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Design and Manufacturing of Flying & Rolling Drone (Morphobot) for Search and Rescue Applications

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ABSTRACT

Search and Rescue (SAR) operations in disaster zones demand robust, multifunctional robotic platforms capable of navigating complex terrains. This paper presents the design and development of a multimodal drone prototype, termed *Morphobot*, which integrates aerial and ground mobility. The system employs 930 KV BLDC flight motors, 5010 360 KV wheel motors, servo actuators, and modular 3D-printed components to achieve hybrid locomotion. Control is achieved using a Radiolink Crossflight controller paired with a FlySky FS-i6 transmitter, ensuring reliable communication and multimodal channel mapping. Morphobot demonstrates smooth transitions between flight and rolling modes, enhancing adaptability in unstable environments. The prototype emphasizes cost-effective manufacturing using PLA and acrylic materials, while ensuring modularity and mechanical strength. Engineering calculations validate thrust requirements, payload capacity, and battery endurance using a 11.1 V, 5200 mAh LiPo battery.

Keywords: Morphobot, SAR Robotics, Hybrid Drone, Multimodal Locomotion, Autonomous Navigation, PLA Prototyping.

1. INTRODUCTION

In the evolving field of robotics, there is a growing demand for multi-purpose platforms capable of operating across diverse environments. Traditional robotic systems often struggle in complex and dynamic disaster scenarios, limiting their effectiveness. To address this gap, multimodal robots have emerged as promising solutions, combining aerial and ground mobility to enhance flexibility, resilience, and mission capability.

Morphobot is a hybrid robotic platform designed to meet these challenges. It integrates quadcopter-based flight with modular ground mobility, enabling rapid transitions between modes. This dual functionality expands applicability in search and rescue (SAR), environmental monitoring, military training, and off-road exploration. The design emphasizes mechanical modularity, lightweight structural materials, and intelligent control systems. Key components include a laser-cut acrylic chassis, detachable PLA rotor arms, adaptive terrain legs, and a Radiolink Crossflight controller with telemetry support. By incorporating servos and modular mechanisms, Morphobot can dynamically adapt its structure in real time, ensuring operational efficiency in unpredictable environments.

Problem Statement

Traditional SAR methods are slow, dangerous, and sometimes inadequate, especially in complex and hostile environments. Rescue teams face a variety of challenges.

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- Time sensitivity: The potential for lifesaving windows are often narrow and require rapid use of rescue teams.
- Environmental factors: Extreme weather conditions such as heat, cold, smoke, and flooding interfere with effective rescue operations.
- The goal is to manage these challenges through the development of flexible multimodal robots that operate autonomously in these challenging environments. Morphobot aims to meet this need with a design focused on mobility, sensory skills and simple control.

Objective

The main objective of this project is to design and manufacture a hybrid flying and rolling drone (Morphobot) for Search and Rescue (SAR) missions. The aim is to reduce human risk, improve efficiency, and provide a cost-effective robotic solution.

Specific Objectives:

1. Reduce human effort and risk in disaster zones.
2. Enable hybrid mobility with flight and rolling modes.
3. Achieve autonomous navigation with obstacle avoidance.
4. Provide modular and cost-effective design for rapid prototyping.
5. Ensure adequate payload capacity for SAR equipment.
6. Optimize energy efficiency with 11.1 V, 5200 mAh LiPo battery.
7. Enable real-time data collection and telemetry support.
8. Support scalability for AI integration and swarm deployment.

2. DESIGN METHODOLOGY

Chassis Design

The chassis is fabricated using 5 mm acrylic sheets reinforced with 3D-printed PLA supports. Acrylic provides rigidity and impact resistance, while PLA ensures lightweight modularity. The design allows easy replacement of damaged parts and supports integration of both aerial and ground subsystems. The chassis also incorporates mounting slots for motors, servos, and electronics, ensuring compactness and balanced weight distribution.

Rotor Arms

PLA ribbed detachable arms are designed to withstand torque loads during flight. Their modular sockets allow quick assembly and disassembly, which is crucial for field maintenance. The ribbed structure reduces vibration and improves lift vector control. Each arm is designed with aerodynamic shaping to minimize drag and enhance stability during flight. (Fig. 3 illustrates the rotor arm assembly.)

Wheel System

The wheel system consists of 3D-printed rims combined with high-grip rubber tires. Wheels are mounted on shafts using fixed hub connections with secure fasteners, ensuring torque transfer and stability. This design enables Morphobot to handle uneven terrain and slopes while maintaining balance. The wheel geometry is optimized for traction, allowing efficient rolling even on rough surfaces.

Motor Selection

- Flight Motors: 930 KV BLDC motors provide high RPM and efficient thrust generation, ensuring stable lift and maneuverability.

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- Wheel Motors: 5010 360 KV BLDC motors deliver high torque for slope climbing and ground stability. The combination ensures balanced performance in both aerial and rolling modes. Motor placement is carefully chosen to maintain center of gravity and reduce mechanical stress.

Flight Controller

The Radiolink Crossflight controller paired with a FlySky FS-i6 transmitter provides multimodal channel mapping, GPS support, and failsafe features. It ensures smooth transitions between flight and rolling modes and allows telemetry monitoring for real-time feedback. The controller also supports programmable modes, enabling autonomous navigation and obstacle avoidance.

Power System

ESCs and a Power Distribution Board regulate energy flow from the 11.1 V, 5200 mAh LiPo battery. The system ensures stable operation, efficient distribution to motors and servos, and protection against overload. The modular battery bay supports hot-swap capability for extended missions. Voltage regulation circuits are included to protect sensitive electronics from fluctuations.

Servo & Actuator Joints

High-torque servo motors rated at 25 kg, 0.13 s/60° at 6.8 V are employed to control the lifting and lowering of the rotor arms. These servos are mounted within PLA armatures and directly drive the linear actuators that reposition the rotors. By raising the rotor arms during flight mode and lowering them for rolling mode, the servos enable Morphobot to dynamically switch between aerial and ground mobility.

The integration of linear actuators ensures smooth and precise vertical movement of the rotor assemblies, reducing mechanical stress during transitions. This mechanism allows the drone to maintain stability while adapting to different terrains and mission requirements. The servo response time provides rapid actuation, while the actuator system guarantees controlled motion, making the hybrid transformation reliable and repeatable.

Electronics Bay

A PLA snap-fit modular enclosure houses the controller, ESCs, and telemetry modules. The removable tray design supports easy upgrades and maintenance. The bay is designed to protect sensitive electronics from vibration, dust, and minor impacts, ensuring reliability in harsh environments. Cooling slots are incorporated to prevent overheating during extended missions.

Hybrid Linkage Assembly Mechanism

Morphobot employs a hybrid linkage assembly that integrates rotary and linear motion transfer for terrain adaptation. This mechanism connects the wheel system and rotor arms through gears, joints, and support frames, enabling smooth conversion between flight and rolling modes. The design ensures structural stability and efficient load transfer. The linkage also minimizes mechanical stress during transitions, improving durability.

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Battery Endurance Calculations

Battery endurance is calculated using the formula:

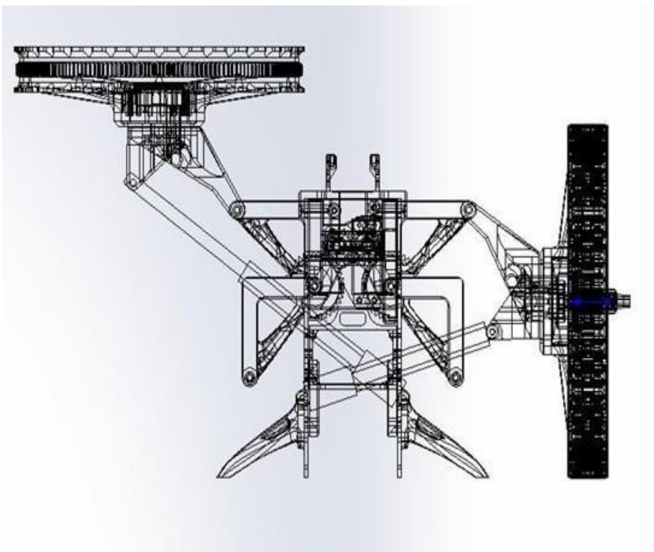
$$\text{Endurance (min)} = \frac{\text{Battery Capacity (mAh)}}{\text{Current Draw (mA)}} \times 60$$

For a 5200 mAh LiPo battery with an average current draw of 27 A (27,000 mA):

$$\text{Endurance} = \frac{5200}{27000} \times 60 \approx 11.5 \text{ minutes}$$

This validates the operational time per pack, with scalability possible through hot-swap battery modules. Future improvements may include higher-capacity batteries or dual-pack configurations to extend mission duration.

Fig.1 view of Morphobot



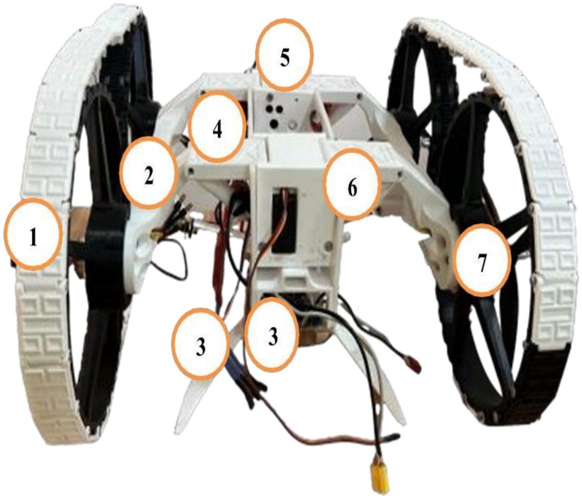


Fig.2 Labelled Assembly of Morphobot

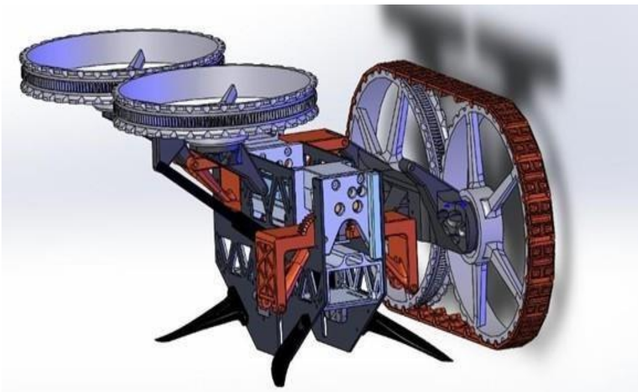


Fig. 3 3D model Assembly of Morphobot

Table 1. COmparative Study

Parameter	Traditional SAR Robots	Morphobot Innovation
Mobility	Single mode (flight or ground)	Dual mode (flight + rolling)
Chassis Material	CNC aluminum / ABS	Acrylic + PLA modular supports
Rotor Arms	Fixed carbon fiber	Detachable PLA arms
Wheels	Fixed rubber/pneumatic	3D-printed rims + high-grip tires
Controller	Basic flight control	Radiolink Crossflight multimodal
Payload Capacity	~1–2 kg	~2.5 kg
Battery Endurance	10–15 min	~11.5 min per pack (hot-swap capable)
Cost	High	Cost-effective prototyping

3. CONCLUSION

Morphobot demonstrates the feasibility of a hybrid aerial-ground robotic platform for Search and Rescue missions. Its modular design, combining rotor arms, wheel systems, servo-actuator mechanisms, and a compact electronics bay, enables seamless transitions between flight and rolling modes.

Tests validated stable aerial-ground mobility, slope climbing up to 30°, payload capacity of ~2.5 kg, and battery endurance of ~11.5 minutes per pack. While endurance remains a

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limitation, the architecture supports upgrades such as higher-capacity batteries and autonomous navigation.

In summary, Morphobot offers a cost-effective, adaptable, and reliable solution for disaster robotics, bridging the gap between drones and ground robots.

4. REFERENCES

1. Han, D., Shin, J., & Park, J., *"A novel hybrid ground–aerial robot capable of seamless transition between walking and flying,"* Robotics and Autonomous Systems, vol. 132, p. 103593, 2020.
2. Kalantari, A., & Spenko, M., *"Design and experimental validation of a hybrid aerial–ground robot,"* IEEE Transactions on Robotics, vol. 35, no. 6, pp. 1397–1411, 2019.
3. Beul, M., Droeschel, D., Houben, S., Holz, D., & Behnke, S., *"A high-performance semantic segmentation architecture for aerial and ground mobile robots,"* Journal of Field Robotics, vol. 34, no. 7, pp. 1240–1260, 2017.
4. Guo, J., & Ma, H., *"Design of a modular climbing robot with transition capability for different environments,"* Journal of Mechanical Science and Technology, vol. 30, no. 1, pp. 373– 381, 2016.
5. Di Franco, C., & Buttazzo, G., *"Energy-aware coverage path planning of UAVs,"* Proc. IEEE Int. Conf. Autonomous Robot Systems and Competitions (ICARSC), pp. 111–117, 2015.
6. Mulgaonkar, Y., Whitzer, M., Kumar, V., & Mellinger, D., *"Power and weight considerations in small, agile quadrotors,"* Proc. IEEE Int. Conf. Robotics and Automation (ICRA), pp. 4393–4398, 2014.
7. Mellinger, D., Michael, N., & Kumar, V., *"Trajectory generation and control for precise aggressive maneuvers with quadrotors,"* The International Journal of Robotics Research, vol. 31, no. 5, pp. 664–674, 2012.
8. Penders, J., Alboul, L., Witkowski, U., Naghsh, A., Saez-Pons, J., & Moody, L., *"A robot swarm assisting a human firefighter,"* Advanced Robotics, vol. 25, no. 1–2, pp. 93–117, 2011.
9. Bogue, R., *"Search and rescue robots: A review,"* Industrial Robot: An International Journal, vol. 38, no. 3, pp. 262–268, 2011.
10. Kamegawa, T., Hashimoto, M., Matsuno, F., & Fukuda, T., *"Development of a transformable mobile robot with crawler and wheel mechanisms,"* Advanced Robotics, vol. 24, no. 18, pp. 2463–2482, 2010.
11. Godase, M. V., Mulani, A., Ghodak, M. R., Birajadar, M. G., Takale, M. S., & Kolte, M. A MapReduce and Kalman Filter based Secure IIoT Environment in Hadoop. Sanshodhak, Volume 19, June 2024.
12. Mulani, A. O., & Mane, P. B. (2017). Watermarking and cryptography based image authentication on reconfigurable platform. Bulletin of Electrical Engineering and Informatics, 6(2), 181-187.
13. Gadade, B., Mulani, A. O., & Harale, A. D. IoT Based Smart School Bus and Student Tracking System. Sanshodhak, Volume 19, June 2024.
14. Dhanawade, A., Mulani, A. O., & Pise, A. C. IOT based Smart farming using Agri BOT. Sanshodhak, Volume 20, June 2024.
15. Mulani, A., & Mane, P. B. (2016). DWT based robust invisible watermarking. Scholars' Press.

ISSN: 2945-4565 VOL 05, ISSUE 02, 2026

16. R. G. Ghodke, G. B. Birajdar, A.O. Mulani, G.N. Shinde, R.B. Pawar, Design and Development of an Efficient and Cost-Effective surveillance Quadcopter using Arduino, Sanshodhak, Volume 20, June 2024.
17. R. G. Ghodke, G. B. Birajdar, A.O. Mulani, G.N. Shinde, R.B. Pawar, Design and Development of Wireless Controlled ROBOT using Bluetooth Technology, Sanshodhak, Volume 20, June 2024.