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Preliminary Design Optimization for Internal Arrangement and Hull Geometry of a Bio-Inspired Autonomous Underwater Glider through Machine Learning

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ABSTRACT

The preliminary design of bio-inspired vehicles demands balancing complex trade-offs between hydrodynamic performance, structural integrity, and payload accommodation [1]. This study focuses on the design of an autonomous underwater glider inspired by the manta ray (Fig. 1), achieved via the solution of a multi-objective optimization problem. The objectives include maximizing hydrodynamic efficiency, minimizing the overall vehicle weight, and ensuring sufficient volume for the payload.

To tackle these challenges, we integrate advanced machine learning techniques into the design process. An unsupervised learning approach, based on a physics-informed formulation of parametric model embedding (PI-PME) [2], is employed to capture and represent the design space variability while incorporating physical constraints. This enables a reduced-dimensionality representation of design variations and therefore the efficient exploration of possible configurations with reduced computational cost. Additionally, a multi-fidelity surrogate model, combining potential flow and RANS (Fig. 2) simulations, is used to solve the multi-objective optimization problem. Starting from a limited number of initial samples, the surrogate model is iteratively refined through adaptive sampling to improve accuracy and efficiency in predicting objective functions [3].

This work discusses the development and validation of a methodological framework for design optimization, demonstrating its applicability to a wide range of engineering problems. The bio-inspired underwater glider serves as a challenging yet illustrative test case, showcasing the potential of the proposed methods to address complex design scenarios in emerging fields.

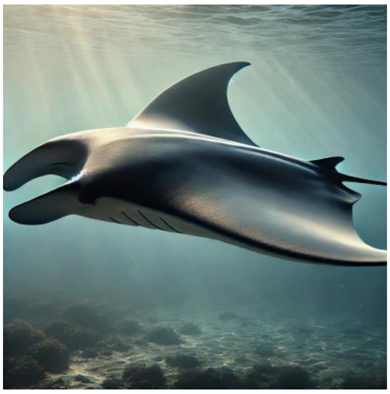

Fig. 1: Manta ray.

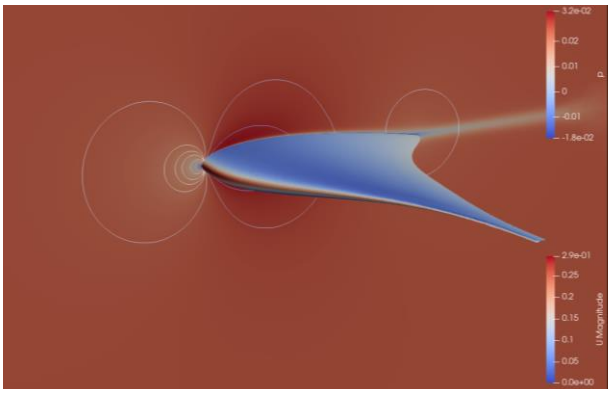

Fig. 2: RANS analysis of Manta ray AUG.

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References

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