Gust Estimation and Rejection for Underwater Crafts with Morphing Control Surfaces.

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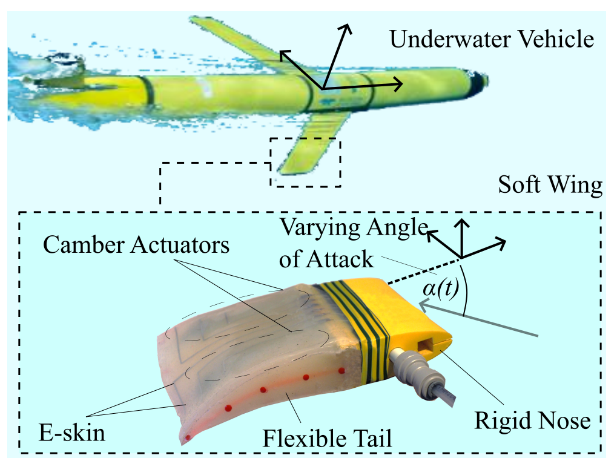
ABSTRACT

Autonomous underwater vehicles are essential for surveying and maintenance tasks at sea. However, differently from deep-sea environments, operations in shallow waters can be daunting or altogether unfeasible due to the occurrence of severe hydrodynamic disturbances. Disturbances generated by waves, currents and turbulence vary across a broad spectrum of temporal and length scales and can dramatically impact the stability and performance of autonomous self-propelled vehicles, critically hindering their operational envelope.

In nature, the interaction with highly non-stationary flows is dealt with by ocean dwelling organisms by means of continuously deforming fins and tails which can actively or passively mitigate the impact of the unsteady flow patterns. Inspiration can be drawn from such specimens in the design of morphing wings and their control systems to enable engineered self-propelled systems to better cope with unwanted disturbances for improved maneuverability and propulsive efficiency.

Here we demonstrate a nonlinear controller and disturbance estimator for the purpose of gust rejection of morphing control surfaces. We make use of a proprioceptive underwater morphing wing (Micklem et al, 2022) which employs soft hydraulic actuators to adjust its own camber and which relies on a flexible e-skin for real time shape estimation. We develop and validate a dynamic model of the soft wing and derive a non-linear observer that successfully estimates the sudden change in angle of attack due to a gust and corrects the wing camber accordingly to minimize unwanted deviations in the lift force.



Our results show excellent disturbance rejection performances, offering the chance to endow underwater craft with superior stability and maneuverability during gliding and station keeping tasks even when subject to aggressive environmental perturbations.

References

L.Micklem, G.D.Weymouth and B.Thornton. Energy-efficient tunable-stiffness soft robots using second moment of area actuation. In 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2022