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Multi-Objective Hull Form Optimization with CAD Engine-based Deep Learning Physics for 3D Flow Prediction

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ABSTRACT

In this work, we propose a built-in *Deep Learning Physics Optimization (DLPO)* framework to set up a shape optimization study of the Duisburg Test Case (DTC) container vessel. We present two different applications: (1) sensitivity analysis to detect the most promising generic basis hull shapes, and (2) multi-objective optimization to quantify the trade-off between optimal hull forms. DLPO framework allows for the evaluation of design iterations automatically in an end-to-end manner. We achieved these results by coupling Extrality's *Deep Learning Physics (DLP)* model to a CAD engine and an optimizer. Our proposed DLP model is trained on full 3D volume data coming from RANS simulations, and it can provide accurate and high-quality 3D flow predictions in real-time, which makes it a good evaluator to perform optimization of new container vessel designs w.r.t the hydrodynamic efficiency. In particular, it is able to recover the forces acting on the vessel by integration on the hull surface with a mean relative error of $3.84\% \pm 2.179\%$ on the total resistance. Each iteration takes only 20 seconds, thus leading to a drastic saving of time and engineering efforts, while delivering valuable insight into the performance of the vessel, including RANS-like detailed flow information. We conclude that DLPO framework is a promising tool to accelerate the ship design process and lead to more efficient ships with better hydrodynamic performance.

Keywords: Hull Form Optimization; Geometric Morphing; Multi-Objective Optimization; Deep Learning Physics; Computational Fluid Dynamics; Reynolds-Averaged Navier-Stokes Equations.