Generative Ship Hull Form Optimisation with ShipHullGAN

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Abstract

Conventional ship design process typically commences by understanding customer requirements and exploring existing design databases to identify a baseline design that closely aligns with the new specifications. An iterative approach is then employed to refine the design by focusing on performance-related parameters. Each iteration involves comprehensive evaluations and, if the design fails to meet the specified requirements, modifications are implemented and reassessed. This process often undergoes multiple iterations before progressing to the detailed design phase.

However, initiating the design process with a baseline model is becoming increasingly inadequate due to the evolving regulatory landscape and stricter compliance requirements. The maritime industry is experiencing significant shifts driven by regulations such as the IMO 2020 mandate for emissions reduction, the emergence of disruptive carbon-saving technologies and the adoption of alternative fuels. Consequently, vessel design necessitates a paradigm shift, moving away from traditional baseline-driven approaches towards more innovative and adaptive methodologies.

To address these challenges, Khan et al. introduced ShipHullGAN [1], a generic parametric model developed using a deep generative convolution model to enable the versatile representation and generation of ship hull designs. ShipHullGAN has been trained on a dataset of 52,591 physically validated ship hull designs, encompassing a diverse range of vessel types, including container ships, tankers, bulk carriers, tugboats, and crew supply vessels. This model aims to overcome the inherent conservatism of conventional parametric design paradigms, which are typically constrained to specific ship types. ShipHullGAN not only supports the generation of various ship hull types but also facilitates the transformation of one hull type into another and the creation of novel geometries by integrating features from different ship types.

Despite the demonstrated capabilities of ShipHullGAN, its efficacy in large-scale holistic optimisation remains to be fully validated. In this study, we adopt a generative search approach to optimise the design process. Initially, we explore ShipHullGAN's generative design space to identify a diverse set of candidate designs that closely align with preliminary design requirements. From this candidate pool, three distinct designs that closely match the design criteria are selected. Subsequently, we conduct an exploitation phase, wherein localised design subspaces around these selected designs are explored to minimise total resistance while satisfying design constraints. Once convergence is achieved within these individual subspaces, a secondary optimisation phase is conducted by interlinking the subspaces to identify potential further improvements.

Finally, our optimisation strategy is benchmarked against the conventional baseline-driven approach, demonstrating that our generative search methodology yields superior-performing and more innovative ship hull designs. The results underscore the potential of generative design frameworks in advancing the ship design paradigm, offering enhanced flexibility and performance optimisation beyond traditional methodologies.

References

[1] S. Khan, K. Goucher-Lambert, K. Kostas, P. Kaklis, ShiphullGAN: A generic parametric modeller for ship hull design using a deep convolutional generative model, Computer Methods in Applied Mechanics and Engineering 411 (2023) 116051. doi:https://doi.org/10.1016/j.cma.2023.116051.