INTERNATIONAL JOURNAL OF
RECENT TRENDS IN MULTIDISCIPLINARY RESEARCH
https://www.doi.org/10.59256/ijrtmr.20260603025
May-June 2026, Vol 6 (03), 209-217. ISSN No: 2583-0368

Remote Controlled Unmanned Ground and Aerial Vehicle (UGAV) for Waste Disposal

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OPEN ACCESS
Article Citation:
Chandana R[1], Nagashree M[2], Nishanth S[3], Ramya K[4]," Remote Controlled Unmanned Ground and Aerial Vehicle (UGAV) for Waste Disposal", International Journal of Recent Trends in Multidisciplinary Research, May-June 2026, Vol 6(03), 209-217.

Abstract: The rapid expansion of urban environments and the increasing demand for automated cleaning solutions highlight the operational limitations of existing robotic vacuum systems, which are largely constrained to planar surfaces and require manual intervention for waste disposal. This study proposes a remote-controlled hybrid unmanned ground and aerial vehicle (UGAV) designed to perform integrated waste collection and disposal through dual-mode mobility. The system employs a wheeled ground platform equipped with a vacuum suction mechanism to collect debris and store it in an onboard container, followed by a controlled transition to an aerial operation for transporting and releasing the collected waste at a predefined disposal location. A unified control architecture governs locomotion, actuation, power allocation, and safety constraints to ensure stable operation during the ground and flight phases. The design emphasizes energy efficiency by favoring terrestrial movement for routine cleaning tasks while reserving aerial operations exclusively for disposal requirements. Experimental trials confirmed reliable waste collection, smooth mode transitions, and consistent aerial disposal behavior under varying operational conditions. By combining surface cleaning and airborne waste handling within a single robotic framework, the proposed UGAV reduces human involvement, enhances safety, and extends the functional coverage beyond that of conventional cleaning robots. The system demonstrates a strong potential for deployment in smart homes, industrial facilities, and public infrastructure as a scalable and intelligent waste management solution.

Key Words: Unmanned Ground and Aerial Vehicle (UGAV), Hybrid Robot, Vacuum Cleaning, Aerial Waste Disposal, Robotics, Automation.

1. Introduction

Robotics and automation technologies are becoming increasingly important in modern society for improving efficiency, safety, and operational performance in various applications. Waste management is one of the major challenges faced in urban areas, industries, railway stations, hospitals, and disaster-affected environments. Proper waste collection and disposal are essential for maintaining cleanliness, preventing environmental pollution, and reducing health risks. Traditional cleaning and waste disposal methods mainly depend on manual labor, which is time-consuming, labor-intensive, and unsafe in hazardous or hard-to-reach areas.

Improper waste disposal can lead to environmental contamination, spread of harmful diseases, and unhealthy surroundings. In many locations such as uneven terrains, staircases, drainage systems, and industrial zones, manual cleaning becomes difficult and risky for sanitation workers. Existing robotic vacuum cleaners are mainly designed for flat indoor surfaces and are unable to operate efficiently on rough terrains or across obstacles. Similarly, drones are capable of aerial navigation and surveillance but cannot perform continuous ground cleaning operations due to limited payload capacity and high-power consumption.

Recent advancements in robotics, embedded systems, and unmanned vehicle technologies have enabled the development of intelligent hybrid systems capable of performing multiple operations efficiently. Unmanned Aerial Vehicles (UAVs) and Unmanned Ground Vehicles (UGVs) are widely used in military, surveillance, agricultural, industrial, and disaster management applications. By integrating both aerial and ground mobility into a single platform, the system can achieve better flexibility, obstacle handling capability, and improved operational efficiency.

Flight controllers, BLDC motors, Electronic Speed Controllers (ESCs), GPS modules, IMU sensors, and wireless communication systems are commonly used in modern unmanned vehicle technologies for stable navigation and control. DC gear motors and wheeled mechanisms provide energy-efficient ground movement, while aerial operation helps the system overcome stairs, gaps, and difficult terrains. Vacuum cleaner modules can also be integrated into robotic systems for automatic dust and waste collection during operation.

The proposed Remote Controlled Unmanned Ground and Aerial Vehicle (UGAV) for Waste Disposal integrates aerial mobility, ground mobility, and vacuum-cleaning mechanisms into a single intelligent platform. The developed system consists of a quadrotor frame mounted on a wheeled rover structure integrated with a vacuum cleaner setup. During operation, the vehicle performs waste collection while moving on the ground and switches to aerial mode whenever obstacles or uneven terrains are encountered. The collected waste is stored in a dust collection container for proper disposal. The main objective of the proposed system is to develop a low-cost, energy-efficient, and intelligent waste disposal system capable of reducing human involvement in hazardous cleaning operations. The proposed UGAV improves cleaning flexibility, obstacle navigation capability, and operational efficiency while supporting modern smart sanitation and automated waste management applications.

2. Problem statement

The rapid increase in urbanization and industrial activities has created a major challenge in efficient waste collection and disposal. Conventional cleaning and waste management methods mainly depend on manual labor, which exposes sanitation workers to hazardous waste, polluted environments, and unhealthy working conditions. In many areas such as industrial zones, railway tracks, drainage systems, staircases, and disaster-affected locations, manual cleaning becomes difficult, unsafe, and time-consuming. Existing cleaning systems are often unable to operate effectively in uneven terrains, narrow spaces, or obstacle-filled environments.

Traditional robotic vacuum cleaners are mainly designed for flat indoor surfaces and cannot move across stairs, rough terrains, or elevated regions. Similarly, drones are capable of aerial movement and surveillance but are not suitable for continuous ground cleaning operations due to high battery consumption and limited payload capacity. Separate UAV and UGV systems increase operational complexity, maintenance cost, and power requirements. Most existing systems also require continuous human supervision and lack efficient integration between aerial mobility, ground mobility, and waste collection mechanisms.

Improper waste management can lead to environmental pollution, spread of harmful diseases, and unsafe surroundings. In hazardous environments, direct human involvement in waste collection may create serious health risks. In addition, existing systems often lack real-time remote operation, intelligent navigation, efficient obstacle handling, and energy optimization capabilities. These limitations reduce cleaning efficiency and increase operational expenses in large-scale sanitation applications.

Although recent developments in robotics, automation, and embedded systems have enabled the growth of smart cleaning technologies, many existing waste disposal systems still suffer from limitations such as low mobility, short operational time, and poor adaptability to complex environments. Most systems are designed either for ground operation or aerial operation individually and fail to provide a complete hybrid solution for efficient cleaning and waste disposal.

Therefore, there is a need to develop an efficient, low-cost, and remotely operated Unmanned Ground and Aerial Vehicle (UGAV) capable of performing both ground cleaning and aerial navigation in a single integrated platform. The proposed system aims to overcome the limitations of conventional cleaning systems by combining UAV and UGV functionalities along with a vacuum cleaning mechanism for efficient waste collection and disposal in hazardous and hard-to-reach environments.

3. Proposed System

Traditional waste disposal systems mainly depend on manual labor and conventional cleaning machines, which are time-consuming, labor-intensive, and inefficient in hazardous or hard-to-reach environments. Existing robotic vacuum cleaners are limited to flat surfaces and cannot move across stairs, uneven terrains, or obstacles. Similarly, drones can perform aerial navigation but are not suitable for continuous ground cleaning operations due to high power consumption and limited cleaning capability. There is a need for a hybrid system capable of performing both aerial and ground operations efficiently for smart waste management applications.

The proposed Remote Controlled Unmanned Ground and Aerial Vehicle (UGAV) for Waste Disposal combines UAV and UGV functionalities into a single integrated platform. The system consists of a quadrotor drone mounted on a wheeled rover structure integrated with a vacuum cleaner mechanism for waste collection. The vehicle performs cleaning while moving on the ground and switches to aerial mode whenever obstacles or difficult terrains are encountered. The proposed system reduces human effort, improves mobility, and provides an efficient solution for waste disposal in hazardous and inaccessible environment.

4. Objective

- To design and development of robot with Flying (Drone), Driving (Rover) and Sucking (Vacuum cleaner) applications.
- To design and development of robot for picking and dropping dust and minute particles to the desired location.
- To make robot light weight as much as possible to help in flying.
- To control the activities through remote from distant places.

5. Literature Survey

Due to the rapid advancement of robotics, automation, unmanned vehicle technologies, and intelligent cleaning systems, several researchers have developed hybrid UAV–UGV platforms for surveillance, transportation, obstacle navigation, and autonomous mobility applications. These systems improve operational flexibility, mobility, and efficiency by integrating aerial and ground locomotion into a single robotic platform.

K. Wu et al. [1] proposed a full coverage path planning strategy for robotic cleaning systems operating in static semi-structured environments. Their study focused on improving navigation efficiency and cleaning coverage for autonomous robotic vacuum cleaners. The proposed method reduced redundant movement and improved surface cleaning performance; however, the system was limited to ground-based operation only.

I. Munasinghe et al. [2] presented a comprehensive review of UAV–UGV collaborative systems and discussed recent advancements, coordination techniques, and operational challenges. The study highlighted the benefits of combining aerial and terrestrial robots for complex tasks such as inspection, transportation, and environmental monitoring. However, issues related to synchronization, communication reliability, and energy consumption were identified as major limitations.

D. D. Sharma and J. Lin [3] developed a secure learning-based coordinated UAV–UGV framework for medical waste transportation. Their work demonstrated efficient communication and transportation of hazardous waste materials using coordinated robotic systems. Although the framework improved transportation efficiency, it required separate UAV and UGV platforms, increasing system complexity and operational cost.

Aizelman et al. [4] designed a quadrotor integrated with wheels to achieve both flying and rolling mobility. Experimental evaluation showed improved obstacle traversal capability and enhanced manoeuvrability across different terrains.

Similarly, D. Zhang et al. [5] introduced an autonomous quadrotor tilting hybrid robot capable of seamless transition between terrestrial and aerial locomotion. Their work demonstrated improved flexibility in navigating complex environments.

Z. Ren et al. [6] reviewed the integration of UAV–UGV collaborative systems in smart agriculture and emphasized the importance of intelligent coordination, energy management, and autonomous navigation in hybrid robotic platforms. The study concluded that hybrid robotic systems have significant potential for future smart applications.

The Roller-Quadrotor system [7] demonstrated a hybrid aerial and terrestrial quadrotor mechanism using rotor-assisted turning and rolling movement. The system improved energy efficiency by reducing flight duration during ground navigation tasks.

D. Wang et al. [8] proposed a robust cooperative positioning algorithm for UAV–UGV systems using object detection techniques to improve localization accuracy during cooperative operations.

M. Koshy et al. [9] designed and tested a hybrid locomotion robot integrating quadrotor and quadruped concepts. Their study demonstrated improved mobility over uneven terrains and highlighted the advantages of combining multiple locomotion mechanisms within a single robotic platform.

N. Meiri and D. Zarrouk [10] proposed the Flying STAR robot, a hybrid crawling and flying robotic system designed for enhanced mobility in difficult environments. The system successfully combined aerial and crawling movements to improve accessibility and adaptability.

S. Sabet et al. [11] introduced the Rollocopter, an energy-aware hybrid aerial-ground robotic system developed for extreme terrains. Their work emphasized minimizing power consumption by prioritizing rolling movement over continuous flight operations.

The UAV–UGV Cooperative 3D Environmental Mapping system [12] demonstrated collaborative mapping using aerial and ground robots to improve environmental awareness and navigation efficiency in complex environments.

Kalantari and M. Spenko [13] developed the HyTAQ hybrid terrestrial and aerial quadrotor system capable of both rolling and flying operations. Their research demonstrated stable transitions between locomotion modes and efficient obstacle traversal, which significantly influenced the development of modern hybrid robotic platforms.

Although several hybrid UAV–UGV systems have been developed, many existing systems still suffer from limitations such as lack of integrated waste collection mechanisms, higher power consumption, limited obstacle handling capability, and absence of efficient cleaning systems. Therefore, the proposed Remote Controlled Unmanned Ground and Aerial Vehicle (UGAV) for Waste Disposal aims to overcome these limitations by integrating aerial mobility, ground mobility, vacuum cleaning mechanisms, and intelligent remote-control operation into a single efficient hybrid platform.

6. Methodology

The proposed Remote Controlled Unmanned Ground and Aerial Vehicle (UGAV) for Waste Disposal follows a systematic methodology for performing ground cleaning, waste collection, obstacle navigation, and aerial waste disposal using a hybrid robotic platform. The system combines both unmanned ground vehicle (UGV) and unmanned aerial vehicle (UAV) functionalities into a single compact robot capable of operating in hazardous and hard-to-reach environments. The methodology integrates sensors, flight control systems, motor drivers, propulsion systems, and vacuum-based waste collection mechanisms for efficient cleaning and waste management operations.

The methodology begins with system initialization and power distribution. A Li-Po battery supplies power to the entire UGAV system through a power distribution board and voltage regulator circuits. The flight controller acts as the central processing and control unit responsible for coordinating both aerial and ground operations. Initially, the remote controller establishes wireless communication with the flight controller to provide movement commands and operational control.

The input section of the system consists of different sensing and navigation modules. The GPS module provides location and navigation information for aerial movement and directional control. The IMU sensor continuously monitors orientation, stability, acceleration, and angular motion of the vehicle during both driving and flying operations. The ultrasonic sensor detects nearby obstacles and helps in safe navigation during ground movement. These sensors continuously transmit real- time data to the flight controller for processing and decision-making operations.

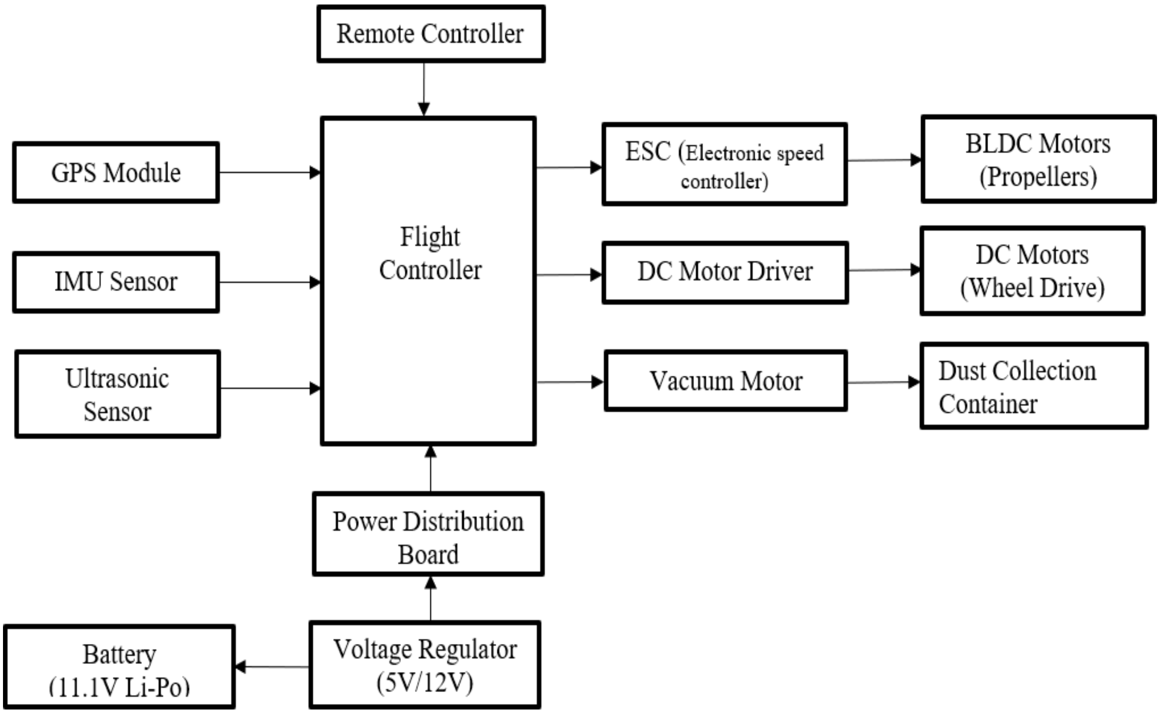

Figure 1: Block Diagram of Remote Controlled UGAV for Waste Disposal

Figure 1 illustrates the structural block diagram of the proposed UGAV system. The architecture is centered around a Pixhawk flight controller, which controls both aerial and terrestrial movement mechanisms. The remote controller provides navigation commands to the flight controller. Sensor modules such as GPS, IMU, and ultrasonic sensors continuously provide navigation, stability, and obstacle detection information. Based on processed sensor data and user commands, the flight controller controls the ESC modules connected to BLDC motors for aerial propulsion and the L298N motor driver connected to DC motors for wheel-based ground movement. The vacuum motor and dust collection container are integrated for cleaning and waste storage operations.

The proposed methodology mainly operates in two modes: ground mode and aerial mode. During ground mode, the DC motors drive the wheels for movement while the vacuum motor collects dust and lightweight waste materials from the surface. The collected waste is stored inside the dust collection container mounted on the vehicle. Ground mode is mainly used for energy-efficient cleaning operations on flat surfaces and indoor or outdoor environments.

Whenever obstacles such as stairs, uneven terrain, pits, or inaccessible regions are encountered, the system switches to aerial mode. In aerial operation, the flight controller activates the ESC modules and BLDC motors to generate lift and enable drone flight. The UGAV can then fly over obstacles and reach disposal locations safely. After reaching the required location, the collected waste can be disposed manually or through a release mechanism depending on operational requirements.

Figure 2 illustrates the operational workflow of the proposed UGAV system. Initially, the system powers ON and initializes all sensors, motor drivers, and control modules. The UGAV first operates in ground mode, where wheel motors and the vacuum cleaner perform waste collection. The collected waste is continuously stored inside the dust container while monitoring the bin level. If the waste bin is not full, the system continues cleaning operations. Once the dust bin becomes full or obstacle conditions are detected, the system switches to aerial mode. The drone mechanism then flies toward the disposal location, releases the collected waste, and safely returns to the base position for the next cleaning operation.

The developed methodology improves cleaning efficiency, reduces manual labor, and enhances operational safety in hazardous or difficult-to-access environments. The integration of flying, driving, and vacuum-cleaning mechanisms into a single robotic platform makes the proposed UGAV system suitable for smart sanitation, industrial cleaning, disaster management, and intelligent waste disposal applications.

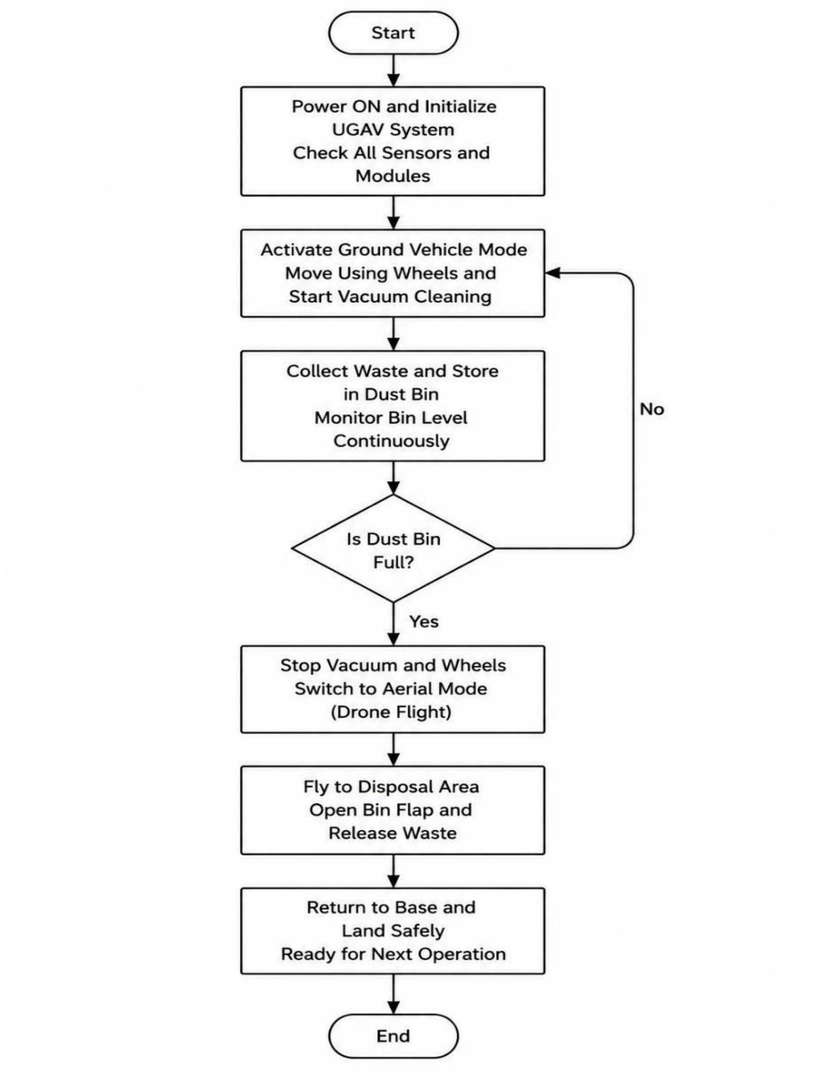

Figure 2: Flowchart of Remote Controlled UGAV for Waste Disposal

7. System Architecture

The proposed Remote Controlled Unmanned Ground and Aerial Vehicle (UGAV) for Waste Disposal is designed as an integrated hybrid robotic architecture that combines aerial mobility, ground mobility, vacuum cleaning, wireless communication, sensor monitoring, and remote-control operation into a single intelligent platform. The developed architecture enables efficient waste collection, obstacle navigation, and remote-controlled operation in hazardous and hard- to-reach environments.

The overall system architecture is centered around the flight controller, which acts as the main processing and control unit of the system. Multiple components such as BLDC motors, Electronic Speed Controllers (ESCs), DC gear motors, GPS module, IMU sensor, ultrasonic sensor, vacuum cleaner module, transmitter-receiver communication system, and Li-Po battery are connected to the flight controller for coordinated operation. These components continuously work together to provide stable aerial movement, ground navigation, obstacle detection, and cleaning functionality.

The BLDC motors connected through ESCs are responsible for aerial movement and stable flight operation of the drone section. The DC gear motors drive the wheeled rover mechanism for ground movement and energy-efficient cleaning operation. The flight controller continuously manages aerial stability, motor speed control, navigation, and transition between flying and driving modes during operation. The GPS module and IMU sensor are used for navigation, orientation sensing, and maintaining system stability during both aerial and ground movement. The ultrasonic sensor continuously detects nearby obstacles and assists in safe navigation. Whenever obstacles such as stairs, uneven terrains, or barriers are detected, the system can switch from ground mode to aerial mode for obstacle crossing and improved accessibility.

The vacuum cleaner module is integrated with the rover platform for automatic dust and waste collection during ground movement. The vacuum motor sucks dust and small waste particles into the dust collection chamber provided inside the system. The collected waste is stored safely until disposal at the required location. The vacuum cleaner setup operates simultaneously during rover movement for efficient cleaning performance.

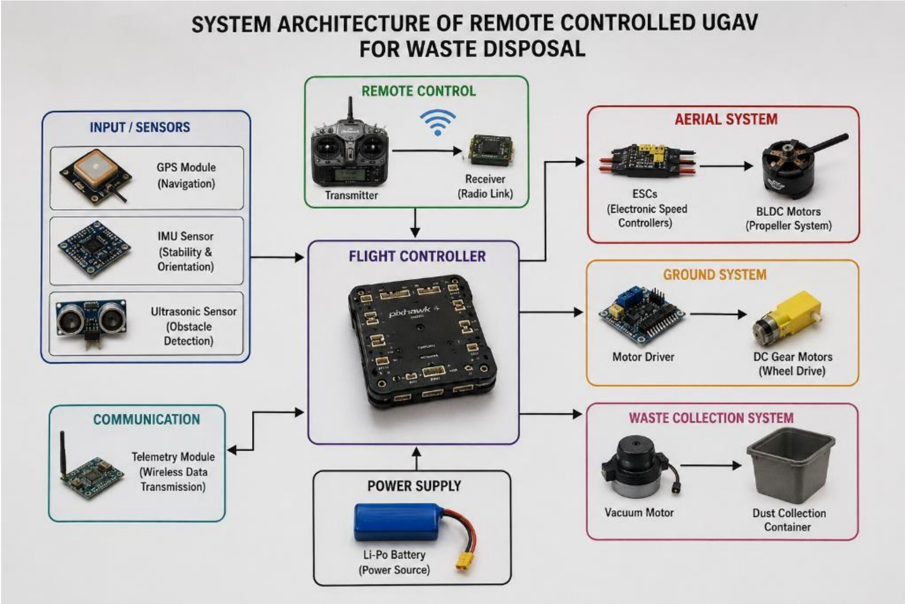

Figure 3: System Architecture of Remote Controlled UGAV for Waste Disposal

The transmitter and receiver communication modules enable wireless remote-control operation of the UGAV system. The operator can remotely control aerial navigation, ground movement, cleaning operations, and waste disposal activities from distant locations. The Li-Po battery acts as the primary power source for all electrical and electronic components integrated within the system.

The proposed architecture follows a hybrid operational mechanism in which the system performs energy-efficient cleaning during ground operation and activates aerial mode only when required. This approach helps reduce overall power consumption while improving mobility and cleaning coverage. The integration of aerial mobility, ground locomotion, sensor technologies, wireless communication, and vacuum-cleaning mechanisms make the proposed architecture suitable for smart waste management, industrial sanitation, railway cleaning, disaster management, and modern automated cleaning applications.

8. Results and Discussions

The proposed Remote-Controlled Unmanned Ground and Aerial Vehicle (UGAV) was successfully designed, developed, and tested under different operating conditions. The system effectively performed ground movement, aerial navigation, and vacuum-based waste collection through remote operation. Experimental testing confirmed stable operation during both ground and aerial modes.


Figure 4: Side View of Unmanned Ground and Aerial Vehicle

The prototype successfully collected dust and lightweight waste particles while moving on flat and moderately uneven surfaces. The integrated vacuum-cleaning mechanism stored the collected waste efficiently in the onboard dust chamber without affecting vehicle stability. During testing, approximately 190 g of waste material was collected within 30 minutes operation, demonstrating effective cleaning performance.

Figure 5: Top View of Unmanned Ground and Aerial vehicle

Figure 6: Cleaning Efficiency vs Time

Figure 3 Shows the Battery performance analysis showed that aerial mode consumed more power compared to ground mode because of the additional energy required for flight and stabilization. In ground mode, the battery retained nearly 80% capacity after 10 minutes of operation, whereas aerial mode reduced to approximately 43% during the same duration. The results indicate that ground operation is more energy efficient for continuous cleaning tasks.

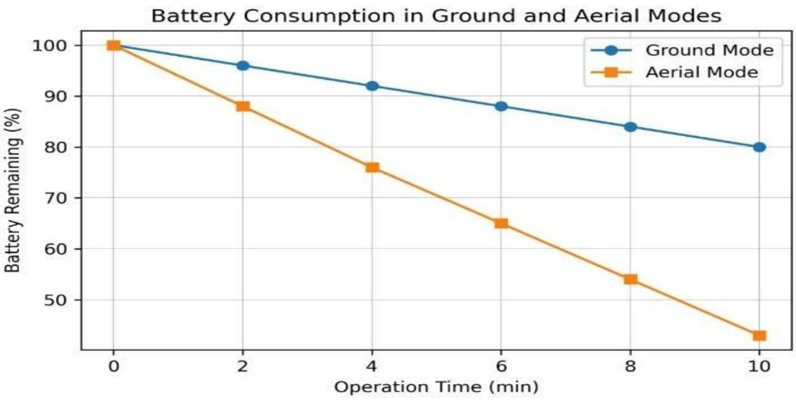

Figure 7: Battery Consumption in Ground and Aerial Modes

The Figure 4 shows Altitude stability testing confirmed reliable aerial performance during waste transportation and disposal operations. The UGAV maintained stable hovering near the target altitude of 1.5 m with only minor variations during operation. The flight controller provided smooth stabilization and controlled manoeuvrability throughout the testing process.

9. Advantages

The proposed Remote Controlled UGAV for Waste Disposal offers several advantages compared to conventional waste collection systems. The integration of aerial and ground mobility improves operational flexibility, navigation efficiency, and waste handling performance in hazardous and hard-to-reach environments.

• Hybrid ground and aerial mobility for efficient navigation

• Reduces human exposure to hazardous and contaminated waste
• Capable of operating in uneven and inaccessible areas
• Remote-controlled operation with real-time monitoring
• Energy-efficient waste collection during ground movement
• Improved obstacle avoidance and terrain adaptability
• Low-cost and compact system design for smart sanitation applications

10. Application

The proposed Remote Controlled UGAV for Waste Disposal provides several applications in smart sanitation, hazardous waste handling, and autonomous cleaning operations. The hybrid aerial-ground mobility and remote-control architecture improve operational safety, accessibility, and waste management efficiency in complex environments.
• Waste collection in hazardous and contaminated areas
• Cleaning and monitoring in hard-to-reach environments
• Smart sanitation applications in urban areas
• Remote waste disposal in industrial zones and factories
• Surveillance and inspection during waste management operations
• Autonomous navigation in uneven or obstacle-filled terrains
• Low-cost intelligent cleaning and disposal system for smart cities

11. Future Scope

The future scope of the Remote Controlled UGAV for Waste Disposal is highly promising in the field of smart sanitation, robotics, and autonomous waste management systems. The proposed system can be further enhanced by integrating artificial intelligence and machine learning algorithms for autonomous navigation, intelligent obstacle avoidance, and automated waste detection. Advanced computer vision techniques and object recognition systems can improve the accuracy of waste identification and collection in complex environments. Cloud-based monitoring and IoT communication can also be integrated for real-time tracking, remote supervision, and data analysis of waste management operations. The project can be expanded by incorporating GPS-based autonomous path planning and advanced wireless communication technologies such as LoRa, 5G, and MAVLink for long-range operation and reliable control. Solar-powered charging systems and high- capacity batteries can improve energy efficiency and operational time. Additional environmental sensors for gas detection, temperature monitoring, and hazardous material identification can be integrated for safer operation in industrial and contaminated areas. In the future, the UGAV system can also be implemented in smart cities, disaster management, military surveillance, and automated cleaning applications to reduce human effort and improve operational safety and efficiency.

12. Conclusion

The proposed Remote Controlled Unmanned Ground and Aerial Vehicle (UGAV) for Waste Disposal was successfully developed for smart cleaning and waste management applications. The system integrated aerial mobility, ground mobility, vacuum cleaning mechanisms, wireless communication, and sensor technologies into a single intelligent platform for efficient waste collection and disposal operations.

The developed prototype successfully performed both ground movement and aerial navigation using DC motors, BLDC motors, ESCs, and flight controller systems. The integrated vacuum cleaner module effectively collected dust and small waste particles during ground operation, while the aerial mode enabled the vehicle to overcome obstacles and access hard- to-reach areas. The GPS, IMU, and ultrasonic sensors provided stable navigation, obstacle detection, and improved operational control during system operation.

The proposed system reduced human effort and improved cleaning flexibility in hazardous and inaccessible environments. The hybrid operational mechanism helped minimize power consumption by using ground movement for normal cleaning operations and activating aerial mode only when necessary. The remote-control communication system enabled smooth wireless operation and monitoring of the UGAV platform. The developed system operated efficiently without major instability during aerial and ground transitions. The integration of hybrid mobility, intelligent cleaning mechanisms, and remote-control technologies makes the proposed UGAV suitable for smart sanitation systems, industrial cleaning, disaster management, and modern automated waste disposal applications.

Thus, it can be concluded that the developed Remote Controlled UGAV for Waste Disposal provides a low-cost, reliable, and efficient solution for intelligent waste collection and automated cleaning operations while supporting the advancement of smart robotics and modern waste management technologies.

Acknowledgement

We express our sincere gratitude to the Department of Electronics and Communication Engineering, BGS Institute of Technology, for providing an opportunity to carry out this project successfully. We would like to thank our project guide and faculty members for their valuable guidance, support, and encouragement throughout the project work. We also thank our friends and family members for their continuous support and motivation. We also express our appreciation to the laboratory staff and technical members who provided necessary facilities and resources for completing the implementation and verification process. Their support and assistance played an important role in the successful completion of this project work.

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