ECCOMAS
European Community on
Computational Methods in
Applied Sciences

ECCOMAS
Thematic Conference

# MORTech 2019
## 5th international Workshop
## Reduced Basis, POD and PGD
## Model Reduction Techniques

November 20-22, 2019 @ FIAP Jean Monnet Conference Center
PARIS

An IACM Special Interest Conference

mortech2019.sciencesconf.org

co-organized by
LMT (ENS Paris-Saclay/CNRS/Université Paris-Saclay)
PIMM (Arts et Métiers ParisTech, CNRS, CNAM)

# Reduced Basis, POD and PGD Model Reduction Techniques

## Co-Chairmen

P. Ladevèze - LMT (ENS Paris-Saclay/CNRS/Université Paris-Saclay)

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## Scope

Mechanics, like other domains, continues to supply numerous engineering problems which, despite the impressive progress of computational simulation techniques, remain intractable today. RB, PGD and other model reduction methods are leading to a new generation of high-performance computational tools which provide solutions to engineering problems which are inaccessible to standard codes based on classical and well-established numerical techniques.

The workshop is intended to be a meeting ground for the various contributors, including mechanicians, applied mathematicians and other researchers and engineers involved in testing and computation. The Workshop should provide answers to such questions as:

- What are the maturity and the benefits of RB and POD/PGD methods?
- What are also their limitations?
- What engineering challenges, especially in mechanics, could be addressed in the near future?
- What are the key scientific issues?

## Main topics

- Convergence, verification and adaptive approaches
- ROM for large numbers of parameters and nonlinear problems
- Uncertainty quantification and propagation
- Multiscale and multiphysics problems
- Quasi-real-time simulations: control, optimization, design...
- Data-based and data-driven ROM
- Non-invasive approaches
- Engineering applications

## Local organizing and scientific committee

P.-A. Boucard (ENS Paris-Saclay), L. Chamoin (ENS Paris-Saclay), F. Chinesta (ENSAM Paris), C. Farhat (Stanford Univ.), P.-A. Guidault (ENS Paris-Saclay), P. Ladevèze (ENS Paris-Saclay), D. Lange (NAFEMS), Y. Maday (Sorbonne Université), D. Néron (ENS Paris- Saclay).

## Advisory scientific committee

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## Practical information

The Lisbonne and Berlin rooms are located on level -2.
Coffee breaks will be held at level 0.
The "Wine and Cheese" Poster session will take place on level 0.
Finally, lunches will be taken at level 1 where the restaurant is located.

For your presentation, a MacBook Pro (Catalina OS) with Acrobat Reader DC, Office for Mac (PowerPoint) 2019 and Keynote 9 is available.
VLC media player 3 for videos is also installed.
Please bring your presentation material with USB memory device and install it on the computer **before the beginning of the session.**
You can use your own computer **as soon as you have ensured that it is working properly on the beamer.**

Oral presentations will be **30 min long,** including **5 minutes** of discussion.

***Session Chairs will enforce these times strictly and will stop presentations that run over time.***

A wifi access is available in each conference room.
The SSID (name) of the WiFi network is: **WIFIAP**
It is an open wireless network so you don't need any password.

You need assistance?

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# Low-order feature extraction technique and unsupervised learning for SHM under high-dimensional data

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## Abstract

Data-driven damage localization is a demanding process for vibration-based structural health monitoring (SHM) strategies. The ability to locate single and multiple damage states featuring different severity levels, particularly the smaller ones, plays a prominent role in establishing an effective and robust method for damage assessment. The statistical pattern recognition paradigm based on feature extraction and statistical decision-making can be a successful framework for this process [1,2]. In case of data gathered by dense sensor networks, which provide vibration datasets of high dimensionality and large volume, this framework may be time-consuming or complex; it also results questionable whether existing order selection techniques are able to provide a low-order feature extraction approach [1]. Furthermore, a fast decision-making process within an unsupervised learning strategy can help overcome the main obstacles experienced in the accurate localization of damage, if large volumes of damage-sensitive features are extracted from high-dimensional samples gathered by the mentioned dense sensor networks. In this study, we propose an efficient unsupervised learning method for feature extraction by an iterative approach based on order reduction in AutoRegressive (AR) modelling [3], and for damage localization through a statistical distance method termed Kullback-Leibler Divergence with Empirical Probability Measure (KLDEPM).

The proposed iterative feature extraction approach mainly aims at model order reduction. In the training phase, this is accomplished simultaneously with parameter estimation and residual extraction; in the following monitoring phase, the low-order AR model is adopted to only extract the new residuals. With this approach, correlated residual samples of the AR model are adopted as a new time series dataset to reduce the model order at each iteration. This strategy is shown to effectively and efficiently reduce the order of the AR model necessary for feature extraction. Selecting a reduced AR order that guarantees model sufficiency and accuracy by generating uncorrelated residuals is

therefore the main strength of the proposed order selection method; in case of an inadequate order selection, the model may not be able to capture the underlying dynamics of the structure, and lead to the extraction of features insensitive to damage.

The proposed KLDEPM, which is an enhancement of the classical KLD technique, next exploits a segmentation technique to subdivide the handled random data (i.e. the AR model residuals relevant to the virgin and damaged conditions) into independent segments, and compute a distance between the features relevant to the training stage and those relevant to the monitoring stage, based on the theory of empirical probability measure. This procedure provides an effective distance approach for damage identification and a fast tool for decision-making. To establish an unsupervised learning strategy, a threshold limit is determined by computing the mean of the 95% confidence intervals of distance quantities obtained from the virgin conditions in the training phase. The sensor location(s) associated with the KLDEPM value(s) greater than the threshold limit is (are) identified as the damaged area(s) of the structure.

Numerical concrete beam and IASC-ASCE experimental benchmarks are considered to assess the accuracy of the proposed SHM method, and the improvement in the performance (in terms of feature extraction and damage localization) against alternative approaches available in the literature. More specifically, the proposed order selection method aimed at reducing the model order is compared with the state-of-the-art Bayesian Information Criterion technique, and with a conventional residual-based feature extraction approach. Furthermore, the method is benchmarked by the classical KLD technique and the Kolmogorov–Smirnov test. Results demonstrate that both the iterative feature extraction technique and the KDLEPM method are superior to their counterparts, and provide fast unsupervised learning strategies to extract reliable damage-sensitive features and locate single and multiple damages of different severities.

# References


[1] C.R. Farrar, K. Worden, Structural Health Monitoring: A Machine Learning Perspective, John Wiley & Sons Ltd, 2013.

[2] F. Kopsaftopoulos, S. Fassois, Vibration based health monitoring for a lightweight truss structure: experimental assessment of several statistical time series methods, *Mechanical Systems and Signal Processing*, 24:1977-1997, 2010.

[3] G.E. Box, G.M. Jenkins, G.C. Reinsel, G.M. Ljung, Time series analysis: forecasting and control, Fifth ed., John Wiley & Sons, 2015.

# Supporting organizations