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Integrated Submersible Hull and Folding Tilting Multirotor Airframe with Ballast Management for Controlled Water Entry, Submerged Transit, and Water Exit to Flight

Marginal · 64.3/100 | 12 claims

TECHNICAL FIELD

Airframe and hull architecture for transmedium unmanned vehicles that transition between multirotor flight and submerged transit.

ABSTRACT

A transmedium unmanned vehicle integrates a streamlined submersible hull with a multirotor airframe whose rotor arms fold or tilt between a deployed flight configuration and a stowed submersible configuration. A ballast subsystem with a controllable pump and variable-buoyancy chamber, together with depth and pressure sensing, manages controlled water entry, neutral or negative buoyancy for submerged transit, and a controlled ascent and water exit back to flight. During entry the rotor arms move toward the stowed configuration and ballast is taken on to reduce buoyancy; during submerged transit the hull form reduces drag and the ballast is trimmed for the commanded depth; during exit the ballast is expelled, the vehicle ascends, the arms deploy, and the rotors spin up for take-off from the surface. The integration of a pressure-tolerant hull, foldable or tiltable multirotor arms, and active ballast in a single body enables repeatable air-to-water and water-to-air transitions for one compact platform.

BACKGROUND

Vehicles that must both fly and operate underwater face conflicting structural demands. Multirotor aircraft are open frames optimised for low mass and exposed propellers, whereas submersibles are sealed, pressure-tolerant, streamlined bodies that manage buoyancy. Crossing the air-water interface is mechanically violent: water entry imposes impact loads, exposed rotors are unsuited to submerged propulsion, and a frame sized for flight has the wrong buoyancy for diving. Prior transmedium concepts exist, including academic dipping and plunging multirotors and fixed-wing water-launch vehicles, but they commonly omit active ballast control, treat water entry as a passive plunge, or do not stow the rotor arms to present a clean submersible hull. Sealed thruster submersibles, in turn, cannot fly. There remains a need for a single airframe that integrates a streamlined pressure-tolerant hull, multirotor arms that fold or tilt to switch between an open flight frame and a clean submersible body, and an active ballast subsystem that sequences buoyancy with the arm configuration and with sensed depth, so that the vehicle can enter water in a controlled manner, transit submerged at a commanded depth, and exit the water and resume flight repeatably rather than as a one-shot plunge.

SUMMARY OF THE INVENTION

The invention provides a transmedium airframe in which a submersible hull and a folding or tilting multirotor frame are integrated and coordinated with active ballast. Rotor arms actuate between a deployed flight configuration and a stowed configuration that presents a streamlined hull. A ballast subsystem, including a pump, a variable-buoyancy chamber, and depth and pressure sensing, is sequenced by a controller through three phases: controlled water entry with arms stowing and buoyancy reduced; submerged transit with buoyancy trimmed to a commanded depth; and water exit with ballast expelled, ascent, arm deployment, and rotor spin-up for surface take-off. Interlocks tie the arm configuration to the ballast state and to sensed depth so that, for example, rotors are not spun for flight while submerged and arms are not deployed under load. The integrated body enables repeatable, controlled bi-directional transitions across the air-water interface for a compact single platform.

DETAILED DESCRIPTION

FIG. 1 is a perspective view of the vehicle in the deployed flight configuration with rotor arms (50) extended from a hull (52). FIG. 2 is a perspective view in the stowed submersible configuration with the arms (50) folded against the hull (52) to present a streamlined body. FIG. 3 is a section view of the ballast subsystem showing a pump (54), a variable-buoyancy chamber (56), and a depth/pressure sensor (58). FIG. 4 is a sequence diagram of the water-entry phase. FIG. 5 is a sequence diagram of submerged transit. FIG. 6 is a sequence diagram of the water-exit-to-flight phase. FIG. 7 is a state diagram of the interlocks coupling arm configuration, ballast state, and sensed depth. Referring to FIG. 1 and FIG. 2, the rotor arms (50) are mounted to the hull (52) by actuated joints that fold or tilt the arms between the deployed flight configuration, in which the rotors are spaced for multirotor flight, and the stowed configuration, in which the arms lie close to the hull to reduce drag and protect the rotors during submersion. The hull (52) is shaped as a streamlined, bullet- or torpedo-like body and is pressure tolerant to a design depth. Referring to FIG. 3 to FIG. 6, the controller sequences the transition phases. During water entry (FIG. 4) the controller commands the arms (50) toward the stowed configuration and operates the pump (54) to admit fluid to or otherwise reduce the buoyancy of the chamber (56), so the vehicle takes on negative buoyancy in a controlled manner rather than an uncontrolled plunge. During submerged transit (FIG. 5) the controller trims the chamber (56) using feedback from the depth/pressure sensor (58) to hold a commanded depth at neutral or slightly negative buoyancy, and a submerged propulsor moves the streamlined hull (52) with low drag. During water exit (FIG. 6) the controller expels ballast to make the vehicle positively buoyant, the vehicle ascends to the surface, the arms (50) deploy, and the rotors spin up for take-off. The interlocks of FIG. 7 couple the subsystems: rotors intended for aerial thrust are inhibited while the depth/pressure sensor (58) indicates submersion; arm deployment is inhibited until buoyancy and depth conditions for surfacing are met; and ballast trimming is bounded to the hull design depth. In an embodiment the same motors drive both the aerial rotors and a submerged propulsor in cooperation with the medium-keyed winding control of a companion disclosure.

DRAWINGS

FIG. 1 is a perspective view in the deployed flight configuration with rotor arms extended from the hull; FIG. 2 is a perspective view in the stowed submersible configuration with arms folded against the hull; FIG. 3 is a section view of the ballast subsystem showing the pump, variable-buoyancy chamber, and depth or pressure sensor; FIG. 4 is a sequence diagram of the water-entry phase; FIG. 5 is a sequence diagram of submerged transit; FIG. 6 is a sequence diagram of the water-exit-to-flight phase; FIG. 7 is a state diagram of the interlocks coupling arm configuration, ballast state, and sensed depth.

CLAIMS

1. A method of operating a transmedium unmanned vehicle having a submersible hull and a multirotor frame with rotor arms movable between a deployed flight configuration and a stowed submersible configuration, the method comprising: during a water-entry phase, moving the rotor arms toward the stowed configuration and operating a ballast subsystem to reduce buoyancy of the vehicle for controlled entry into water; during a submerged-transit phase, trimming the ballast subsystem using a sensed depth to hold a commanded depth; and during a water-exit phase, expelling ballast to ascend, deploying the rotor arms to the flight configuration, and spinning up rotors for take-off from a surface.

2. A transmedium unmanned vehicle comprising: a streamlined pressure-tolerant submersible hull; a plurality of rotor arms mounted to the hull by actuated joints arranged to move the rotor arms between a deployed flight configuration and a stowed submersible configuration; a ballast subsystem comprising a controllable pump and a variable-buoyancy chamber; a depth or pressure sensor; and a controller configured to sequence the actuated joints and the ballast subsystem through a controlled water entry, a submerged transit at a commanded depth, and a water exit to flight.

3. The method of claim 1, further comprising inhibiting spin-up of rotors for aerial flight while the sensed depth indicates that the vehicle is submerged.

4. The method of claim 1, further comprising inhibiting deployment of the rotor arms to the flight configuration until a buoyancy condition and a depth condition for surfacing are satisfied.

5. The method of claim 1, wherein trimming the ballast subsystem comprises closed-loop control of the variable-buoyancy chamber from the sensed depth to maintain neutral or slightly negative buoyancy during submerged transit.

6. The method of claim 1, wherein operating the ballast subsystem to reduce buoyancy during the water-entry phase converts an uncontrolled plunge into a buoyancy-managed descent bounded to a hull design depth.

7. The method of claim 1, wherein a submerged propulsor moves the hull during the submerged-transit phase, and wherein rotors used for aerial flight are stowed during the submerged-transit phase.

8. The system of claim 2, wherein the controller is configured to inhibit aerial rotor spin-up while the depth or pressure sensor indicates submersion.

9. The system of claim 2, wherein the hull is shaped as a bullet or torpedo form and the stowed rotor arms lie against the hull to reduce submerged drag and protect the rotors.

10. The system of claim 2, wherein the controller is configured to bound trimming of the variable-buoyancy chamber to a design depth of the hull.

11. The system of claim 2, wherein common motors are arranged to drive aerial rotors in the flight configuration and a submerged propulsor in the submersible configuration.

12. The system of claim 2, further comprising interlocks coupling an arm configuration, a ballast state, and the sensed depth such that the rotor arms deploy only after a surfacing condition is met.

PATENTABILITY SELF-ASSESSMENT (30-FACTOR)

Patentability	78.0%
Prior-art position	48.0%
Technical merit	52.0%
Commercial	68.0%
Composite genius score	**64.3/100 (Marginal)**

FILING ROUTES

United Kingdom (UK IPO)
GB national application at UK IPO with combined search and examination; narrow the independent claims around the ballast-sequenced arm-stowing interlocks given dense transmedium prior art.

Ireland (IPOI / Irish PATO)
IE 10-year short-term patent as a quick keystone, with PCT or EPO extension only if a clearly distinguishing interlock feature survives search.

PRIOR-ART VERIFICATION (LIVE SEARCHES)

UK IPO patent search (Ipsum)
UK national register and file inspection
https://www.search-for-intellectual-property.service.gov.uk/SearchByNumber

Espacenet (EPO)
European/worldwide prior-art search
https://worldwide.espacenet.com/patent/search?q=transmedium%20hull%20rotor%20airframe%20drone%

Google Patents
Full-text + family view
https://patents.google.com/?q=(transmedium%20hull%20rotor%20airframe%20drone%20UAV%20transmedium)&type=PATENT

IPOI (Irish Patents Office)
Irish national filing route (short-term + full-term)
https://www.ipoi.gov.ie/en/types-of-ip/patents/

EPO CPC B64U (UAS)
Unmanned-aircraft classification
https://worldwide.espacenet.com/patent/search?q=cpc%3DB64U