Abderahmane MAROUF,   University of Strasbourg

Title: Machine Learning and reduced order modelling for aerodynamic turbulent flows

Abstract:

In the context of the national French research project Electrical Multiscale Bio-inspired live skin Interfaces in Aeronautics “EMBIA” and the European project “BEALIVE”, a novel methodology is proposed to predict turbulent flow dynamics around wings using high-fidelity simulation in synergy with the Proper Orthogonal Decomposition ‘POD’ and Machine Learning algorithms based on the Long Short-Term Memory “LSTM” methodology. High Reynolds number of 1 million and an angle of attack of 10° have been fixed (figure 1). This will lead to a separated boundary layer near the trailing-edge region and therefore a formation of wake instabilities such as shear-layers and coherent structures leading to non-linear wake dynamics. Unsteady simulations using refined grids need a considerable time to converge and to calculate the statistics such as the mean drag and lift forces. Consequently, it is difficult to perform large parametric studies and it is impossible to use optimization algorithms to find best morphing wing configuration [1-5]. This work proposes a new methodology to reduce the time consumption of unsteady turbulent simulations while maintaining the non-linear character of the separated boundary layer and the sheared layers and therefore a better prediction of the aerodynamic forces could be achieved. The flow at the first is decomposed using POD, then temporal coefficients are used and predicted in time using the Machine Learning LSTM method. These predicted modes are then used for the reconstruction of the solution through the multiplication of the spatial and temporal modes. The high-fidelity solution will be prolongated in time which accelerates the prediction of the flow compared to an unsteady classical CFD simulation.

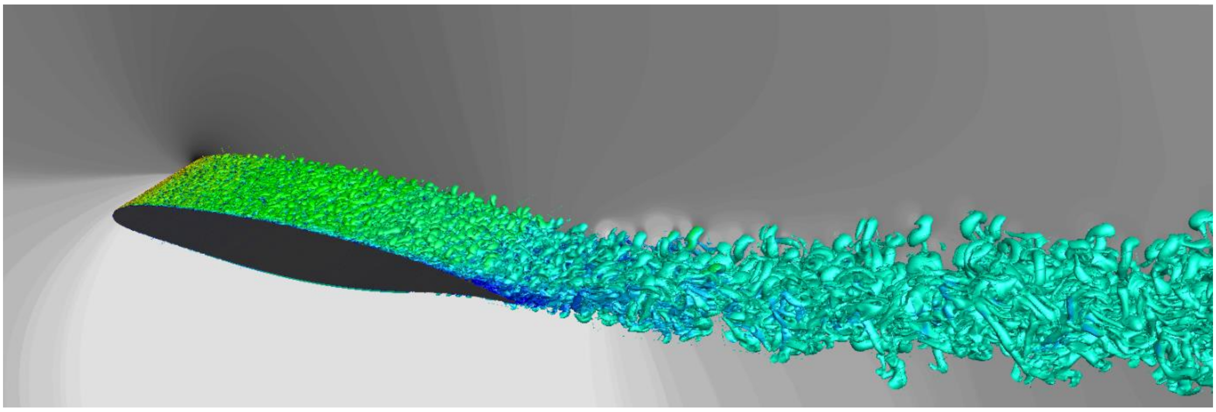

Figure 1: flow structures around the wing at high angle of attack and Reynolds number.

References:

1. Yannick T. Bmegaptche Tekap, Alexandre Giraud, Gurvan Jodin, Clément Nadal, Abderahmane Marouf, Isabel Gortazar Martinez, Dominique Harribey, Bertrand Nogarede, Jean-François Rouchon and Marianna Braza. "Design of a Large-Scale High-Lift Morphing A320 Wing Based on Electro-Mechanical Actuators and Shape Memory Alloys," AIAA 2019-2908. AIAA Aviation 2019 Forum. June 2019. https://doi.org/10.2514/6.2019-2908
2. Marouf, Y. Hoarau, J. B. Vos, D. Charbonnier, Y. Bmegaptche Tekap and M. Braza. "Evaluation of the aerodynamic performance increase thanks to a morphing A320 wing with high-lift flap by means of CFD Hi-Fi approaches," AIAA 2019-2912. AIAA Aviation 2019 Forum. June 2019. https://doi.org/10.2514/6.2019-2912
3. Abderahmane Marouf. Physical analysis of electroactive morphing concepts for the aerodynamic performance increase of future wing design through high-fidelity numerical simulation and turbulence modelling in high Reynols number. Diss. Ph. D. thesis, 2020, thèse de doctorat dirigée par Hoarau, Yannick et Braza, Marianna, Mécanique Des Fluides, Université de Strasbourg, 2020. URL https://www. theses.fr/s184078
4. Abderahmane, Marouf, et al. "DDES and OES simulations of a morphing airbus A320 wing and flap in different scales at high Reynolds." Progress in Hybrid RANS-LES Modelling: Papers Contributed to the 7th Symposium on Hybrid RANS-LES Methods, 17–19 September, 2018, Berlin, Germany. Springer International Publishing, 2020. https://doi.org/10.1007/978-3-030-27607-2_20
5. Marouf, A., Hoarau, Y., Rouchon, J.-F. and Braza, M. (2023), "Three-dimensional simulation effects of trailing-edge actuation on a morphing A320 wing by means of hybrid turbulence modelling", International Journal of Numerical Methods for Heat & Fluid Flow, Vol. 33 No. 4, pp. 1436-1457. https://doi.org/10.1108/HFF-09-2022-0559