Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

Deutscher Akademischer Austauschdienst
German Academic Exchange Service

Linder Höhe
D-51147 Köln
Telephone: +49 (0)2203 601-0
Internet: https://www.dlr.de

Kennedyallee 50
D-53175 Bonn
Telephone: +49 (0)228 882-0
E-mail: dlr-daad-program@daad.de
Internet: https://www.daad.de/dlr

DLR – DAAD Fellowships

Fellowship No. 647

Research Area : Aeronautics

Research Topic: **Data-driven Turbulence Models using Machine Learning for Aerodynamic Applications**

DLR Institute: Aerodynamics and Flow Technology

Location: Göttingen, Germany

Position: Doctoral Fellow

Openings: 1

Job Specification: The global aviation currently contributes to 5% of anthropogenic climate change. This share is expected to increase due to the growth in aviation passenger traffic in the coming decades. In response, the European Commission has set ambitious goals to reduce CO2 emissions, for which substantial technological advancements are an indispensable component. New technologies promise drag reduction up to 50% leading to significant fuel savings. To mature these technologies, a new generation of intelligent aerodynamic simulation techniques is needed. A major challenge in aerodynamic simulation is the prediction of turbulent flows. Accurate predictions of turbulent flows are crucial for designing and operating many mission-critical systems, such as the aircraft itself and the aircraft engines. Traditionally, aircraft design relies on wind tunnel tests, supplemented by simplified and rapid computational fluid dynamics (CFD) simulations. These simulations, often based on the solution of the Reynolds-averaged Navier-Stokes (RANS) equations, only consider the statistically averaged mean quantities of turbulent flows. This approach leaves the intricate physics of aerodynamic turbulence to be modeled by a set of restrictive assumptions. As a result, RANS-based predictions are plagued with large uncertainties, compelling designers to incorporate substantial safety margins. Such conservatism often compromises the efficiency of the designed vehicles.

In contrast, the emergence of machine learning (ML) has opened up new opportunities for turbulence modeling to reexamine and revise the simplifying assumptions. In the past few years, researchers have used supervised ML and data to revise the underlying restrictive assumptions of RANS models, for example, by searching for nonlinear function relations in the form of neural networks or symbolic expressions, and to modify the turbulent transport equations, for example, through multiplicative correction terms. One of the promising methods is the field inversion and machine learning (FI/ML) approach proposed by Duraisamy et al. to modify the turbulent transport equations with multiplicative correction terms, which involves two steps: (i) field inversion where a RANS turbulence model correction term is determined by minimizing the deviation from the target data and (2) machine learning where the correction term is expressed as a functional relationship depending on selected characteristic properties of the local flow (features) through ML (for example, neural networks). Using these machine-learning methods, isolated turbulent flow phenomena could be predicted with significantly higher accuracy. We successfully applied FI/ML to the Spalart-Allmaras turbulence model, trained on two-dimensional airfoils for improving the prediction of pressure-induced trailing-edge separation. We obtained and published highly promising results for both, subsonic and transonic airfoil flows, also for a set of validation cases that were not part of training process (Grabe et al. and Jäckel).
An important step towards the industrial applicability of these so-called data-driven turbulence models is to ensure that the trained RANS models will not deteriorate the prediction for flows or for flow phenomena that were not part of the model training. Current research is directed towards tailored data-driven models (“agents”) for certain isolated flow phenomena which are locally blended and activated or de-activated in more complex flow fields, for example, de Zordo-Banliat et al., to generate improved predictions in the overall flow field.

With this PhD project we aim at achieving two goals. First, we want to apply our FI/ML workflow to new flow phenomena, for example, the reattachment of separated flow as it can be observed for a backward-facing step. This goal includes the selection of training data from various testcases and the training process using the FI/ML approach for the reattaching flow. The second step is to combine and blend two data-driven model corrections in a testcase that contains the different flow phenomena. For this second step, the currently available activation/de-activations functions need to be revisited and blended. Additionally, results from the literature for the blending of data-driven model corrections need to be adopted and tested. The topic of the PhD thesis will pave the way towards applying ML-based data-driven turbulence models to complex, industrially-relevant flows.
To strengthen the international collaboration on data-driven topics the PhD project is organized as a co-funded coupled PhD together with ONERA, that is, a close cooperation and exchange between the two PhD activities is planned. The two PhD projects are co-supervised at ONERA and DLR and mutual visits and research stays of the PhD candidates are expected.

Required Qualification: University degree in Mathematics, Computer Science, Data Science or Engineering (Aerospace engineering, mechanical engineering, or equivalent)

Knowledge and skills in
- Machine Learning and Artificial Intelligence
- High-level programming languages (C/C++, Python) with Linux/Unix
- High Performance Computing (HPC)

Capacity for teamwork

Good English skills

Advantageous Skills: Additional knowledge in Numerical Methods and/or Computational Fluid Dynamics (CFD), Aerodynamics and Turbulence Modeling is preferable

English competence: See requirements on www.daad.de/dlr

Earliest Start Date: 01-10-2024

Application Deadline: **15-07-2024**

Further Information: http://www.dlr.de
http://www.daad.de/dlr

More information may be obtained by contacting:

Andreas.krumbein@dlr.de
Cornelia.grabe@dlr.de

Thank you for your attention!
We look forward to receiving your application!