DRONE ON WHEELS: A HYBRID UAV-UGV SYSTEM FOR PRECISION COURSE NAVIGATION

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Introduction

- Unmanned aerial vehicles (UAVs) **offer rapid deployment and aerial perspectives**, while unmanned ground vehicles (UGVs) bring extended endurance capabilities and ground-level interaction.
- Yet **UAVs have a short battery life**, payload constraints, and in certain airspaces, regulatory restrictions [1]; furthermore, **UGV mobility is restricted** in highly obstructive or impassable terrain.
- By combining the two systems, hybrid aerial-ground robotic platforms **address operational limitations** of single-mode vehicles while **leveraging their individual strengths.**

Objectives

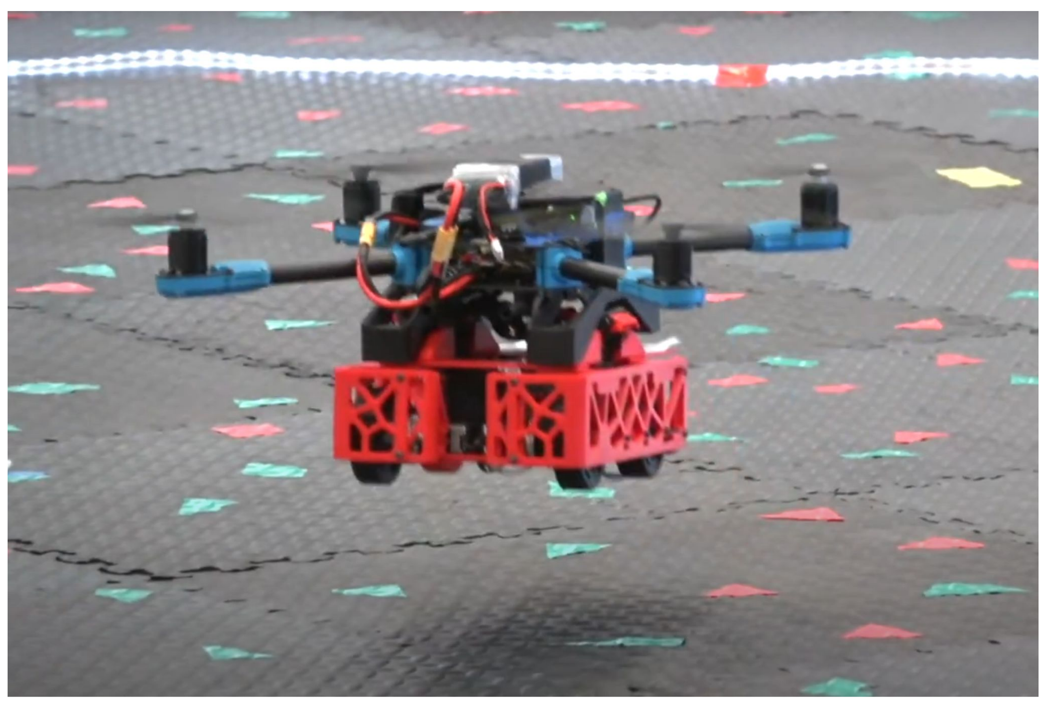

Figure 1: Airborne UAV-UGV

Develop a novel coordinated UAV-UGV platform that:

- Seamlessly transitions between aerial and ground mobility;
- Maximizes operational range by reducing continuous drone flight time;
- Enables terrain versatility with a detachable land platform; and
- Maintains autonomy by independently controlling both aerial and ground units.

Methodology

Design: The hybrid UAV-UGV system was designed around a passive latching mechanism, offering rapid docking and release capabilities between the aerial and ground units. The UAV was mounted on the UGV during ground traversal to conserve battery power; when aerial deployment was required for obstacle avoidance or vertical data collection, it detached. Figures 2A and 2B show the CAD design for the UGV and shows it connected to the UAV.

Testing:

- The ground vehicle was tested on six terrain types – foam, concrete, grass, mulch, sand, and forest floor to simulate a variety of field conditions – at a constant operating voltage of 8.0 V (Figure 4 - forest floor).
- Both linear velocity (m/s) and angular velocity (rad/s) were measured across three trials per surface using a meterstick and stopwatch for linear motion as well as a protractor with timing for angular motion.
- The strength of the latches was evaluated using weights that were added incrementally until the latches failed.

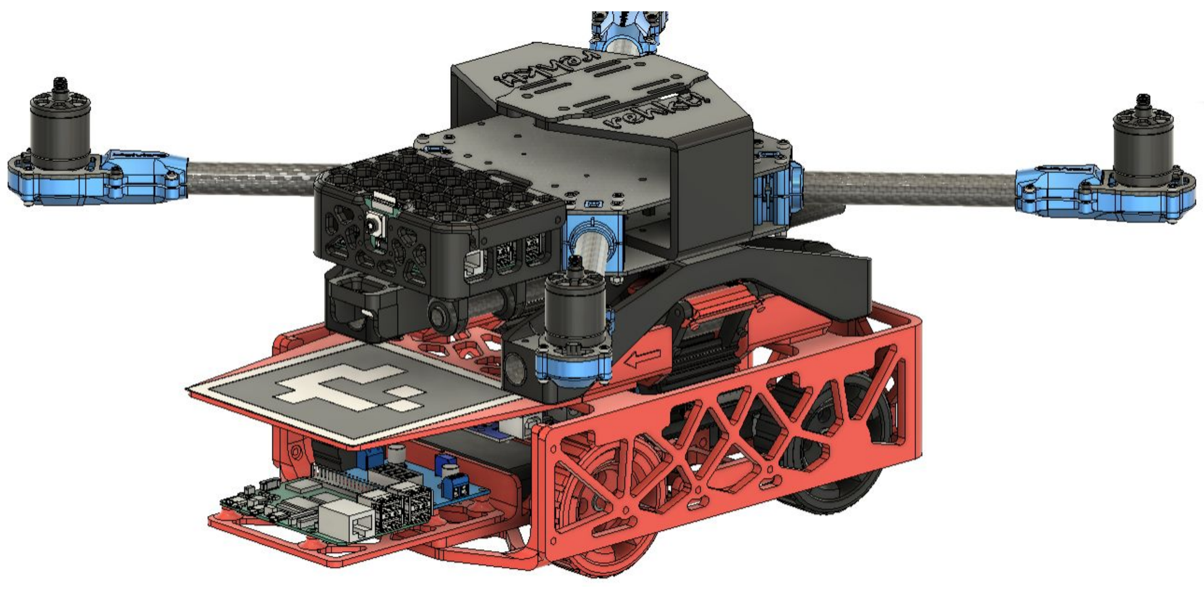

Figure 2A: Full Hybrid UAV-UGV CAD Model

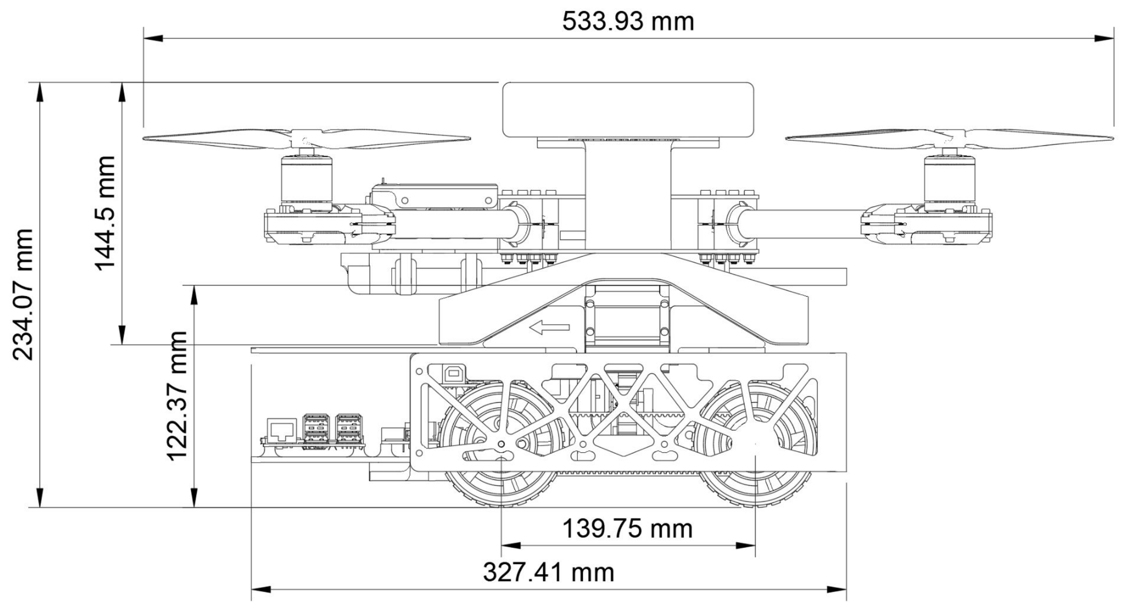

Figure 2B: Wireframe Side View of UAV-UGV

Materials and parts: A Holybro X500 V2 quadcopter and 5000 mAh battery was used, weighing 1.1 kg with 18 minutes of hover time [2]. The UAV landing gear was 3D printed (Figure 3), designed to dock with the UGV.

Figure 3: 3D Printed Landing Gear

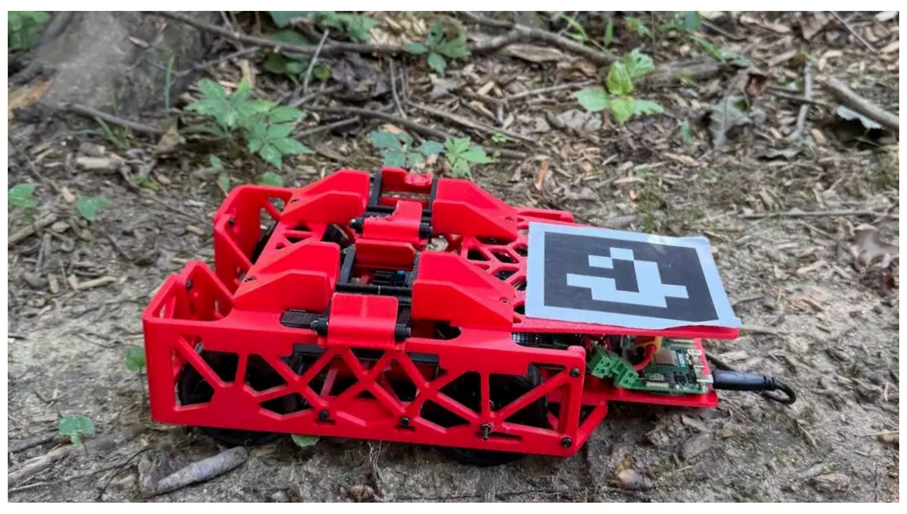

Figure 4: UGV on Forest Floor

Results

The hybrid UAV-UGV system demonstrated successful aerial flight and ground traversal.

Table 1 shows the average linear and angular UGV velocities for each terrain:

- Concrete: Provided the highest average linear velocity (0.6276 m/s)
- Sandy surface: Yielded the highest average angular velocity (3.403 rad/s)
- Grass: The UGV was unable to pass over grass, underscoring the need for aerial deployment in dense vegetation and improvements for UGV wheels
- Forest terrain: The UGV maintained moderate linear velocity (0.5853 m/s) but exhibited low angular velocity (1.254 rad/s), indicating reduced maneuverability on uneven surfaces

Table 2 shows each latch could hold a max of 27.28 Newtons of force. This only occurs when the orientation is perfectly vertical; if the UGV is off-center or the drone rolls, the system is more susceptible to unlatching.

Table 1: Average Linear and Angular Velocities (tested at 8.0 V)

	Foam	Concrete	Grass	Mulch	Sand	Forest
Linear Average (m/sec)	0.6234	0.6276	0.0000	0.5747	0.5980	0.5853
Angular Average (rad/sec)	4.203	4.046	0.000	1.882	3.403	1.254

Table 2: Average Latch Strength

	Weight (incl. car, grams)	Weight (excl. car, grams)
Average	5564	4337

$$m \cdot a = F$$

$$5.564 \cdot 9.807 = 54.57 \text{ N}$$

Each latch can hold 27.28 N

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Conclusion

- A UAV-UGV hybrid platform **can adapt to different terrains** by utilizing the UGV in situations conducive to wheeled travel while reserving the UAV for areas with low ground accessibility or situations better suited to aerial perspectives.
- The performance data highlight the importance of **terrain-aware mission planning**: surfaces with low mobility (i.e. forest floor, mulch) may require more frequent UAV deployment, while smooth, high-velocity surfaces (i.e. concrete) favor UGV usage.
- By combining the endurance and payload advantages of UGVs with the mobility and vantage point of UAVs, the proposed hybrid platform **enhances operational flexibility.**
- This low-cost, lightweight UAV-UGV system could be valuable for environmental monitoring, search and rescue, and urban settings.
- Areas of potential further research include **autonomous docking and multi-agent integration.**

References & Acknowledgments

[1] S. A. H. Mohsan, N. Q. H. Othman, Y. Li, M. H. Alsharif, and M. A. Khan, "Unmanned Aerial Vehicles (UAVs): Practical aspects, applications, Open challenges, Security issues, and Future Trends," Intelligent Service Robotics, vol. 16, no. 1, Jan. 2023, doi: https://doi.org/10.1007/s11370-022-00452-4.

[2] "X500 V2 Kits," Holybro Store. https://holybro.com/products/x500-v2-kits.

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