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Title

Deep learning-based model for predicting the unsteady fluid-structure interaction of flapping wings

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Abstract

The significant interest in the research on flow physics of birds and insects has led to rapid developments in biologically-inspired micro aerial vehicles (MAVs) for surveillance and military use. While some MAVs have been developed, the underlying physics of the complex flapping wing motion must be better understood to design more efficient MAVs. The thrust generation from the wing flapping of insect motion requires careful analysis of the coupled aerodynamics and flight mechanics associated with evolution of the leading-edge vortices. Additionally, to develop highly manoeuverable MAVs, accurate flight controllers with a real-time prediction of nonlinear unsteady aeroelastic responses are required. To enable such real-time prediction of the complex fluid-structure interaction phenomena, we need reduced-order models which can learn the problem physics directly from data and perform generalised prediction over a wide range of operating conditions. Data-driven deep learning architectures like convolutional autoencoders have shown promise in generalised learning of complex flow physics in low-dimensions. Unlike projection-based dimensional reduction approaches, convolutional autoencoders have been efficient for learning low-dimensional models even for transport-driven flow phenomena. Thus, convolutional autoencoders have been integrated with data-driven nonlinear autoregressive model like long short-term memory recurrent neural networks for real-time prediction of flow physics around various slender structures. However, such integrated convolutional recurrent autoencoder networks have been primary employed for learning the flow fields around fixed solid interfaces. In this research, an approach for learning the flow-field around pitching and plunging aerofoils, similar to flapping motion, is presented via the convolutional recurrent autoencoder network. Here, a convolutional autoencoder with self-attention mechanism is integrated with a single-shot long short-term memory network to obtain the low-dimensional flow-field evolution model. The deep learning-based aeroelastic prediction methodology presented here can be applied for real-time control and design of MAVs.

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