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Flow field prediction around 2D bluff bodies

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Abstract

External flow prediction is a routine task in many industrial disciplines, including automotive, marine and aerospace fields. This task has been traditionally approached with Computational Fluid Dynamics, as a routine analysis for aerodynamics/hydrodynamics performance and optimisation. Optimisation as a process is related to the solution of the inverse problem, i.e. the definition of an unknown shape that minimises/maximises a desired characteristic (e.g. drag, lift etc). Given that the inverse problem is ill-posed with multiple local extrema, the optimisation process often requires an iterative process, resolving the flow in different candidate geometries, effectively exploring the design space, and assessing performance.

The aforementioned process inherently requires numerous resolutions of the flow field and can take a significant part of the design process of new products. It is hence of interest to explore methods that can potentially accelerate the process of evaluating new design points without the costly requirements of resolving the direct problem (flow field simulation given the geometry). Within the context of the present investigation, we aim to explore the possibility of applying machine learning techniques (such as: E(n)- Equivariant Graph Neural Networks (EGNNs)[1]) to predict 2D flow fields around bluff bodies, resulting to integral quantities such as drag, lift. The whole process is illustrated in Figure 1; first, we construct a database of resolved flow fields for different shapes, using traditional CFD techniques (k-ω SST [2], SIMPLE, steady-state) for a Reynolds range of Re = 1 - 10000. This database is then used to train an Artificial Neural Network (ANN), based on Graph Neural Networks (GNNs) framework . Then we evaluate different ANN architectures, compare the result with the 'ground truth' solution from the CFD solver, assessing their performance.

Our ultimate goal is the application of the aforementioned method to 3D geometries and eventually ships, for ship hydrodynamic prediction and definition of fast, surrogate digital twins, both for optimisation purposes and for path planning.

Keywords: flow field prediction, external flows, surrogate models, machine learning, digital-twin.

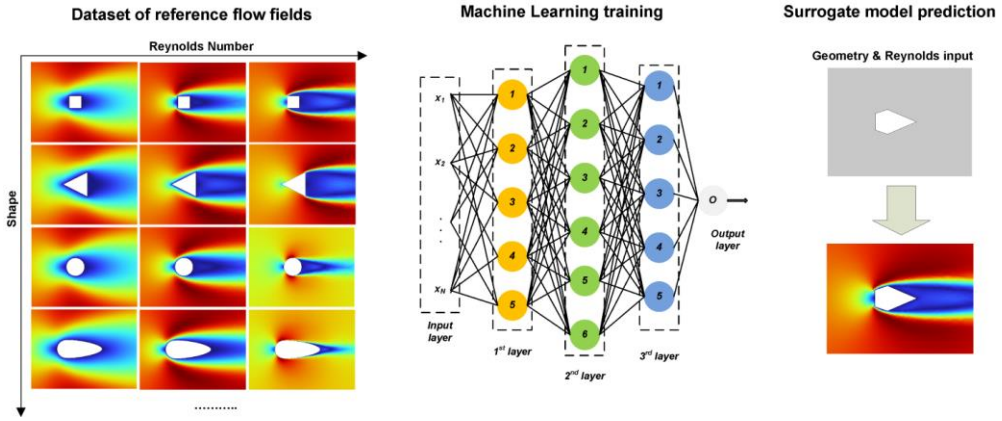

Figure 1. Flow field prediction using Machine Learning

References

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This submission is for poster session / short presentation.