POD for the Study of Unsteady Behaviors with Adjustable Realistic Units

Bastien Lagneaux*[1], Gurvan Jodin[2,3], and Florence Razan[1]

[1]Institut d'Électronique et des Technologies du numéRique – Université de Rennes, Institut National des Sciences Appliquées - Rennes, CentraleSupélec, Centre National de la Recherche Scientifique, Nantes Université - pôle Sciences et technologie – France

[2]Systèmes et Applications des Technologies de lÍnformation et de lÉnergie (SATIE) – École normale supérieure - Cachan, Université Paris-Sud - Paris 11, École normale supérieure - Rennes, Université de Cergy Pontoise : UMRCNRS 8029, Conservatoire National des Arts et Métiers [CNAM], Centre National de la Recherche Scientifique : UMR8029, Institut français des sciences et technologies des transports, de l'aménagement et des réseaux : UMR8029, école normale supér – 61 av du President Wilson 94235 CACHAN Cedex, France

[3]École Normale Supérieure de Rennes (ENS Rennes) – - – École normale supérieure de Rennes Campus de Ker Lann Avenue Robert Schuman 35170 BRUZ - France, France

Résumé

Proper Orthogonal Decomposition (POD) is a powerful mathematical technique for dimensionality reduction, applicable across various scientific disciplines. In hydrodynamics, where experiments and simulations lead to very large amount of spatio-temporal data, POD has been deeply studied, particularly when applied to fixed cylinders periodic flow at low Reynolds numbers. Since Noack's seminal work in 2003, this method has been augmented with a shift mode, thus highlighting the inherent limitations of POD even in these classical settings, underscoring challenges in capturing transient dynamics effectively.
This study addresses the efficacy of POD in less conventional and more complex fluid dynamics scenarios, for which a custom data set has been generated through CFD. Here we show that the sensitivity of POD to changes in system parameters-specifically the gap between a cylinder and a wall, and the Reynolds number-can significantly affect the quality of dimensionality reduction and reconstruction achieved. Our results indicate sensitivity is mainly related to the gap width, as it as already been demonstrated to be the case for more classical hydrodynamics parameters, for example in Prices 2002's work.

Contrary to common perceptions of POD as a robust tool for reducing dimensionality to a manageable number of modes (typically five to nine), our findings suggest that in more realistic scenarios, such reductions could lead to substantial reconstruction errors. These errors far exceed those observed in simpler, more controlled experiments.

Further exploration of POD's applicability aims to reveals that its performance also varies with the cylinder's motion relative to boundaries, the observation window, and the resolution of the simulation. Such findings prompt a reevaluation of the conventional wisdom regarding the capabilities of POD in fluid dynamics.

*Intervenant

In broader terms, this study not only challenges existing assumptions about the utility of POD in complex scenarios but also sets the stage for future research to optimize and adapt dimension reduction techniques to better suit realistic applications in scientific and engineering fields.