SISSA mathLab

Main references and open source software for (aeronautical, mechanical, automotive, nuclear, industrial, sport) engineering problems

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October 2022

The following is a comprehensive list of the SISSA mathLab publications in different engineering fields together with a brief introduction of each one of them. The next page presents all the open source software libraries developed by the group in the same context.

A presentation of **different geometrical parameterisation techniques** and **data-driven model order reduction techniques** such as POD with interpolation and dynamic mode decomposition (DMD), for an integrated optimization pipeline:

- M. Tezzele, N. Demo, A. Mola, and G. Rozza. ***An integrated data-driven computational pipeline with model order reduction for industrial and applied mathematics***. In M. Günther and W. Schilders, editors, Novel Mathematics Inspired by Industrial Challenges, number 38 in Mathematics in Industry. Springer International Publishing, 2022. [arxiv] [doi].

Parameter space dimensionality reduction through active subspaces (AS) with heterogeneous parameters.

- M. Tezzele, F. Salmoiraghi, A. Mola, and G. Rozza. ***Dimension reduction in heterogeneous parametric spaces with application to naval engineering shape design problems.*** Advanced Modeling and Simulation in Engineering Sciences, 5(1):25, Sep 2018. [arxiv] [doi].
- F. Romor, M. Tezzele, and G. Rozza. ***A local approach to parameter space reduction for regression and classification tasks.*** Submitted 2021. [arxiv].

Structural optimization of passenger ship hulls with both model and parameter space reduction.

- M. Tezzele, L. Fabris, M. Sidari, M. Sicchiero, and G. Rozza. ***A multi-fidelity approach coupling parameter space reduction and non-intrusive POD with application to structural optimization of passenger ship hulls.*** To Appear in International Journal for Numerical Methods in Engineering, 2022. [arxiv].

Comparison between data driven model order reductions techniques such as DMD and POD with interpolation for **hydroacoustics analysis**, using LES full order simulations on a benchmark problem.

- M. Gadalla, M. Cianferra, M. Tezzele, G. Stabile, A. Mola, and G. Rozza. ***On the comparison of LES data-driven reduced order approaches for hydroacoustic analysis.*** Computers & Fluids, 216:104819, 2021. [arxiv] [doi].

Coupling of parameter space reduction and non-intrusive reduced order modeling for structural and CFD problems:

- N. Demo, M. Tezzele, and G. Rozza. ***A non-intrusive approach for proper orthogonal decomposition modal coefficients reconstruction through active subspaces.*** Comptes Rendus de l'Académie des Sciences, DataBEST 2019 Special Issue, 2019. [arxiv].

Shape optimization using OpenFOAM solver, free form deformation for the geometrical parameterisation, DMD to accelerate the single simulation, and POD with interpolation to construct the surrogate model to optimize:

- N. Demo, M. Tezzele, G. Gustin, G. Lavini, and G. Rozza. ***Shape optimization by means of proper orthogonal decomposition and dynamic mode decomposition***. In Technology and Science for the Ships of the Future: Proceedings of NAV 2018: 19th International Conference on Ship & Maritime Research, pages 212–219. IOS Press, 2018. [arxiv] [doi].

Few contributions that employ AS to assess che parameter influence on the target functions and **reduce the dimension of the parameter space**:

- M. Tezzele, N. Demo, and G. Rozza. ***Shape Optimization through Proper Orthogonal Decomposition with Interpolation and Dynamic Mode Decomposition Enhanced by Active Subspaces.*** In The Proceedings of VIII International Conference on Computational Methods in Marine Engineering, pages 122–133, 2019. [arxiv] [doi].
- A. Mola, M. Tezzele, M. Gadalla, F. Valdenazzi, D.Grassi, R. Padovan, and G. Rozza. ***Efficient Reduction in Shape Parameter Space Dimension for Ship Propeller Blade Design***. In The Proceedings of VIII International Conference on Computational Methods in Marine Engineering, pages 201–212, 2019. [doi].

Reduced order models for CFD problems using the FV method with and without heat transfer, with some applications in industrial flows**:**

- G. Stabile, G. Rozza. ***Finite volume POD-Galerkin stabilised reduced order methods for the parametrised incompressible Navier–Stokes equations***. Computers & Fluids. 2018. [arxiv] [doi].
- S. Georgaka, G. Stabile, G. Rozza, and M. J. Bluck. ***Parametric POD-Galerkin Model Order Reduction for Unsteady-State Heat Transfer Problems***. Communications in Computational Physics, 2019. [arxiv].

Reduced order models for CFD problems using the Discontinuous Galerkin Method, with applications related to weakly compressible flows.

Combination of data-driven and intrusive reduced order modeling techniques for fluid dynamics problem with and without heat transfer, with some applications in industrial engineering field:

- S. Hijazi, G. Stabile, A. Mola, and G. Rozza. ***Data-Driven POD-Galerkin Reduced Order Model for Turbulent Flows***. Submitted, Journal of Computational Physics, 2019. [arxiv].
- S. Hijazi, S. Ali, G. Stabile, F. Ballarin, and G. Rozza. ***The Effort of Increasing Reynolds Number in Projection-Based Reduced Order Methods: from Laminar to Turbulent Flows***, FEF special Volume, 2018. [arxiv].
- S. Georgaka, G. Stabile, K. Star, G. Rozza, and M. J. Bluck. ***A Hybrid Reduced Order Method for Modelling Turbulent Heat Transfer Problems***. Submitted, Computers and Fluids, 2019. [arxiv].

UQ techniques for CFD problems using reduced order models:

- S. Hijazi, G. Stabile, A. Mola, and G. Rozza. ***Non-Intrusive Polynomial Chaos Method Applied to Full-Order and Reduced Problems in Computational Fluid Dynamics: a Comparison and Perspectives***. QUIET special volume, 2019. [arxiv]**.**

Geometrical parametrization for heat transfer and fluid dynamics problems:

- G. Stabile, M. Zancanaro, and G.Rozza. ***Efficient Geometrical parametrization for Finite-Volume based Reduced Order Methods***. Submitted, IJNME, 2019. [arxiv].

SISSA mathLab Open Source Software and Tools

The complete list of SISSA mathLab software is available on GitHub and on SISSA mathLab website**,** here we present the most interesting ones from a naval engineering point of view.

PyGeM (Python Geometrical Morphing) is a package that allows you to deform a given geometry or mesh with different deformation techniques such as Free Form Deformation, Radial Basis Functions and Inverse Distance Weighting. [github] [SISSA mathLab].

- F. Salmoiraghi, A. Scardigli, H. Telib, and G. Rozza, ***Free Form Deformation, mesh morphing and reduced order methods: enablers for efficient aerodynamic shape optimization,*** Int. J. CFD, 2018 [arxiv].

EZyRB (Easy Reduced Basis method) is a package to perform non-intrusive model order reduction based on Proper Orthogonal Decomposition. [github] [SISSA mathLab].

- N. Demo, M. Tezzele, and G. Rozza. EZyRB: ***Easy Reduced Basis method.*** The Journal of Open Source Software, 3(24):661, 2018. [doi].

PyDMD is a package that uses Dynamic Mode Decomposition for a data-driven model simplification based on spatiotemporal coherent structures. [github] [SISSA mathLab].

- N. Demo, M. Tezzele, and G. Rozza. ***PyDMD: Python Dynamic Mode Decomposition.*** The Journal of Open Source Software, 3(22):530, 2018. [doi].

ITHACA-FV is an implementation in OpenFOAM of several reduced order modelling techniques. [github] [SISSA mathLab].

- G. Stabile, G. Rozza. ***Finite volume POD-Galerkin stabilised reduced order methods for the parametrised incompressible Navier–Stokes equations.*** Computers & Fluids. 2018. [doi] [arxiv].

ATHENA is a Python package for reduction of high dimensional parameter spaces. It implements several dimensionality reduction techniques such as Active Subspaces (AS), Kernel-based Active Subspaces (KAS), and Nonlinear Level-set Learning (NLL). [github] [SISSA mathLab].

- F. Romor, M. Tezzele, and G. Rozza, ***ATHENA: Advanced Techniques for High dimensional parameter spaces to Enhance Numerical Analysis,*** Software Impacts, 10:100133, 2021. [doi].

BladeX (Python Blade Deformation) is a Python package for geometrical parametrization and bottom-up construction of propeller blades. It allows to generate and deform a blade based on the radial distribution of its parameters. [github] [SISSA mathLab].

- M. Gadalla, M. Tezzele, A. Mola, and G. Rozza. ***BladeX: Python Blade Morphing.*** The Journal of Open Source Software, 4(34):1203, 2019. [doi].

ITHACA-DG is an implementation in HopeFOAM (an extension of OpenFOAM) of reduced order modelling techniques starting from high order simulations based on the Discontinuous Galerkin Method. [github] [SISSA mathLab].

Projects

ARIA, ERC AROMA-CFD, ROMSOC, ARGOS, eFlows4HPC are H2020/HE projects funded by European Commission to enhance methodological developments in reduced order methods with a focus in CFD:

http://people.sissa.it/grozza

http://mathlab.sissa.it/projects-list