Morphable Quadrotor

TECHNOLOGY NUMBERS: 2024-135, 2024-571

Accelerate Blue Foundry - 2025 (Physical Sciences)

OVERVIEW

A novel quadrotor, enabled by co-adaptive mechanical and artificial intelligence, that expands the operational envelope of current quadrotors to enable (i) human-like manipulation, (ii) extreme maneuverability, and (iii) assured reliability against disturbances, unmodeled dynamics, and rotor failures. The quadrotor is being developed to seamlessly operate between air and water.

(a) Inspection and Maintenance. (b) Delivery to Moving Vehicles. (c) Disaster Response.

Fig. 1: **Motivating Examples**. *Inspection and maintenance* (a), *package delivery* (b), and *disaster response* (c) can benefit from cross-domain air-underwater vehicles that can execute complex sensing, motion, and manipulation actions reliably and efficiently. Such tasks are challenging since they require small vehicles that hover and/or fly at arbitrary orientations, exert maximum force at arbitrary directions, and are accurate despite being exposed to difficult-to-model disturbances, such as wake, packages with sloshing liquid, and contact forces. In this proposal, we pioneer such a quadrotor (CAD model depicted) via the first morphable (variable rotor-tilt) structure that enables continuous omnidirectional thrust vectoring with maximum force at any direction (Fig. 2).

The quadrotor is poised to revolutionize autonomy in industries such as robotics, public safety, and logistics, addressing demanding applications like disaster response, precision agriculture, surveillance, and close-proximity infrastructure inspection—tasks that often occur in remote, confined, or hazardous environments. These jobs currently rely on human labor, incurring high costs, downtime, and safety risks, because existing aerial and underwater vehicles can't physically interact with their surroundings like a human, navigate tight spaces, or withstand complex disturbances. As a result, conventional drones are limited to distant monitoring or simple inspections, lacking the dexterity, maneuverability, and reliability required for truly transformative impact.

DESCRIPTION

Technology ID
2024-135

Category
Software
Software & Content
Accelerate Blue Foundry - 2025/Physical Sciences

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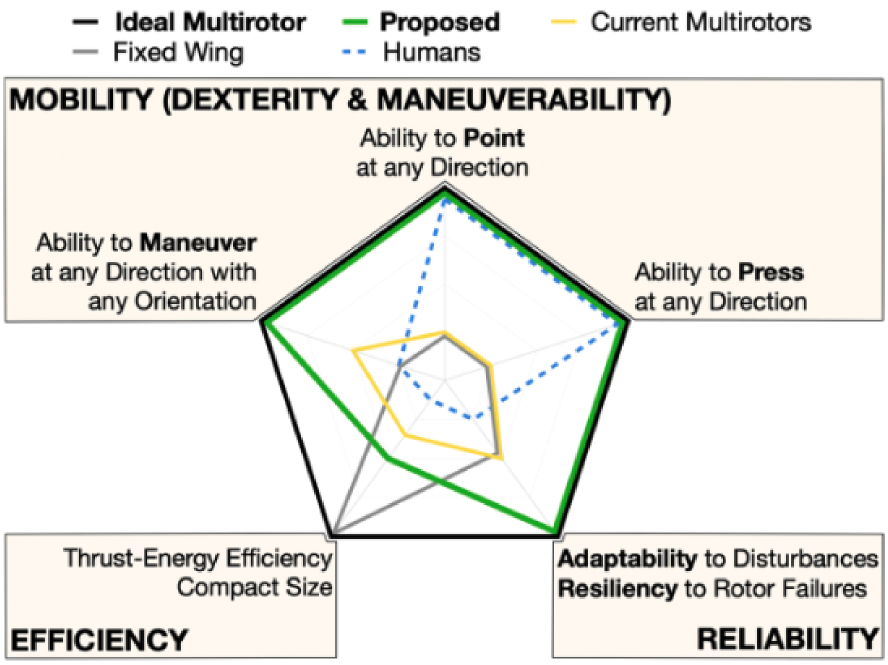

Fig. 2: **Proposed *vs.* Current Multirotors.**

Current multirotor drones, whether for air, underwater, or limited cross-domain use, fail to meet the demanding needs of applications like disaster response, precision agriculture, surveillance, and up-close infrastructure inspection or maintenance. These sectors require machines with human-like dexterity for accurate sensor placement and physical manipulation, agile movement for seamless transitions between air and water, adaptability to unpredictable real-world disturbances, and resilient operation even when some motors fail. Interviews with the top and most relevant potential competitors (including Voliro, Skygauge, and wind power operators) confirm that today's drones cannot generate strong, precisely directed forces in all directions, meaning they cannot approach objects closely or interact with them, handle turbulent delivery conditions, or replace humans in costly, risky, and labor-intensive inspection or repair tasks. The root causes are limited mechanical tilting of rotors and outdated control algorithms that can't predict or adapt to real-time disturbances, resulting in conservative, inefficient, and sometimes unsafe performance.

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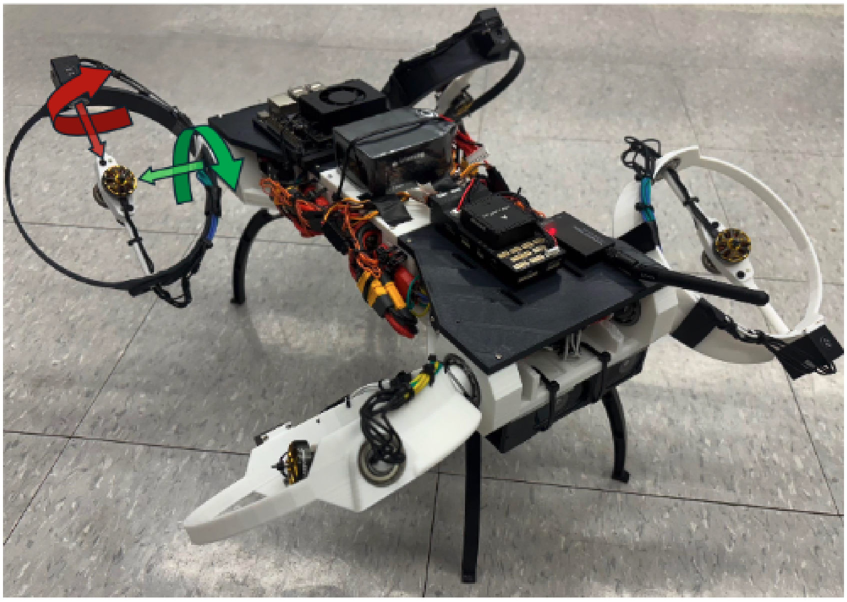

Fig. 3: **Prototype of Morphable Quadrotor for Aerial Operation Only** (CAD depicted in Fig. 1). The curved green and red arrows depict the rotational degrees of freedom of the gimbal rotor arm .

Our solution is a breakthrough quadrotor featuring completely independent, unlimited-tilt motors enabling continuous omnidirectional force and torque generation, both in air and underwater. This architecture empowers the drone with human-like manipulation abilities and extreme maneuverability for uninterrupted, orientation-agnostic movement—even during complex transitions between mediums. Complemented by advanced, bio-inspired trajectory planning and adaptive, learning-based control systems, the drone can anticipate and reject challenging disturbances (wind, water currents, contact forces) while dynamically adapting to unknown dynamics and functioning even after losing multiple rotors. This unique combination of morphable hardware and intelligent autonomy finally enables safe, efficient, and high-precision operation in scenarios where conventional multirotors and manually operated systems fall short.

VALUE PROPOSITION

- **Dexterity Enabler:** The morphable quadrotor expands the operational envelope of current quadrotors to enable human-like dexterity to point or press sensors/tools from any orientation at any direction, with maximum force, as a flying hand would do. In contrast, current omnidirectional aerial vehicles cannot exert maximum force and maneuver at any direction and, thus, do not present a viable solution for tasks that require complex sensing, motion, and human-level manipulation capabilities.
- **Radically Enhanced Maneuverability:** Enables true 6-degrees-of-freedom flight—independent and full-range control of both orientation and translation, even in tight/confined spaces or while performing difficult maneuvers (e.g., agile obstacle navigation) or while in dynamic contact with sufraces/infrustructure. In contrast, current omnidirectional aerial vehicles can only maneuver in limited directions (only pitch) and for a limited range and, thus do not present a viable solution for tasks that require complex motion, such as the inspection of the underside of bridges or the periphery of pipes.
- **Resilience and Safety:** Maintains stability and control even if one or more rotors fail, and automatically compensates for unpredictable disturbances that may hit the vehicle from any direction such as winds, ground/wall/ceiling effects, and contact forces (e.g., friction) using assured online learning algorithms that leverage the quadrotor’s morphability to cancel such disturbances. In contast, the current omnidirectional aerial vehicles are unable to cancel such disturbances since they are unable to generate thrust at arbitrary directions.
- **Autonomy at the Edge:** The integrated autonomy suite enables fully independent operation, reducing the need for active human remote pilots and enabling intelligent fleet behavior for smart applications (e.g., swarms, search-and-rescue).

Beyond research papers, all above are also supported by our customer discovery, which includes interviews with direct potential customer and current servisors from the sectors of:

- **Energy (wind farms, oil and gas):** Chevron; ExxonMobil, Shell, Zephyr Power
- **Monitoring and surveillance (environmental monitoring and 3D mapping):** DusiTech, Yellowscan, Quantum Aerial, Voliro
- **Inspection and maintance (cleaning of high rises, inspection of superstructures):** Voliro, Skygauge, Skyspecs, Aspira and Apis DroneTech

TECHNOLOGY READINESS LEVEL

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INTELLECTUAL PROPERTY STATUS

Proprietary software & patent pending

MARKET OPPORTUNITY

There is a pressing and growing need for drones that can operate safely and autonomously in environments that are crowded and dynamic while being able to perform complex sensing, motion, and manipulation actions reliably and efficiently. Key application verticals include:

- **Public Safety & Disaster Response:** Safer indoor or urban deployments where (i) GPS is unreliable, (ii) tight and hard-to-reach geometries must be navigated, and(iii) collisions with people or infrastructure must be avoided.
- **Industrial Inspection & Maintainance:** Complex aerial manipulation tasks in settings with obstacles, unpredictable disturbances around structures (wind, airflow, friction, etc.), and high cost of mission failure.
- **Logistics & Last-Mile Delivery:** Ability to reliably carry out deliveries despite environmental disruptions or partial system failures.

Drone adoption is growing at ~15% CAGR globally, with market analysts especially noting regulatory, safety, and reliability as key adoption barriers—barriers this technology directly addresses. For context, the top and most relevant potential competitors that have introduced morphable quadrotors to target the above markets —but with limited capabilities as described above—, the European-based Voliro and Canada-based Skygauge, raised at least US$ 18 million since 2021 [Source 1; source 2; source 3; source 4].

- This project has participated in Customer Discovery and received translational funding from MTRAC Advanced Transportation.