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Data-Driven Surrogate Modelling of Aerodynamic Forces on the Superstructure of Container Vessels

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The operation of fluid engineering systems is usually governed by a wide range of different parameters. Investigations of the entire parameter spectrum using classical, first-principle based CFD methods are costly with regards to CPU and wall-clock time. Therefore a near real-time assessment of complex flows using CFD to support the operation is deemed unfeasible. The present work is concerned with methods for data-based surrogate models to predict the forces exerted by the aerodynamic pressure field on the superstructure of a full-scale container ship for different container loading conditions and wind directions.

Pressure fields obtained from hybrid RANS-LES simulations [1] serve as the data basis. The offline/online method aims to assist a fuel efficient operation method and is based on a two-step projection based approach [2]. During the first offline step, the dimensionality of the data is reduced. To this extent, a classical proper orthogonal decomposition (POD) is compared with convolutional neural network autoencoders (CNN-AE) and the influence of a different number of reduced variables is explored. A subsequent parametrization maps the reduced space to the input parameters, i.e. the angle of attack and container loading condition. As regards the regression, different regressions techniques to perform the mapping are compared, e.g. kriging or neural network (NN) techniques.

We aim to assess the attainable accuracy of the two reduction strategies for a confined reduced space in a real world case, and highlight the predictive differences returned by the POD and the CNN-AE. Both methods provide a similar agreement for the pressure fields, as well as the resulting forces, with the CNN-based surrogate model being significantly more compact. In contrast to the order reduction method, the regression approach seems more crucial to the predictive success.

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