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On analytical construction of observable functions in extended dynamic mode decomposition for nonlinear estimation and prediction

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Abstract—We propose an analytical construction of observable functions in the extended dynamic mode decomposition (EDMD) algorithm. EDMD is a numerical method for approximating the spectral properties of the Koopman operator. The choice of observable functions is fundamental for the application of EDMD to nonlinear problems arising in systems and control. Existing methods either start from a set of dictionary functions and look for the subset that best fits the underlying nonlinear dynamics or they rely on machine learning algorithms to "learn" observable functions. Conversely, in this paper, we start from the dynamical system model and lift it through the Lie derivatives, rendering it into a polynomial form. This proposed transformation into a polynomial form is exact, and it provides an adequate set of observable functions. The strength of the proposed approach is its applicability to a broader class of nonlinear dynamical systems, particularly those with non-polynomial functions and compositions thereof. Moreover, it retains the physical interpretability of the underlying dynamical system and can be readily integrated into existing numerical libraries. The proposed approach is illustrated with an application to electric power systems. The modeled system consists of a single generator connected to an infinite bus, where nonlinear terms include sine and cosine functions. The results demonstrate the effectiveness of the proposed procedure in off-attractor nonlinear dynamics for estimation and prediction; the observable functions obtained from the proposed construction outperform methods that use dictionary functions comprising monomials or radial basis functions.

References

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