster response could also benefit from "Aerogi's" ability to assess flood-prone areas and access submerged regions. With these capabilities, "Aerogi" holds promise in transforming aerial and aquatic exploration, making it a trailblazer in the realm of unmanned systems.

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