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Surrogate modeling of unsteady aerodynamic loads acting on a plunging airfoil

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Cost effective parameteric surrogate models of unsteady aerodynamic loads acting on a flapping wing are highly desirable. They would enable real time aerodynamic load prediction and optimal control of intelligent flapping wing flight devices. Given load time histories obtained for a sample of input parameters, parametric surrogate modeling[1] involve the following steps: (i) projection on to a lower dimensional space to obtain latent representations, (ii) regression of reconstruction coefficients as a function of the input parameters, and, (iii) prediction of the load time histories for previously unseen parametric instances. In the present work, we develop a hybrid Proper Orthogonal Decomposition(POD) based parametric surrogate model of the aerodynamic load time histories for unsteady flow past a plunging 2D airfoil. The load time histories are obtained for different plunging frequencies and amplitudes using an inhouse immersed boundary method based unsteady flow solver[2]. Given a fixed time window of the aerodynamic load time histories, POD is used to obtain the latent space representations for a sample of input kinematic parameters. A parametrised low rank approximation of the time histories is then obtained by a linear combination of the POD modes where the coefficients of linear combination are expressed as a function of the plunging frequency and amplitude. Parametric dependency of the coefficients of linear combination is then modeled using linear regression, polynomial regression and a feed forward neural network. The surrogate model predictions on unseen parametric instances are compared against true values to understand the generalisability of the hybrid POD surrogate model. As a result, a set of recommendations to appropriately choose the regression method is evolved.

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