MSc. Thesis Proposal

Title: Wind Turbine Surrogate Model for Digital Twinning

Supervisors
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Introduction
Motivation
A Digital Twin comprises a virtual model that aims at representing a real-world object through sensor-data being collected and sent in real-time. Such a solution enables a higher-level of scrutiny over the status of the system, with possible advantages in performance analysis, maintenance or even decision making. The wind energy industry is one of the many areas where Digital Twins are being developed [1], with one potential application being in the optimization of the turbine's performance based on environmental variables. Thus, two characteristics are necessary from the digital model: speed and accuracy. While the first can be easily achieved with well-known software, such as OpenFAST, these tend to have limited accuracy considering the low-fidelity models used. On the other hand, the higher accuracy of CFD simulations comes at a higher computational cost, prohibitive to be used in a real-time Digital Twin. This is where a Machine Learning based model can be advantageous: by being trained with high-fidelity data from CFD simulations, a model can be generated, which can then be quickly evaluated in a Digital Twin framework, to optimize the turbine's operating point.

Existing work
A surrogate model for the Wageningen B-series propeller has been developed by Boogaard et al. [2] by taking advantage of Geodesic Convolutional Neural Networks (GCNNs). By parametrizing the geometry of the family of propellers, the whole mesh generation and CFD simulation process was automatized and fed to the network for training. Based on the initial flow conditions, the final model was able not only to predict integral quantities of performance, but also a 2D plane of the flow – all with reasonable accuracy and speed. Another relevant work was performed by Molinaro et al. [3], which presented a framework that used Machine Learning to generate physics-based models, to substitute CFD simulations in various situations. One of the advantages pointed out was precisely the ability of getting a rich overview of the performance of a given system over a wide range of operating conditions, enabling relations to be established and mechanisms to be unveiled that would not be possible with a few CFD simulations.

Objectives
The objectives of this thesis are:

- To analyze existent Machine Learning strategies to generate physics-based surrogate models and select one to work with (potential candidate is GCNN);
- To generate a dataset of CFD simulations of a wind turbine using the CFD solver ReFRESCO (www.refresco.org);
- To train the ML-based surrogate model using the previous data-set;
- To couple the resulting model with a hypothetical Digital Twin;

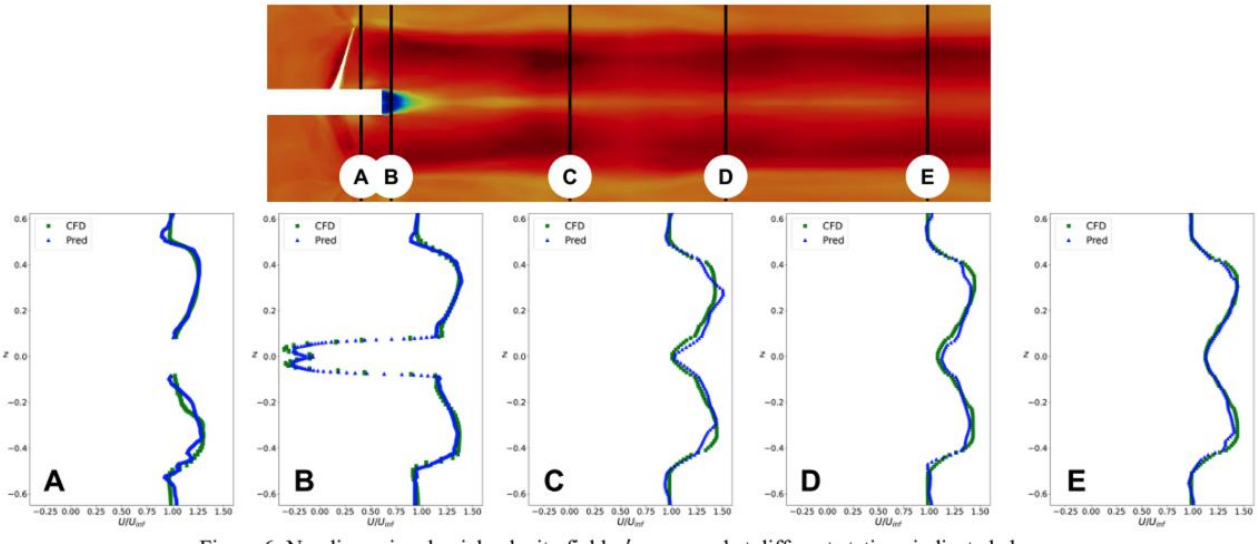

Figure 1: Wageningen B-series propeller wake: CFD vs. GCNN prediction [2].

The expected tasks are:

- Literature review on the existing methodologies;
- Identification of the environmental variables that would be fed by the sensors to the Digital Twin (wind speed, turbulence intensity, blade pitch, etc.)
- Generation of the data set, with automatization of the whole simulation process;
- Training of the ML algorithm with the data set, using state-of-the art techniques (e.g. Physics Informed Neural Networks) to maximize its accuracy and generalizability;
- Creation of a hypothetical Digital Twin, with sensor data being provided to the surrogate model, to evaluate its performance.

Requisites

Applicants must have:

- General knowledge on Artificial Intelligence.
- General knowledge on Fluid Dynamics and CFD.
- General knowledge on CAD software.
- Affinity with data processing.
- Coding experience with Python or similar.

Good to have:

- Linux experience.
- LaTeX experience.
- Git experience.

Location

blueOASIS (www.blueoasis.pt) Edifício D. Pedro, Quinta da Fonte, R. Malhões, 2770-071 Lisboa or Ericeira Business Factory, R. Prudêncio Franco da Trinitade 4, 2655-344 Ericeira.
The student must be present at the office **at least 4 days per week**. This is mandatory to pursue a thesis with blueOASIS.

Companies Involved

blueOASIS is a young team with more than 65 years of combined knowledge and experience on Aerospace, Mechanical, Naval and Maritime engineering. The multicultural and multidisciplinary team is committed to make our oceans safer and greener, using state of the art numerical and data science tools. BlueOASIS focuses on renewable energies, ocean cleaning, decarbonization, sustainable offshore structures and green ships optimization.

Bibliography

[1] P. Jamieson and L. Morgan, Trends, Prospects and R&D Directions in Wind Turbine Technology, vol. 2. Elsevier Ltd., 2022. doi: 10.1016/b978-0-12-819727-1.00176-x.

[2] M. van den Boogaard, G. Alessi, B. Mallol, D. Wunsch, and N. Clero, “Accelerating marine propeller development in early design stages using machine learning”.

[3] R. Molinaro, J. S. Singh, S. Catsoulis, C. Narayanan, and D. Lakehal, “Embedding data analytics and CFD into the digital twin concept,” Comput Fluids, vol. 214, p. 104759, 2021, doi: 10.1016/j.compfluid.2020.104759.