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Data-based surrogate modeling to reconstruct pressure fields of ships in arbitrary sea-states

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Abstract

Merchant shipping is responsible for more than 90% of the global trade and has a significant environmental impact, accounting for over 2% of global greenhouse gas emissions. Therefore, fuel-saving measures are becoming increasingly important to reduce the ecological footprint and to increase the fuel efficiency of maritime transport. Routing optimization systems represent an essential pillar here. However, state-of-the-art CFD simulations are too costly and time consuming to provide accurate real-time predictions of the current fluid dynamic resistance. This work proposes a data-based surrogate modeling approach to predict the hydrodynamic forces of ships in arbitrary sea-states, including pressure fields and related added resistance in seaways. The online/offline-procedure is exemplarily applied on a representative free-floating merchant vessel and essentially consists of two building blocks, i.e. a convolutional autoencoder (CAE) based order-reducing step and a neural network-based (NN) regression step that adapts the reduced space of the autoencoder to the sea state. In the offline phase, the combined CAE/NN is trained to capture averaged pressure fields for a variety of different sea-state conditions. For this purpose, a process chain is outlined that takes into account both the ship motion and the transient pressures and provides a projection of these quantities into the structured data environment of the AI process. During ship operation (online phase), the surrogate model is able to reconstruct three-dimensional pressure fields in response to the weather data. Integrating the pressure fields, additional resistance forces of the corresponding sea state are available to guide the route. The accuracy of different procedural elements is assessed. In general, the method shows promising results for the different building blocks and may represent a first milestone for cost-efficient surrogate modeling of instantaneous multiphase flow fields.

Keywords: Surrogate modeling, multiphase flows, pressure fields, seaway, ship routing.