Machine Learning approach POD-LSTM and reconstruction to reduced order modelling for aerodynamic turbulent flows

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In the context of the national French research project Electrical Multiscale Bioispired live-skin Interfaces in Aeronautics "EMBIA", a novel methodology is proposed to predict turbulent flow dynamics around wings using high-fidelity simulation in synergy with the Proper Orthogonal Decomposition[1] 'POD' and Machine Learning algorithms based on the Long Short-Term Memory[2] "LSTM" methodology. High Reynolds number of 1 million and an angle of attack of 10° have been fixed. 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. As consequently, it is difficult to perform large parametric studies and it is impossible to use optimisation algorithms to find best morphing wing configuration. 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. In this work, different methods of LSTM are analysed and compared with high-fidelity simulations.

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[1] L.Sirovich, *Quarterly of applied mathematics, 45(3):561-571,* (1987).

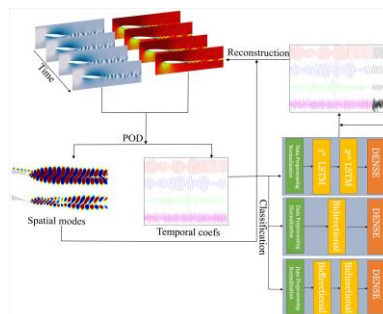[2] S. Hochreiter, J.Schmidhuber., *Neural Computation,* 9(8): (1997).

Figure 1: Description of the methodology POD-LSTM