Dr. Igor Pontes Duff

Curriculum Vitæ

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Current position

2021–Present **Team Leader**, *Max Planck Institute for Dynamics of Complex Technical Systems*, Magdeburg, Germany.

Leader of the Structured Dynamical Systems (SDS) team. This team consists of three members, including myself and two Ph.D. students. My mission as a team leader is to propose and manage projects among team members. In addition, I mentor and provide support to the Ph.D. students.

Team description

Dynamical processes may have intrinsic structures, including time-delays, second-order and fractional derivatives. These processes may be subjected to stochastic and switching behaviors. The SDS team dedicates its efforts to develop new theoretical and computational results to allow efficient simulation, optimization, and control for high-fidelity structured models.

Research interests

- **Structured dynamical systems:** Analysis, stability, approximation of linear and nonlinear systems having a particular structure, e.g., time-delays, second-order, switched and hybrid system, and stochastic systems.
- **Model order reduction and reduced-order modeling:** Balanced truncation, $\mathcal{H}_2$-optimal model approximation, error bounds, applications of model approximation.
- **Scientific machine learning:** Learning dynamical system from data, non-intrusive model reduction, operator inference, eigensystem realization methods and Loewner framework.

Experience

2017–2021 **Postdoctoral Research Scientist**, *Max Planck Institute for Dynamics of Complex Technical Systems*, Magdeburg, Germany.

Development of new computational methods for large-scale control systems. Extension of classical methodologies to different classes of dynamical systems, including switched and structured dynamical systems.

2014–2017 **Ph.D. Researcher**, *University of Toulouse/ISAE/ONERA*, Toulouse, France.

Ph.D. in Control Systems and Applied Mathematics. Thesis developed at the French Aerospace Lab (ONERA) and the National Higher French Institute of Aeronautics and Space (ISAE).

- **Ph.D. thesis:** Large-scale and infinite dimensional dynamical model approximation.
- **Advisors:** C. Poussot-Vassal and C. Seren
- **Research focus:** This thesis aims at developing new techniques to find simpler models from large-scale complex ones. Major work have been done to find reduced order models with delay structure, $\mathcal{H}_2$ model reduction and stability analysis and control of large-scale systems. Keywords: dynamical system approximation, numerical linear algebra, time-delay systems, stability analysis.

Oct.–Dec. 2015 **Visiting scholar at Virginia Tech**, *Blacksburg, Virginia, EUA.*

Visiting scholar at the research group of Serkan Gugercin and Christopher Beattie. The main goal of this visit was to devellop $\mathcal{H}_2$ oriented model reduction techniques to time-delay systems.

Apr.–Jul. 2012 **Research internship**, *INRIA Sophia Antipolis, France.*
Reaserach project on low-thrust orbital transfer and optimal control. Advisor: Jean-Baptiste Pomet.

Aug.-Sept. 2011 **Internship at EDF Saint Alban**, *EDF, Saint Alban, France.*
Internship in the maintenance department at Saint Alban nuclear power station.

Education

2014–2017 **Doctor of Philosophy**, *University of Tououse/ISAE/ONERA*, Toulouse, France.
Speciality: Applied mathematics and control systems.

2012–2014 **Master of Science**, *ENS Cachan/Supelec/ISAE*, Toulouse and Paris, France, simultaneously with Supaero/ISAE's degree.
Speciality: Control systems and signal processing.

2012–2013 **Double Engineering Degree**, *Supaero/ISAE*, Toulouse, France.
Speciality: Aerospace and control systems.

2010–2012 **Engineer Polytechnicien Program**, *École Polytechnique*, Paris, France.
Speciality: Applied mathematics.

Teaching Activities

2021 and 2023 **Lecturer at Otto-von-Guericke-University**, *Model Reduction for Dynamical Systems*, 6 ECTS, Online Module.
I have developed the online teaching module *Model Reduction for Dynamical Systems*. This module was held entirely online during the pandemic restrictions. It consisted of videos online containing the theory, together with biweekly online meetings to discuss the material.
- Target audience: Master students, Ph.D. students and senior undergraduate student.
- Development of lecture notes and exercise sheets.
- Elaboration of videos and code tutorials structured in small chapters.
- Discussion and questions in real-time meetings.
- Module material available in www.mpi-magdeburg.mpg.de/4094969/mor.

2016 **Teaching assistant at Ecole Doctorale Systèmes (EDSYS)**, *Approximation of Large-Scale Dynamical Systems*, Lectures given together with my Ph.D. supervisor C. Poussot-Vassal and colleague P. Vuillemin to Ph.D. students of EDSYS (15h), Toulouse, France.

2014-2016 **Teaching assistant at INSA (Toulouse)**, *Continuous Linear Systems (3rd year), Control laboratory (2nd year), Nonlinear control systems (4th year)*, Exercises and tutorials lectures given to control engineering students at INSA(100h), Toulouse, France.

2014-2015 **Teaching assistant at ISAE/Suapero (Toulouse)**, *Control systems (4rd year)*, Exercises and tutorials lectures given to control engineering students at ISAE/SUPAERO(40h), Toulouse, France.

Supervision Activities

2021-Present **Yevgenyia Filanova**, *Mentor of Ph.D. student*, Ph.D. topic: Non-intrusive Model Reduction for Mechanical Systems.

2020-Present **Jennifer Przbilla**, *Mentor of Ph.D. student*, Ph.D. topic: Damping Optimization of Mechanical Systems.

Student Supervision

Apr. 2022-Present **Celine Reddig**, Master project: Identifying dominant subspaces in structure dynamical systems via a greedy approach.

Jun.-Sept. 2019 **Ali Seyfi**, Project: Development of structure preserving model reduction toolbox.

Sep.-Dec.. 2018 **Adil Ahsan**, Project: Implementation of different reduction methods for systems with quadratic output observation.

Awards and Scholarships

April 2016 **Prix des doctorans**, *ONERA, 2016*, Best Ph.D. student award of the French Aerospace Lab (ONERA).

Oct.-Dec. 2015 **Bourse Mobilité International**, *EDSYS*, International mobility scholarship.

2012-2013 **Bourse Excellence**, *Fondation Polytechnique*, M.Sc. scholarship.

2010-2012 **Bourse École Polyetchnique**, *Fondation Polytechnique*, Engineer program scholarship.

Submitted Papers

[SP6] P. Goyal, I. Pontes Duff, P. Benner, *Inference of Continuous Linear Systems from Data with Guaranteed Stability*, arXiv preprint arXiv:2301.10060, 2023.

[SP5] P. Goyal, I. Pontes Duff, P. Benner, *Dominant Subspaces of High-Fidelity Nonlinear Structured Parametric Dynamical Systems and Model Reduction*, arXiv preprint arXiv:2301.09484, 2023.

[SP4] P. Benner, P. Goyal, I. Heiland, I. Pontes Duff, *A Quadratic Decoder Approach to Nonintrusive Reduced-order Modeling of Nonlinear Dynamical Systems*, arXiv preprint arXiv:2209.15412, 2022.

[SP3] Y. Filanova, I. Pontes Duff, P. Goyal, P. Benner, *An Operator Inference Oriented Approach for Mechanical Systems*, arXiv preprint arXiv:2210.07710, 2022.

[SP2] J. Przybilla, I. Pontes Duff, P. Benner, *Model Reduction for Second-Order Systems with Inhomogeneous Initial Conditions*, arXiv preprint arXiv:2206.06896, 2022.

[SP1] P. Benner, P. Goyal, and I. Pontes Duff, *Identification of Dominant Subspaces for Linear Structured Parametric Systems and Model Reduction*, preprint arXiv:1910.13945, math.NA, 2019.

Journal Papers

[J9] M. Redmann, I. Pontes Duff, *Model Order Reduction for Bilinear Systems with Non-Zero Initial States–Different Approaches with Error Bounds*, International Journal of Control, 2022.

[J8] M. Redmann, I. Pontes Duff, *Full State Approximation by Galerkin Projection Reduced Order Models for Stochastic and Bilinear Systems*, Applied Mathematics and Computation, 2022.

[J7] P. Benner, P. Goyal, J. Heiland, I. Pontes Duff, *Operator Inference and Physics-Informed Learning of Low-Dimensional Models for Incompressible Flows*, Electronic Transactions on Numerical Analysis, Vol. 56, pp. 28–51, 2022.

[J6] P. Benner, P. Goyal, and I. Pontes Duff, *Gramians, Energy Functionals, and Balanced Truncation for Linear Dynamical Systems With Quadratic Outputs*, IEEE Transactions on Automatic Control, Vol. 67(2), pp. 886–893, 2021.

[J5] X. Cao, P. Benner, I. Pontes Duff, and W. Schilders, *Model Order Reduction for Bilinear Control Systems with Inhomogeneous Initial Conditions*, International Journal of Control, Vol. 94(10), pp. 2886–2895, 2021.

[J4] I. Pontes Duff, and P. Kürschner, *Numerical Computation and New Output Bounds for Time-Limited Balanced Truncation of Discrete-Time Systems*, Linear Algebra and its Applications, Vol. 623, pp. 367–397, 2021.

[J3] I. Pontes Duff, P. Goyal, and P. Benner, *Balanced Truncation for a Special Class of Bilinear Descriptor Systems*, IEEE Control Systems Letters, Vol. 3(3), pp. 535–540, 2019.

[J2] I. Pontes Duff, S. Grundel, and P. Benner, *New Gramians for Switched Linear Systems: Reachability, Observability, and Model Reduction*, IEEE Transactions on Automatic Control, Vol. 65(6), pp. 2526–2535, 2019.

[J1] I. Pontes Duff, C. Poussot-Vassal, and C. Seren, *$\mathcal{H}_2$-Optimal Model Approximation by Input/Output-Delay Structured Reduced Order Models*, Systems & Control Letters, Vol. 117, pp. 60–67, 2018.

Conference Papers

[C6] I. V. Gosea, I. Pontes Duff, *An Iterative Realization-Free Approach for Model Reduction of Bilinear Systems via Hermitian Interpolation*, In: Proceedings on the 20th European Control Conference, London, UK, July, 2022.

[C5] I. V. Gosea, I. Pontes Duff, P. Benner, A. C. Antoulas, *Model Order Reduction of Bilinear Time-Delay Systems*, In: Proceedings on the 18th European Control Conference, Naples, Italy, June, 2019.

[C4] V. Dalmas, G. Robert, C. Poussot-Vassal, I. Pontes Duff, C. Seren, *From infinite dimensional modelling to parametric reduced-order approximation: Application to open-channel flow for hydroelectricity*, In: Proceedings on the 15th European Control Conference, October, 2016.

[C3] I. Pontes Duff, S. Gugercin, C. Beattie, C. Poussot-Vassal, C. Seren, *$\mathcal{H}_2$-Optimality Conditions for Reduced Time-Delay Systems of Dimension one*, In: Proceedings of the 13th IFAC Workshop on Time-delay Systems, Istanbul, Turkey, June, 2016.

[C2] I. Pontes Duff, C. Poussot-Vassal, C. Seren, *Realization Independent Single Time-Delay Dynamical Model Interpolation and $\mathcal{H}_2$-Optimal Approximation*, In: Proceedings of the 54th IEEE Conference on Decision and Control, Osaka, Japan, December, 2015.

[C1] I. Pontes Duff, P. Vuillemin, C. Poussot-Vassal, C. Briat, C. Seren, *Approximation of Stability Regions for Large-Scale Time-Delay Systems using Model Reduction Techniques*, In Proceedings of the 14th European Control Conference, Linz, Austria, July 2015.

Book Chapters

[B4] I. Pontes Duff, P. Goyal and P. Benner, *Data-Driven Identification of Rayleigh-Damped Second-Order Systems*, In: Beattie, C., Benner, P., Embree, M., Gugercin, S., Lefteriu, S. (eds) Realization and Model Reduction of Dynamical Systems, pp. 255-272, Springer, Cham. 2022.

[B3] I. V. Gosea, I. Pontes Duff, *Toward Fitting Structured Nonlinear Systems by Means of Dynamic Mode Decomposition*, In: Benner, P., Breiten, T., Faßbender, H., Hinze, M., Stykel, T., Zimmermann, R. (eds) Model Reduction of Complex Dynamical Systems. International Series of Numerical Mathematics, vol 171, pp 53–74, Birkhäuser, Cham. 2021.

[B2] I. V. Gosea, I. Pontes Duff, P. Benner, and A. C. Antoulas, *Model Order Reduction of Switched Linear Systems with Constrained Switching*, In: IUTAM Symposium on Model Order Reduction of Coupled Systems, Stuttgart, Germany, May 22–25, 2018, pp. 41–53, Springer, 2020.

[B1] I. Pontes Duff, P. Vuillemin, C.Poussot-Vassal, C. Briat, and C. Seren. Model Reduction for Norm Approximation: An Application to Large-Scale Time-delay Systems, *In: Delays and Networked Control Systems, pp. 37-55. Springer, Cham, 2016.*

Selected Talks at International Conferences

Mar. 2023 **SIAM Conference on Computational Science and Engineering**, *Amsterdam, Netherlands*, "Eigensystem realization algorithm for continuous-time LTI systems".

Jun. 2022 **XXI Householder Symposium on Numerical Linear Algebra**, *Selva di Fasano, Italy*, "Balanced Truncation for Linear System with Quadratic Output: Theory, Error Bounds and Numerics".

Jul. 2021 **SIAM Conference on Control and Its Applications**, *Online*, "Operator Inference and Physics-Informed Learning of Low-Dimensional Models for Incompressible Flows".

Feb. 2020 **ICERM Workshop- Mathematics of Reduced Order Models**, *Providence, US*, "Automatic Generation of Minimal and Reduced Models for Structured Parametric Dynamical Systems".

August. 2019 **4th Workshop on Model Reduction of Complex Dynamical Systems**, *Graz, Austria*, "Balanced Truncation for Linear System with Quadratic Output".

Jun. 2019 **The 28th Biennial Numerical Analysis Conference**, *Glasgow, UK*, "Data-Driven Model Order Reduction for Rayleigh-Damped Second-Order Systems".

Feb. 2019 **SIAM Conference on Computational Science and Engineering**, *Spokane, Washington, USA*, "Novel Structure Preserving Model Reduction Schemes".

Avr. 2018 **Model Reduction of Parametrized Systems IV**, *Nantes, France*, "Balanced Truncation Model Reduction for Polynomial Control Systems".

Programming skills

Expert	MATLAB, Python, Scilab, LaTeX
Advanced	C, Mathematica, Octave
Intermediate	C++, Java, FreeFem++

Languages

- **Portuguese:** Mother tongue
- **English:** Business fluent
- **German:** Intermediate
- **French:** Business fluent
- **Spanish:** Intermediate

About myself

Date of birth	16-06-1989
Birth place	Rio de Janeiro, Brazil
Nationality	Brazilian

References

Prof. Dr. Peter Benner
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