Parametric dynamic mode decomposition for nonlinear parametric dynamical systems

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A non-intrusive model reduction method which combines features of the dynamic mode decomposition (DMD) and the radial basis function (RBF) as a network, is proposed to predict the dynamics of parametric nonlinear dynamical systems. In lots of applications, the information of the whole system is not accessible, which motivates non-intrusive model reduction. The most complex point is to capture the dynamics of the solution without knowing the physics inside the "black-box" system. DMD is a powerful tool to mimic the dynamics of the system and give a reliable approximation in the time domain using only the dominant DMD modes. However, DMD cannot reproduce the parametric behaviour of the dynamics.

Our contribution focuses on extending DMD to parametric DMD by RBF interpolation. Specifically, a RBF network is first trained using snapshots at limited parameter samples. The snapshot matrix learned by the RBF network at any new parameter is passed to DMD to predict the time patterns of the dynamics corresponding to this new parameter sample. The proposed formulation and algorithm are tested and validated with numerical examples including models with parametrized and time-varying inputs. One of them is a complex and nonlinear Pseudo-two-dimensional (P2D) battery model, which is sequentially excited by a periodic current signal at a defined amplitude $0.77A$ but parametrized with the frequency $\omega \in [10^{-3}, 10^{4}]Hz$. We study the behaviour of the voltage as the output response to the parametrized current. In Figure 1, the time-evolution of the output at a new specific frequency $\omega^* = 3.69Hz$ computed by the proposed parametric DMD is compared with the reference solution obtained from direct numerical simulation as well as the solution computed by the RBF network only. The green lines separate the whole simulation into the training phase and the prediction phase. While the RBF solution cannot commit predictions beyond the training time period $[0, 0.6748s]$, it shows the prediction quality in the parameter domain. The DMD-RBF solution computed by the proposed method demonstrates good predictive performance in both the parameter and the time domain, which shows the flexibility and stability of the proposed parametric DMD.

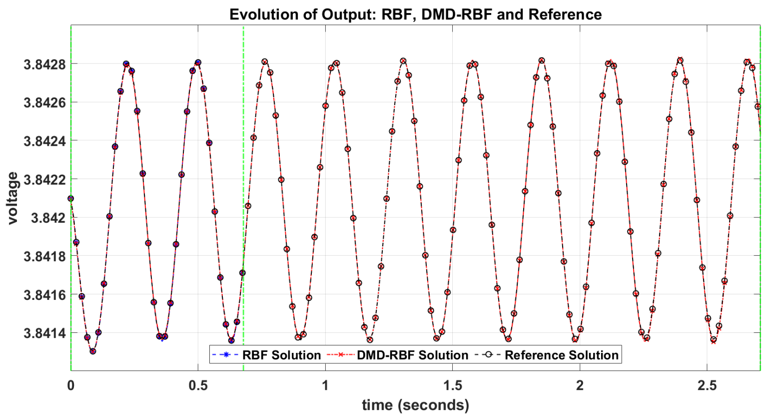

Figure 1: DMD-RBF prediction of the evolution of the voltage in a P2D-battery model