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Deep-learning based aeroelastic modeling for transient flows and non-linear dynamics

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Supervised deep learning algorithms are investigated as reduced order models for the prediction of unsteady forces resulting from flow-induced vibrations of an elastically mounted structures. Several machine learning architectures, namely convolutional, echo state, and long-term memory networks, are deployed to model the transient aerodynamic force and the motion of the structure in the presence of nonlinear dynamics due to cubic structural forces or due to aerodynamic nonlinearities such as moving shock waves and vortex-shedding.

First, machine learning architectures are designed to handle the regression problem where the motion of the structure is learned only in the transient phase. A comparative study is performed to evaluate the accuracy of the prediction of limit cycle oscillations obtained for the case of the pitch and plunge airfoil problem[1], where a nonlinear cubic torsional stiffness is considered in order to observe sub- or super-critical Hopf bifurcations in the airfoil motion[2]. Then, a hybrid neural network architecture is proposed in order to parametrize the bifurcation diagram of the aeroelastic system across multiple coefficients in the nonlinear restoring force.

Finally, the present deep learning algorithm is employed as a meta-model to perform ensemble-based variational data assimilation[3] where pressure sensors, located in the wake flow, are used to identify the structural parameters of the spring-mass system subjected to flow-induced vibrations such as gallop and flutter mechanisms at low Reynolds number.

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