# Dimensionality reduction and physics-based manifold learning for parametric models in biomechanics and tissue engineering

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## ABSTRACT

This work aims at describing dimensionality reduction methods, particularizing in Principal Component Analysis (PCA), the nonlinear version kernel Principal Component Analysis (kPCA) [1], and their potential application to data-assisted Credible models in biomechanics and tissue engineering. These methodologies are intended to discover the low dimensional manifold where an input physical data set lives. Reducing the dimensionality of a complex physical system is a potential tool towards real time Credible and accurate parametric models and patient-specific simulations.

In this direction, the Proper Orthogonal Decomposition (POD) combines PCA with a reduced basis approach to reduce the number of degrees of freedom in parametric boundary value problems. Additionally, for systems whose solutions belong to nonlinear manifolds, kernel Proper Orthogonal Decomposition (kPOD) uses kPCA reduction to find a solution of the problem. The main features of kPOD are the use of local approximations, the possibility of enriching the reduced space with quadratic elements, the use of ad-hoc kernels that include previous knowledge of the input data, and the idea of using an iterative algorithm that explores the Voronoi diagram of the snapshots in the reduced space [2]. Besides, dimensionality reduction in combination with surrogate modelling aims at finding initial (and accurate) approximations of parametric systems without physics involved. All presented methodologies are shown to be strong tools in several fields.

To show the potential of those techniques, here we present several examples of application in the biomechanical field, such as advection diffusion in scaffolds for tissue engineering, and vascular biomechanics.

## REFERENCES

[1] Alba Muixí, Alberto García-González, Sergio Zlotnik, and Pedro Díez. "Linear and nonlinear dimensionality reduction of biomechanical models." *Book Chapter of Book Reduced Order Models for the Biomechanics of Living Organs". Editors: Francisco Chinesta, Elias Cueto, Yohan Payan, Jacques Ohayon. Hardback ISBN: 9780323899673. 1st Edition - March 1st, 2023, Elsevier. Book Chapter*

[2] Díez, P., Muixí, A., Zlotnik, S., & García-González, A. (2021). "Nonlinear dimensionality reduction for parametric problems: A kernel proper orthogonal decomposition." *International Journal for Numerical Methods in Engineering, 122(24), 7306-7327.*