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Fast predicting the transfer function in absence of system matrices using model reduction and machine learning

Content

We propose a novel technique of fast predicting the transfer function lacking information of system matrices by combining machine learning with model order reduction. The transfer function of a linear time invariant system can be written as $H(s) = CG(s)^{-1}B$. In some situations, it is difficult to obtain the individual system matrices that are implicitly included in $G(s)$. The only information available is the data of $G(s)$ at samples of frequency s. The proposed method derives a reduced-order model of the transfer function in the form of neural networks using limited data of $G(s)$. Discrete structure-preserving reduced transfer functions at training samples $s_i, i = 1, \ldots, l$, of the frequency are firstly generated based on the data of $G(s)$ at those training samples, i.e. $\hat{H}(s_i) = \hat{C}\hat{G}(s_i)^{-1}\hat{B}$. A reduced-order model of the original transfer function as a continuous function of the frequency is then learned using the data of the discrete reduced transfer functions. The original transfer function at any testing frequencies can then be quickly predicted using either a compact machine learning model or a deep learning model with a few layers. The discrete reduced transfer functions used as training data for machine learning are guaranteed to be accurate thanks to a cheap and sharp error estimator. If only the data of the original transfer function are available, then the proposed machine learning method and deep learning method can be directly applied without generating the data of the discrete reduced transfer functions. The proposed methods are tested on two PEEC models with many delays, efficiency and accuracy of the reduced-order models are demonstrated.

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