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Multi-Fidelity Hydro-Structural MDO for High-Speed Small Craft via Multi-Loop Digital Design[a]

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ABSTRACT

The digital design process, Stern at al. (2022), Fig. 1, replaces the build-and-test design spiral approach enabling multi-fidelity (MF) and multi-disciplinary design optimization (MDO) to meet customer requirements with many design variables and mission/performance possibilities.
Progress in multi-fidelity fluid-structure interaction (FSI) optimization for weight reduction, Pellegrini et al. (2024), hull-form stochastic optimization, Serani et al. (2021), and multi-fidelity MMG-models, Diez et al. (2024a), enables the next step for hydro-structural multi-loop digital design (ML-DD), which is the objective of the proposed paper with application to a 40 ft high-speed small craft undergoing slamming loads. Here, the ML-DD uses two nested loops, where the outer cycle pertains to the hull form optimization and the inner cycle pertains to the optimization of the internal structural elements (number, location, and sizing). The hull form optimization addresses the maximization of the payload (displacement) and deadrise angle (to reduce the severity of the slamming) and minimization of the resistance. Structural optimization addresses weight minimization while maintaining acceptable factors of safety, all of which are subject to the customer requirements. Hull form design leverages surrogate-based optimization, where the surrogate is trained with potential flow and CFD RANS computations, see Diez et al. (2024a). Structural optimization uses a design-space dimensionality reduction method using physics-relevant geometric parameters, Diez et al. (2024b); an MF-MDO of the hull internal structure is performed in the reduced design space, with a MF surrogate model trained with computational structural dynamics simulations whose fidelity is defined by the load applied (static versus dynamic). Finally, selected solutions undergo design assessment and virtual testing for customer acceptance.

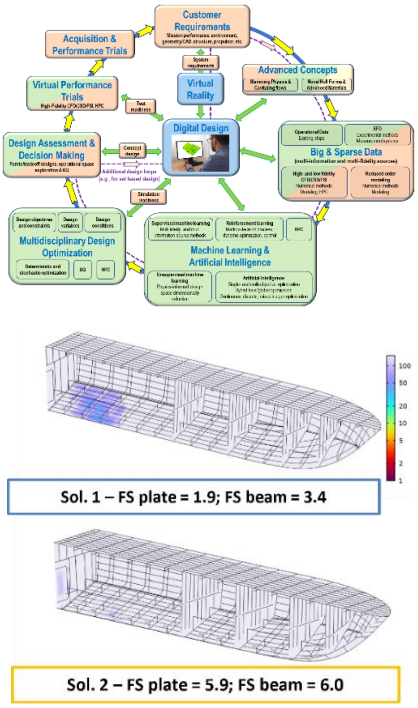

Figure 1: Digital Design Process (top), GPPH designs (middle, bottom).

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