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PROCEEDINGS

Efficient Flow Prediction and Active Control based on Deep Learning Reduced-Order Modeling

Jiaxin Wu [1, 2], Yi Zhan [1], Min Luo [1, *] and Boo Cheong Khoo[2]

[1]Ocean College, Zhejiang University, Zhoushan, 316021, China

[2]Department of Mechanical Engineering, National University of Singapore, Singapore, 117575, Singapore

[*]Corresponding Author: Min Luo. Email: min.luo@zju.edu.cn

ABSTRACT

Research on the mechanism of fluid flows (particularly nonlinear) on solid structures is of great scientific and engineering significance, as well as to implement effective control by using intelligent solid structures (i.e., agents). These dynamical systems involve complex interactions of fluid dynamics and solid mechanics and, thus are typically defined as fluid-structure interaction (FSI) problems. For effective analysis of FSI systems and implementing active control, numerical modeling that couples fluid and solid solvers proves to be an effective approach. However, the efficiency and accuracy of conventional numerical methods for solving such problems are limited due to their intrinsic high nonlinearity and dimensionalities, further posing substantial challenges for implementing effective flow control. In response to these challenges, this study proposes a reduced-order model (ROM) based on deep learning, which efficiently and accurately solves FSI problems. The model utilizes deep learning to perform a nonlinear coordinate transformation between the full-state flow fields and the low-dimensional subspace, which dominantly governs the dynamical evolution of systems and thus is capable of performing an efficient control agent in reinforcement learning. Additionally, this model proposes a physics-oriented subnetwork for quantifying the dynamical stability of FSI system's intrinsic mechanisms from the frequency perspective. The numerical results demonstrate the effectiveness and remarkable improvements of this proposed deep-learning ROM in solving fluid problems and implementing active control.

KEYWORDS

Reduced-order model; fluid-structure interaction; deep learning; flow control

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