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Leveraging Generative AI for Simulation-Driven Optimization of Ship Hull Forms

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Abstract

For design tasks in various industries, including maritime, designers and engineers have begun adopting simulation-driven design (SDO) pipelines that employ parametric modelers to explore design variations. However, these modelers often lack novelty, generating ideas that closely resemble existing baseline designs. They are then coupled with optimization algorithms to improve the baseline design against specific performance criteria, which involve time-consuming solvers. Consequently, the final design frequently lacks innovation, exhibiting only minor variations from the baseline.

To foster true innovation, we must move away from starting SDO workflows with baseline designs. However, this requires design tools capable of generating the necessary shapes, as well as simulation tools to validate these shapes. Therefore, in this work, we develop a generative SDO pipeline using NeuralShipper[1]—a design- and physics-informed generative tool for ship design—and STAR-CCM+[2], a multiphysics simulation solver.

The proposed pipeline begins by exploring a generative design space (GDS) produced by NeuralShipper, creating a set of hull designs that satisfy all preliminary design constraints and requirements. Next, these candidate designs are passed to STAR-CCM+ for detailed evaluation. From the evaluated designs, we select a subset of high-performing candidates and, in the subsequent iteration, employ a nonlinear space-shrinking strategy that narrows the design space around these selected designs. This approach enables our optimizer to focus on the user's preferred regions of the design space. In each following iteration, new designs are generated and evaluated, guiding further space shrinking and targeted exploration. This process continues over several iterations until a more focused GDS is reached. Once a potential concept design is identified, it is established as the baseline for a more detailed, performance-focused SDO phase without further user intervention. Our results show that the proposed pipeline not only enables rapid exploration of efficient designs but also yields multipurpose vessel designs that integrate features from different vessel types.

Keywords: simulation-driven design, parametric design, generative models, computational fluid dynamics

[1] https://www.computemaritime.com/

[2] https://plm.sw.siemens.com/en-US/simcenter/fluids-thermal-simulation/star-ccm/?srsltid=AfmBOorjDTY47y-mm-8lHZMvqT6Xs7P5A2ezaBB6Kx5Dl_4zI6lBd1PE