Proceedings of the 1st international Symposium on AI and Fluid Mechanics
Abstract No S12 A2

A priori and a posteriori tests of data-driven cavitation model

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Abstract

The final goal of this study is to develop a "data-driven cavitation model" based on a machine learning model. Unlike conventional deductive mathematical models, data-driven models are expected to be able to inductively create phenomenon-based models that do not contain artificial approximations or assumptions when trained in appropriate settings. We test the framework of the data-driven cavitation model a priori and a posteriori by using CFD data as a training dataset.

The analysis object is the cavitating flow around a hydrofoil. Cavity is expressed by the liquid volumetric fraction at each cell, and the training dataset consists of the flow field at the current timestep and those at the next timestep. As the problem setting, it is assumed that the liquid volumetric fraction obeys the transport equation with a source term. Two data-driven models are trained: a coefficient in the source term, and a mask function that indicates whether cavitation occurs or not in each cell. By combining these two models, we predict the time evolution of the transport equation for the liquid volumetric fraction. The neural network for both models is basically based on U-Net, which is one of convolutional neural networks (CNN). However, to predict the local unsteady phenomena more accurately, Partial Convolutional Networks is employed instead of the original CNN which is included in U-net. In addition, max-pooling layers are replaced with wavelet layers.

In a priori test, the data-driven model can predict the field of the next step, except for the trailing edge where the cavity grows rapidly. The time evolution of the maximum error in the liquid volumetric fraction field is also very small. However, in a posteriori test, computation becomes unstable where cavity grows rapidly and pressure waves are generated due to cavity volume fluctuations, suggesting that a data-driven cavitation model needs further improvements to robustly capture such highly unsteady phenomena.

Keywords: Cavitation, Machine learning, Computational Fluid Dynamics, Data-driven model

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