Detection of parameter-dependent regimes in complex flows via compressed sensing and dynamic mode decomposition

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Complex flows are parameter dependent and are sensitive to changes in flow topology. Designing controllers and observers for such systems is challenging due to the shear size of the state-space as well as the parametric dependence. Reduced order models combined with an online estimate of the current parameters can be used for observer and controller design for such complex systems.

Using sparse sensing and reconstruction techniques, we present a framework to detect dynamical phenomena such as bifurcations and changes in flow topology in thermo-fluid dynamical systems. First, a library of reduced order models of dynamic regimes is constructed, and online measurements are used to identify the dynamic regime the flow resides at. The proposed method is based on dynamic mode decomposition [2, 3] to obtain a low dimensional representation of the dynamics, and compressed sensing [1], which allows for the use of few sensors to achieve the classification task. Moreover, by processing time-sequential information from the sparse sensor array, the algorithm shows improved robustness to noise. The method is purely data-driven, and can therefore be used in conjunction with experimental or simulation data. This framework can be combined with adaptive reduced order models for improved observation and control. Numerical results for the case of Navier-Stokes and Boussinesq equations are presented.

References

[1] E. J. Candès. Compressive sampling. In *Proceedings oh the International Congress of Mathematicians: Madrid, August 22-30, 2006: invited lectures*, pages 1433–1452, 2006.

[2] C. W. Rowley, I. MEZIĆ, S. Bagheri, P. Schlatter, and D. S. Henningson. Spectral analysis of nonlinear flows. *Journal of Fluid Mechanics*, 641:115–127, 2009.

[3] P. J. Schmid. Dynamic mode decomposition of numerical and experimental data. *Journal of Fluid Mechanics*, 656:5–28, 2010.