DATA-DRIVEN METHODS FOR PATIENT-SPECIFIC REDUCED ORDER MODELING OF COMPLEX AORTIC FLOWS

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Introduction

Data-driven approaches offer great potential to overcome the challenge of high computational cost associated with Computational Fluid Dynamics (CFD) in cardiovascular biomechanics [1]. The need for fast and accurate models has led to the exploration of Proper Orthogonal Decomposition (POD) to create Reduced Order Models (ROMs) that can provide efficient and accurate representations of flow field data, which may be obtained from in-vivo or in-vitro experiments [1, 2]. However, these flow field data are often noisy, and POD may not be effective in handling such noise. This study aims to investigate the use of Robust Proper Orthogonal Decomposition (RPOD) algorithm in cardiovascular biomechanics [3]. The effectiveness of the RPOD method is evaluated in comparison to the traditional POD method in reconstructing the flow dynamics inside a personalized human dissected aorta.

Methods

The flow data is obtained from an in-vitro Particle Image Velocimetry (PIV) experiment using a patient-specific phantom and boundary conditions. [4] This data has been used to validate CFD-derived flow fields with similar settings [5]. The measured flow field is decomposed into multiple POD and RPOD modes. Using these modes, Reduced Order Models (ROMs) are created for both POD and RPOD. The number of modes used for each ROM is 2, 10, and all available modes. The kinetic energy and reconstruction error of each ROM are then calculated.

Results

Modes included	POD		RPOD	
	Energy	Error	Energy	Error
1-2	86.33%	34.18%	98.15%	13.10%
1-10	91.72%	27.06%	99.78%	7.85%
all	~100%	~0%	~100%	~0%

Table 1: Percentage of energy captured in ROMs created from POD and RPOD

Table 1 shows that when using the same number of modes, ROMs based on RPOD capture a greater portion of kinetic energy and have a lower reconstruction error compared to ROMs based on traditional POD. The RPOD reconstructed flow field also appears to be spatially and temporally smoother compared to the original flow field.

However, the Full Order Model (FOM) calculated from RPOD method shows a significant difference compared to the traditional POD based FOM during diastole. (Figure 1) The velocity magnitude of the FOMs from RPOD ranges from 0 to 0.2237 m/s, while the original flow field from 0 to 0.3276 m/s at diastole.

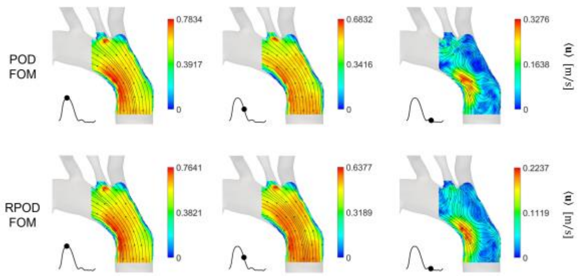

Figure 1: FOM reconstructions of aortic flow: (top) by traditional POD, and (bottom) by RPOD.

Discussion

RPOD has been shown to outperform the traditional POD in reconstructing in vitro aortic flow dynamics due to its ability to filter out noise in the data. This shows the potential of RPOD in enhancing in-vivo velocity measurements obtained via medical imaging techniques. RPOD may over-filter certain parts of the flow field and further work on tuning of the filtering parameter might be worth exploring. Further work on coupling ROMs with machine learning algorithms to reconstruct aortic flows is currently underway.

References

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